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Transfer of Learning for K-12 STEM Teachers: From the GEAR UP Engineering Camp Professional Learning Experience to the Classroom

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TRANSFER OF LEARNING FOR K-12 STEM TEACHERS: FROM THE GEAR UP ENGINEERING CAMP PROFESSIONAL LEARNING EXPERIENCE TO THE CLASSROOM

by

Ryan F. Barlow

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ABSTRACT

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by

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Because of the new Utah Science with Engineering Education (SEEd) standards, which are based on the Next Generation Science Standards (NGSS), Utah science teachers in K-12 schools are now being asked to incorporate engineering into their science classes. Many science teachers in the State of Utah do not have a background in engineering and have not received training in how to incorporate engineering into their classes. To help remedy this problem, six STEM teachers from the State of Utah, and one STEM teacher from Nevada, came to the campus of Utah State University in July 2019 to participate with a group of students in the GEAR UP Engineering Summer Camp. As a part of the camp, the teachers participated in engineering experiences with the students and in engineering education professional development workshops during the evenings of the camp. These workshops focused on the SEEd Standards, the Science and Engineering Practices outlined in those standards, and on one model of the Engineering Design Process. The teachers were given time during the evening workshops to create a series of lesson plans in which they would implement the Science and Engineering Practices (SEPs) with their own students. These workshops, along with the engineering

experiences, constituted a professional learning experience that was intended to help the teachers to implement the SEEd Standards in their own classes.

At the end of the GEAR UP Engineering Camp, the participating teachers were interviewed regarding their experiences at the camp. During the semester following the camp, the teachers were observed teaching a part of the lesson that they had created during the workshops. A second interview was performed following the observed lesson that focused on what they had learned from the Engineering Camp professional learning experience that they had been able to implement in their classes.

The results of the first interview show that overall, the participating teachers had a good experience at the GEAR UP Engineering Camp and that they enjoyed the professional learning experience. The teachers did have some feedback in these interviews that will be implemented into the camp and the professional development workshops in the future.

The results of the analysis of the lesson plans that were created by the teachers at the camp showed that all seven teachers were able to have at least limited application of at least half of the 8 SEPs. The four participating science teachers had the highest level of application of the SEPs, with all four science teachers having substantial application of at least 6 of the SEPs.

The observation data showed that all of the participating teachers, except for one, were able to have substantial application of at least two of the SEPs during the observed lesson. Because the observed lesson was only a portion of the series of lesson plans that were created during the camp, it was made clear to the teachers that all of the SEPs did not necessarily need to be applied in every portion of the lesson.

From all of the data collected in this qualitative epistemological study, it is clear that the combination of the teacher professional development workshops with the student-focused GEAR UP Engineering Summer Camp had a positive effect on the ability of the teachers to transfer what they learned from the GEAR UP Engineering Camp Professional Learning Experience to their own classrooms.

(219 pages)

PUBLIC ABSTRACT

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Because of the new Utah Science with Engineering Education (SEEd) standards, which are based on the Next Generation Science Standards (NGSS), Utah science teachers in K-12 schools are now being asked to incorporate engineering into their science classes. Many science teachers in the State of Utah do not have a background in engineering and have not received training in how to incorporate engineering into their classes. To help remedy this problem, six STEM teachers from the State of Utah, and one STEM teacher from Nevada, came to the campus of Utah State University in July 2019 to participate with a group of students in the GEAR UP Engineering Summer Camp. As a part of the camp, the teachers participated in engineering activities with the students and in engineering teaching workshops during the evenings of the camp. These workshops focused on the SEEd Standards, the Science and Engineering Practices outlined in those standards, and on one model of the Engineering Design Process. The teachers were given time during the evening workshops to create a series of lesson plans in which they would implement the Science and Engineering Practices (SEPs) with their own students. These workshops, along with the engineering activities, were intended to help the teachers to implement the SEEd Standards in their own classes.

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interviewed regarding their experiences at the camp. During the semester following the camp, the teachers were observed teaching a part of the lesson that they had created during the workshops. A second interview was performed following the observed lesson that focused on what they had learned from the Engineering Camp experience that they had been able to implement in their classes.

The results of the first interview show that overall, the participating teachers had a good experience at the GEAR UP Engineering Camp and that they enjoyed the professional learning experience. The teachers did have some feedback in these interviews that will be implemented into the camp and the professional development workshops in the future. From the analysis of the observed lessons and the submitted lesson plans, it is clear that the participating teachers were able to incorporate engineering in their own STEM classes.

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Ryan F. Barlow

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CHAPTER I

INTRODUCTION

Problem

Because of the Next Generation Science Standards (NGSS), K-12 science teachers are now expected to include engineering in their science curriculum. Many states have directly adopted the NGSS and others have developed their own standards based on the same principals as the NGSS. In Utah, the State Board of Education recently approved the new Utah Science with Engineering Education (SEEd) Standards for K-5 and high school (9-12) science classes. The standards for grades 6-8 were adopted in 2015. These new standards in Utah outline several Science and Engineering practices and standards specific to each grade or science subject on how to incorporate the practices (Utah SEEd Standards: Draft for Public Review, 2019). The Science and Engineering Practices include: *Asking questions and defining problems; developing and using models; planning and carrying out investigations; analyzing and interpreting data; using mathematics and computational thinking; constructing explanations and developing solutions; engaging in argument from evidence; obtaining, evaluating, and communication information*. Two of these Science and Engineering Practices have one part specific to science, and the other to engineering. Asking questions and constructing explanations is relate to science, while defining problems and developing solutions is relate to engineering. The SEEd Standards and the SEPs help science teachers to incorporate engineering while teaching scientific principles. Research has shown that many K-12 science teachers lack the engineering knowledge to be able to teach these engineering practices in their classrooms (Ames, 2014; Bybee, 2014; Johnson &

Cotterman, 2013; Lederman and Lederman, 2013).

In 2009, the National Research Council published a report in which the authors stated, "There is considerable potential value… in increasing the presence of technology and, especially, engineering in STEM education in the United States" (National Research Council, 2009, p. 150). It has been shown that there are substantial benefits in including engineering in K-12 classrooms (Hirsch et al., 2007; Koszalka et al., 2007). According to Moore et al. (2014), improvements in STEM education need to focus on improving engineering education. Because of this research, engineering began to be included in K-12 classrooms as a part of the NGSS and other state standards, including the Utah SEEd Standards. Roehrig et al. (2012) said that even with the standards in place, schools and teachers must still develop their own curriculum for K-12 engineering education. But a major question arises from this: Do K-12 science teachers have the ability and self-efficacy to teach engineering practices introduced by the NGSS or other State standards such as the Utah SEEd Standards? And, if they do not have the capability to incorporate the engineering practices, what is the best way to help them to do so?

Research shows that there is a substantial gap in the engineering concept knowledge of K-12 science educators and in their ability to teach those concepts to students (Ames, 2014; Johnson & Cotterman, 2013). According to Bybee (2014), "science teachers express a concern about their lack of understanding engineering" (p. 215). Lederman and Lederman (2013) wonder about how much engineering background will be required for science teachers to teach engineering and where will they get that background. There is evidence from surveys that the science teachers lack self-efficacy (Ambrose et al. 2010; Banilower et al. 2013; Johnson & Cotterman, 2013) in teaching

engineering concepts. Without content knowledge and self-efficacy, science teachers cannot be expected to teach engineering practices effectively to their students.

According to Sanders (2012), there is "unprecedented interest from science, technology, and engineering educators in the idea of situating the teaching and learning of mathematics and science in the context of engineering design activity" (p.11). However, the teachers may not have the capabilities or the background necessary to incorporate such activities successfully. Again, the question arises, how do we help K-12 teachers incorporate engineering design activities?

In some cases, the responsibility to teach engineering in K-12 classrooms falls on technology teachers. Sanders (2009) says that while technology teachers say that they include science, math, and engineering principles in their classrooms, it is often not explicitly included in objectives, nor assessed. Therefore, whoever is teaching, whether it be science teachers or technology teachers, they are now responsible for teaching the engineering practices.

One answer to the question of how to help teachers to better incorporate the new SEEd standards into their classrooms is to provide professional development programs and professional learning experiences focused on engineering education. Although the immediate goal of engineering professional development is to help the teachers, the end goal is for students to better learn engineering in K-12. The question then becomes how well the teachers are able to transfer what they learn in the professional learning experiences to their own classrooms in order to help their students learn.

Most research on transfer of learning focuses on students transferring learning from one problem to another, one class to another, or from school to contexts outside of

school (Barnett, 2005). There is a dearth of research involving the transfer of learning of all teachers from professional learning experiences to their own classrooms. This gap in the research on transfer of learning needs to be filled in order to develop effective professional learning experiences for the K-12 teachers who are now expected to teach engineering. With effective professional learning experiences for K-12 teachers, participating teachers will be able to help their students learn about engineering before college. This gap in the research includes discovering what factors affect the teachers' ability to transfer learning from the professional learning experiences to their own classrooms. It is also necessary to evaluate the effectiveness of the engineering professional learning experiences after they are designed and implemented so that they can be changed to better meet the needs of the participating teachers. If teachers are not able to transfer what they have learned in a professional learning experience to their own classrooms, then the professional learning experience needs to be changed.

Purposes and Objectives

The overall purpose of this study was to examine STEM teacher transfer of learning from a professional learning experience at a GEAR UP Engineering Camp to their own classroom. This involved investigating the factors that influence the teachers' transfer of learning and determining how well the participating teachers were able to transfer the learning related to the Science with Engineering Education Standards (SEEd).

Research Questions

This study was guided by the following research questions:

1. What factors influence transfer of learning for K-12 STEM teachers from an engineering focused summer workshop that includes student and teacher experiences to their classrooms?
2. How well are the participating STEM teachers able to transfer learning related to the Science and Engineering practices into their classrooms?
3. What is the effect of having a teacher professional learning experience combined with a student engineering camp on teachers' transfer of learning?

Positionality

According to the book, Qualitative Inquiry & Research Design: Choosing Among Five Approaches, "Researchers 'position themselves' in a qualitative research study" (Cresswell & Poth, 2018, p. 44). To that end, I am a white, Caucasian male who has a background in both engineering and education. I obtained a bachelor's degree in Mechanical Engineering and a master's degree in Science Education. I am currently a traditional graduate student pursuing a Ph.D. in Engineering Education at Utah State University. I have taught part-time at the community college level and have been a teaching assistant for two undergraduate engineering courses and one graduate engineering education course while pursuing my graduate degrees. I have been researching engineering teacher and faculty development for the last three years.

Because of my experiences as an engineering student, a TA in engineering courses, and as an engineering education student and researcher, I have gained specific beliefs and opinions about what makes for good engineering education. These beliefs include the need for engineering education to be hands-on, focused on design and problem solving, and as similar as possible to what the students will be doing in the

future as practicing engineers. My opinions about engineering education can clearly be seen in the content of the professional development workshops, which I designed.

Because I was acting in the role of a leader of the professional development workshop and the role of a researcher, and because I led a meeting in which the teachers were introduced to the four engineering experiences, the teachers may have seen me in a position of authority. As such, the teachers may have given responses in the interviews that they think I wanted to hear. In order to mitigate this issue, I interacted with the teachers, not only during the professional development workshops, but also during the engineering experiences. I did this in order to build a relationship of trust with the participating teachers. By doing this, it should be less likely that the teachers told me what they think I wanted to hear. It was also important for me to build a relationship of trust with the teachers, so they were more likely to be honest with me during interviews. It was also possible that the teachers may have behaved differently while being observed by the researcher than they normally do in their own classrooms. For this reason, I was particularly careful to interact with the teachers and their students as little as possible during the classroom observations.

Because this study dealt primarily with transfer of learning, it was mainly an epistemological study. Epistemology can be defined as "how knowledge is acquired, recorded, organized, maintained, transmitted and used," (Bassett et al., 2014, p. 29). It was important to conduct an epistemological study in the environment where the participants live or work, which was in the teachers' own classrooms for this research study. Parts of the research study could also be considered axiological because the teachers were making "value judgements" (Sheehan & Johnson, 2012, p. 151) about the

GEAR UP Engineering Camp professional learning experience.

This research study was based on a postpositivistic interpretive framework (Cresswell & Poth, 2018). According to Cresswell, postposivist researchers use “multiple levels of data analysis for rigor, employ computer programs to assist in their analysis, encourage the use of validity approaches, and write their qualitative studies in the form of scientific reports, with a structure resembling quantitative articles” (Cresswell & Poth, 2018, pp. 23-24). Accordingly, this research study involves data analysis in the form of multiple rounds of coding of the interview data using the computer program MAXQDA® 2020, and the use of a rating system, researcher notes, and analytic memos for the observation and lesson plan data. This research also considered the varying perspectives of the participants that are most clearly shown in the interviews that were conducted.

Research Method

This study used qualitative research methods, specifically a cross-case analysis case study (Cresswell & Poth, 2018). The participants in the study were high school and middle school STEM teachers from different schools in the State of Utah, and one school in the State of Nevada. The teachers participated in the professional learning experience incorporated into the GEAR UP Engineering Camp in July 2019. These teachers were divided into five cases based on the differences in their experiences at the camp and the different subjects that they taught. Each case, which included one or two teachers, was analyzed separately, and then all cases were analyzed together for the cross-case analysis.

The data was collected through lesson plans that the teachers created during the professional development workshops, an observation of the teachers in their own classrooms, and a semi-structured interview related to the GEAR UP experience, and to

their transfer of learning. The interview was divided into two parts. One part was conducted at the end of the Engineering Camp, and the other was conducted immediately following the observation of the teachers in their classrooms.

Definition of Terms

STEM: The fields of science, technology, engineering, and mathematics.

NGSS: The Next Generation Science Standards which outline standards that show what students should be learning in their science classes.

SEEd Standards: The Science with Engineering Education Standards adopted by the Utah State Board of Education which outlines standards for what K-12 teachers should be teaching and what the students should be learning. These are based on NGSS.

Science and Engineering practices: The eight practices that are outlined in the Utah SEEd Standards which include: Asking questions or defining problems, developing and using models, planning and carrying out investigations, analyzing and interpreting data, using mathematics and computational thinking, constructing explanations and designing solutions, and obtaining, evaluating and communicating information.

GEAR UP Engineering Camp: Gaining Early Awareness and Readiness for Undergraduate Programs Engineering Camp for students and teachers.

Professional Development: A single workshop for teachers.

Professional Learning: Learning continues because teachers take more responsibility for their learning. Learning is customized to the needs of the specific teachers participating.

Transfer of Learning: The ability to extend what has been learned in one context to new contexts (Bransford et al., 1999, p. 51).

Pre-service teacher: A future teacher who is still in school and is not yet in the classroom.

In-service teacher: A practicing teacher.

Limitations of the Study

This study was limited by the following factors:

1. The study was limited to teachers who volunteered to participate in the GEAR UP Engineering Camp.
2. The participants in the study were limited to teachers from the school districts that participated in the GEAR UP Engineering Camp.
3. The number of teachers was limited to a maximum of 12 teachers, but only 7 teachers participated in the study. This number was based on the desire to have approximately 5 students per teachers with approximately 60 students participating in the GEAR UP Engineering Camp.
4. The observations only included one class period and did not include the entire lesson that the teachers had planned. Thus, the observation data is only a snapshot of the overall lesson plan that was implemented.
5. The observed lesson was limited to activities that could be done by the teachers with their own students either in their classrooms or on a field trip.
6. The lessons taught by the teachers in the observations were limited to content that was taught between August 2019 and the end of January 2020.

Assumptions of the Study

This study assumed the following:

1. Teachers were open and honest in the semi-structured interviews.

2. The presence of the researcher was not detrimental to the observed teachers' lessons.
3. All observations and interviews were conducted by the same researcher and were conducted in the same way.
4. Confounding variables were controlled by having the teachers create lesson plans during the camp that would be implemented during the semester following the GEAR UP Engineering Camp.

CHAPTER II

LITERATURE REVIEW

The concept of professional learning for practicing teachers is not new (Borko, 2004). It is necessary because education research continues to advance and new discoveries about teaching methods are constantly made. However, if the education researchers are the only people who know about these new teaching methods, then the new methods and the research will have had no impact. For education research to be useful, it must be successfully applied in the classroom by the teacher. For this application to be accomplished, teachers need to be informed of the more effective methods. This is generally done through professional development and professional learning. Research has shown that “high-quality professional development programs can help teachers deepen their knowledge and transform their teaching” (Borko, 2004, p. 5). The goal of professional learning is for teachers to be able to take what they have learned in professional learning experiences and professional development workshops and transfer it into actual teaching practice in the classroom.

The study of transfer of learning is also not new. It was first studied by Thorndike in the early 1900’s and has been studied and modified since then. The classical view of transfer was that “transfer occurs to the extent that original learning and transfer situations share identical elements” (Thorndike, 1906 as cited in Lobato, 2006, p. 433). Later, Judd hypothesized that similarity was not enough for transfer, but that “if one can learn generalized rules and how to apply them to different situations, the chances of appropriately applying these rules in new situations will be greatly enhanced” (Judd, 1936, as cited in Johnson et al., 2011, p. 56).

Professional Development and Professional Learning

There have been studies that relate to the need for professional development for teachers (Borko, 2004), and other studies that relate to making professional development more effective (Penuel et al., 2007; Smith & Lindsay, 2016). There have also been studies done on different methods of professional development for K-12 Science teachers. These methods include, but are not limited to, focusing on inquiry-based science education (Kapanadze et al., 2015; Saglam & Sahin, 2017), argue-to-learn intervention (Crippen, 2012), collaboration with a research team (Olin & Ingerman, 2016), forming partnerships with other teachers (Burrows, 2015), and focusing on authentic science experiences (Burrows et al., 2016).

There have been substantial efforts in the last several years to make valuable professional learning experiences that focus on engineering available to K-12 Science teachers. At the 2019 Annual Conference & Exposition of the American Society for Engineering Education, multiple engineering education professional development programs were presented during sessions or through posters. These programs included: two programs that were more traditional professional development programs in which teachers listened to and learned from engineering education experts (Ghosh et al., 2019; Lakin et al., 2019). Teachers who participated in these two programs were either asked to teach a similar program to other teachers after additional training (Ghosh et al., 2019) or to facilitate an informal STEM program for students (Lakin et al., 2019). Another program focused on teaching pre-service teachers about engineering design and having them complete a team design project (Thomas et al., 2019). Several programs that were presented at the conference had in-service teachers participating in actual engineering

research with engineering faculty and students (Krishnamoorthy et al., 2019; Lavelle et al., 2019; Smith & Lohani, 2019; Veety et al., 2019). The participating teachers in a number of these programs were expected to create engineering related lesson plans either during or after the professional development (Thomas et al., 2019; Krishnamoorthy et al., 2019; Lavelle et al., 2019; Veety et al., 2019). In all these professional development programs, the K-12 teachers participated in the program and then returned to their own classrooms, at which point students became involved.

In addition to these programs, the results of the initial pilot study of this research was presented during a poster session at the ASEE Conference as a work in progress (Barlow et al., 2019). Both the pilot study and the research that is the subject of this research focus on combining the teacher professional learning with a student-focused engineering summer camp.

Student Engineering Camps

Engineering camps for K-12 students, including the camp that is the subject of this research, have been running for many years. Much of the research related to student engineering camps is focused on the students, rather than on the participating teachers. The student-focused research relates to engineering outreach and the effect that the engineering camps have on the attitudes, perceptions, and interests of the students related to engineering (Hammack et al., 2015; Mahmoud et al., 2017; Mahmoud et al., 2018; Singh et al., 2019; Yilmaz et al., 2010).

Two of these camps included activities from various engineering disciplines (Singh et al., 2019; Yilmaz et al., 2010). One of these two camps included activities from electrical, mechanical, and chemical engineering that were all related to sustainable

energy (Singh et al., 2019). The other camp included various one-hour projects in various engineering disciplines with the only central focus being hands-on design activities. The other three engineering camps mentioned above focused on a single engineering discipline, either chemical engineering (Hammack et al., 2015) or environmental engineering (Mahmoud et al., 2017; Mahmoud et al., 2018).

Regardless of whether the camp activities were focused on a particular discipline of engineering or covered various disciplines, the purpose of these engineering camps was to increase the participating students' knowledge of and interest in engineering. The results of all these studies showed that there was an increase in student knowledge of and interest in engineering because of the camp especially among those "students who came to the camp with low interest in STEM careers" (Mahmoud et al., 2018, p. 14). One of the studies specifically mentioned that "the selection of highly diversified and hands-on engineering projects was the key to the success of the program" (Yilmaz et al., 2010). Whether the program is focused only on the students, as was the case in the above-mentioned camps, or had an additional teacher focus like the GEAR UP Engineering Camp, one of the key components to the success of the program is allowing the participants to experience engineering for themselves instead of just observing someone else doing engineering.

Experiential Learning

Kolb's Experiential Learning Theory (ELT) defines learning as "the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience" (Kolb, 1984, p. 41). Experiential learning "is making meaning from direct experience" (Matriano 2020,

p. 214). "Experiential learning conceives of the adult learner as participating in an activity, then reflecting on the activity to make generalizations that he or she can then apply in new situation" (Benander, 2009, p. 36). Experiential Learning "can facilitate the learners to make a link between theory and real-world applications, motivation, and retention of learning" (Hulaikah et al., 2020, p. 870).

Because experiential learning was originally developed to model adult learning, "it is now in high demand in higher education" (Heinrich & Green, 2020, p. 206). It has been used as a model for curriculum development in teaching of various disciplines including: business and management (Alon, 2003; Kamath et al., 2008; Vendituoli, 2008), reading for English language learners (Abdul Rahim et al, 2020), political science (Boeckelman et al., 2008), work-based learning and workforce development (Chisholm et al., 2009; Haldane & Wallace, 2009; Mohammadi et al., 2019), social work (Horwath and Thurlow, 2004), problem solving (Hulaikah et al., 2020), medicine and pharmaceuticals (Skledar et al., 2006; Ti et al. 2009, Wuller & Luer, 2008) and even theology (Williams, 2007).

Definition of Transfer of Learning

Perhaps the simplest definition of transfer of learning is "the ability to extend what has been learned in one context to new contexts" (Bransford et al., 1999, p. 51). Bransford et al. further extend this definition by stating that transfer can be "from one problem to another within a course, from one year in school to another, between school and home, and from school to workplace" (Bransford et al., 1999, p. 51). Specifically applying this to non-school settings, transfer could be defined as "the use on the job of what has been learned in training" (Yelon et al., 2004, p. 82). To extend this definition to

teachers, transfer can be from a training, workshop, or professional development program to the classroom.

Types of Transfer

There are several different types of transfer. Johnson, Dixon, Daugherty, and Lawanto (2011) describe two different dichotomies for dividing transfer into types: near versus far transfer and high road versus low road transfer. Near transfer is for similar contexts whereas far transfer "relates to the application of knowledge and skills in situations that are significantly different from the context in which the original learning occurred" (Johnson et al., 2011, p. 57). In the context of this study, an example of near transfer would be an engineering teacher teaching the engineering that was learned at the camp in his or her own classroom. An example of far transfer would be a math teacher applying what was learned in the camp to his or her own classroom. Low road transfer refers to transfer of skills that are automatic and are transferred to similar situations without substantial cognitive effort. For example, if a participating teacher uses an activity in his or her own classroom exactly as it was done at the GEAR UP Camp, then it could be considered low road transfer. High road transfer "involves purposeful and conscious analysis of a situation to determine what prior learning can be applied in novel situations" (Johnson et al., 2011, p. 57). An example of high road transfer in the context of this study would be a teacher applying what was learned at the camp using a different activity that fits more into his or her curriculum. Though transfer is divided into these different types, there is no indication that any one of the types is more important than the other. In some cases, far transfer is necessary, such as for the participating math teachers since they are not specifically required to teach the Science and Engineering practices.

However, they should still be able to transfer some learning from the professional learning experience. In other cases, such as for the participating science and technology teachers, only near transfer is necessary. The same is true for low road transfer and high road transfer. Both are necessary for certain situations.

Contributions and Challenges to Successful Transfer

According to Bransford et al. (1999), "The first factor that influences successful transfer is degree of mastery of the original subject" (p. 53). Similarly, "before the learning experience, a lack of foundational knowledge on the part of the learner serve as a barrier to transfer" (Caffarella, 2002, as cited in Thomas, 2007, pp. 5-6). Therefore, the degree of learning of the initial subject is of primary importance. If the learners, who in the case of professional development are the participating teachers, do not learn "with understanding rather than merely memorize sets of facts or follow a fixed set of procedures" (Bransford et al., 1999, p. 55), then transfer cannot occur.

Transfer can also be inhibited if "during the learning experience, there is a lack of personal motivation or confidence on the part of the learner" (Knowles, 1990, as cited in Thomas, 2007, p. 6). Learner motivation can affect transfer of learning both positively and negatively. Lack of motivation will restrict transfer, while increased motivation can increase transfer of learning. "Motivation affects the amount of time that people are willing to devote to learning" (Bransford et al., 1999, p. 60). The goal is to increase both the extrinsic (e.g. monetary rewards, promotions, etc.) and intrinsic (e.g. challenge oneself, positive emotions, etc.) motivation of the learners in order to increase transfer. There are multiple methods of increasing motivation. Some people are motivated to solve problems and are therefore motivated by a challenge. But the challenge must be at the

"proper level of difficulty" (Bransford et al., 1999, p. 61) in order to increase motivation. Another way to increase motivation is to help the learners to "see the usefulness of what they are learning" (Bransford et al., 1999, p. 60).

The level of context of learning is also an important consideration that can either positively or negatively affect the transfer of learning. If the learning is overly contextualized, then only near transfer can take place, if even that. However, if learning is not sufficiently contextualized, then the learner's motivation to learn may suffer. Therefore, the original learning must be "taught in multiple contexts… and [include] examples that demonstrate wide application of what is being taught" (Bransford et al., 1999, p. 62) in order for transfer to take place.

Not only are there things before and during learning that affect the transfer of learning, but there are things that take place after learning has been completed that influence successful transfer of learning. "After the learning experience, a lack of support from peers and supervisors can adversely affect transfer" (Caffarella, 2002, as cited in Thomas, 2007, p. 6). With the previously mentioned factors that can affect the transfer of learning, the instructor has some amount of control over the factor, but the instructor cannot have a direct influence on the support that the learner receives after the learning has taken place once the student is already in another class or in the workplace.

In addition to the contributing factors mentioned above, there are some cognitive concepts that contribute to successful learning transfer. First among these is metacognition, which "concerns one's ability to control the working of cognition to ensure that cognitive goals have been achieved" (Johnson et al., 2011, p. 59). "Metacognitive approaches to instruction have been shown to increase the degree to

which students will transfer to new situations without the need for explicit prompting" (Bransford et al., 1999, p. 67). Successful transfer of learning depends not only on having a sufficient understanding of the original learning, but also on having "sufficient metacognitive ability that involves awareness and control of that knowledge" (Johnson et al., 2011, p. 58).

Another cognitive concept that can influence the transfer of learning is mental representation. The way that the foundational knowledge is organized by the learner is just as important as the foundational knowledge. "Mental representation is germane to the issue of learning transfer, especially when transferability is required within a context that is quite different from the context" of the original learning (Johnson et al., 2011, p. 59). This mental representation can be in the form of schemata, naïve theories, and mental models. The lack of quality of any of these mental representations of the original learning can inhibit successful transfer. If a learner has an incorrect mental model for the original learning, then that incorrect model could be transferred to the new context. For example, if a participating teacher has an incorrect mental model of what engineering is, then the teacher will transfer this incorrect model to his or her own classroom and therefore to the students in the class.

A third cognitive concept that can affect the transfer of learning is analogical reasoning. Analogical reasoning "occurs when similarities between two situations, concept, or phenomena are identified and the relevant information is mapped from the familiar to the less familiar" (Johnson et al., 2011, p. 61). This is particularly the case for the classical view of transfer, which could basically be equated to near transfer.

Transfer of Learning from Trainings to the Workplace

As was previously mentioned, there has been a substantial amount of research done regarding transfer of learning for students, but less has been done on transfer of learning in the context of trainings, workshops, or professional development for those who are no longer students (e.g. working professionals and teachers).

In 1988, Baldwin and Ford began to research transfer of learning specifically in the context of working professionals rather than students. They called this *transfer of training* rather than transfer of learning because it specifically applied to training that the workers received not in the context of school. However, they identified similar factors that contribute to successful transfer of training to the workplace as were identified for transfer of learning from school to the workplace. They divided these factors into three categories: trainee characteristics, training design, and work environment (Baldwin & Ford, 1988). The trainee characteristics that were identified include: ability (which could be seen as parallel to the quality of original learning discussed previously), personality, and motivation (which was discussed above extensively). The training design characteristics were: principles of learning, sequencing, and training content. These could be seen as parallel to those factors above that had to do with the quality of the instruction. The work environment characteristics included support and opportunity of use. These are the factors that are similar to the after-learning factors that were mentioned by Earl Thomas (Thomas, 2007).

Other work has been done specifically on the motivation or intention of trainees to transfer what they have learned in training to the workplace (Yelon et al., 2004). The study by Yelon and his colleagues showed that that one of the major factors that

determines the intention of the trainees is the value that they place on what has been learned. If the trainee sees the content of the training as credible, practical, and necessary, then there is a higher likelihood that the trainee will apply the training in the workplace. However, like some of the other studies, they mentioned personal factors that could affect the intention to transfer learning. These included job requirements, task memories, self-evaluation, and goals and values. Like some of the other factors mentioned for transfer in general or transfer specific to training to on the job application, these characteristics of either the learner or their environment cannot be controlled by the instructor/trainer.

Transfer of Learning from Professional Development to the Classroom

Similar to the cases of learning transfer of students in school and of trainees from training to the workplace, those few who have written about transfer of learning from professional development to the classroom have identified various factors that can either contribute to or inhibit successful transfer.

Barnett specifically divides these factors into three categories: features of the task, features of the learner, and features of the context (Barnett, 2005). Agyei and Voogt similarly divided factors that influence transfer of learning into characteristics of the learner and characteristics of the school environment (Agyei & Voogt, 2014). Many of the factors stated previously in the other sections of the paper could be divided into these same groups. The features of the task include the perceived benefit of the professional development training, similar to what was seen in Yelon's study. It also includes the "similarity of the task demands between the learning situation and the work setting" (Barnett, 2005, p. 7).

According to Barnett, the one of the features of the learner that affects transfer of

learning is the learner's ability to deal with change based on internal and external influences. This factor was unique to this paper. However, there are many other factors that could be considered features of the learner. Van Duzor specifically focuses on the motivation of the teachers to transfer learning from professional development into the classroom. She stated that "recognizing how concepts from the PD course could be used to address learning needs specific to their students" (Van Duzor, 2011, p. 372) increased motivation for transfer. This is similar to the conclusions of Bransford (Bransford et al., 1999) and Yelon (Yelon et al., 2004) about the importance of the learner seeing the value of what is being learned to have sufficient motivation to have successful transfer. Like Bransford (Bransford et al., 1999), Agyei and Voogt also mentioned that availability of time can be a factor that influences successful transfer. According to Bransford, "It is important to be realistic about the amount of time it takes to learn complex subject matter" (Bransford et al., 1999, p. 56). Agyei and Voogt similarly say that "the adoption of an innovation takes time" (Agyei & Voogt, 2014, p. 95) meaning that it takes time for a teacher to adopt anything learned in a professional development program. Gaining a sufficient understanding of the original learning is also a feature of the learner that affects learning transfer (Agyei & Voogt, 2014; Bransford et al., 1999). One factor that was unique to Agyei & Voogt is that the teacher must have a dissatisfaction with the status quo. If the teacher is not dissatisfied with the way things are currently done, then the teacher will have no motivation to transfer any learning from a professional development into the classroom and change the way that things are done.

The third category of factors that influence transfer was described as features of the context or characteristics of the environment. The major factor of the environment is

the support that is either present or lacking from the school (or other workplace) as the teacher (or worker) attempts to transfer what had been learned to the new context (Agyei and Voogt, 2014; Johnson, 2009; Thomas, 2007). The school culture was another factor that was mentioned by Agyei and Voogt that was not mentioned by the other authors. This culture includes the values and opinions of the administration and teachers of the schools and how the school deals with changes.

Metacognition, mental representation, and analogical reasoning were not mentioned in the literature that was specific to transfer of learning of teachers, however they do need to be considered for application in professional development to improve teachers' transfer of learning to the classroom. One of the challenges in this is mentioned specifically by Johnson et al., which states that "despite numerous research findings suggesting that the use of metacognition is essential in learning…, it is a challenge to adopt metacognitive activities as an integral part of students' routine academic activities in school" (Johnson et al., 2011, p. 59). The same can be said of professional development programs or workshops. It might be even truer for professional development programs because there is even less time in a professional development program than there is in a class for students.

Theoretical Framework

The formation of this research study, and the professional learning experience that drives it, was based on Kolb's Experiential Learning Theory (ELT). The ELT was developed as a "holistic model of the experiential learning process and a multilinear model of adult development" (Kolb & Kolb, 2005, p. 194). Since the ELT was developed to model adult learning, and because "it plays a vital role in facilitating the process of

creating knowledge, sense-making, and knowledge transfer in teaching, training and development" (Matriano, 2020, p. 214), it is a good theoretical framework for this research in teacher transfer of learning from professional learning to the classroom.

Kolb also developed a model of learning which included concrete experience, reflective observation, abstract conceptualization, and active experimentation. The GEAR UP Engineering Camp professional learning experience allows for the participating K-12 STEM teachers to go through this cycle. Participating in the authentic engineering experiences will allow the participating teachers to have a concrete experience and observe the students having that same experience. During the professional development workshops, teachers will have the opportunity to reflect and conceptualize what they learned during the engineering experiences. The expectation of having the teachers apply what they learned in their own classrooms allows the teachers to experiment. It is expected that having the teachers participate in a professional learning experience which is based on Kolb's ELT will help to increase the teachers' transfer of learning from the professional learning experience into the classes which they teach.

Summary

Because of the implementation of the Next Generation Science Standards (NGSS) or other state science standards, such as the Utah Science with Engineering Education (SEEd) Standards, K-12 science teachers are now expected to implement engineering practices in their science classrooms. Many teachers have a lack of engineering content knowledge or a lack of confidence in teaching engineering. To remedy this, there are several professional development opportunities available which help the science teachers to incorporate engineering practices in their classes. The GEAR UP Engineering Camp

Professional Learning Experience was designed to help K-12 science teachers to incorporate the Utah SEEd Standards, the Science and Engineering Practices, and the Engineering Design Process through participating in evening professional development workshops combined with participating in engineering experiences along with their students as a part of the GEAR UP Engineering Camp.

However, there is a clear gap in the literature regarding transfer of learning for teachers from professional development programs to the classroom. The literature that is there is not specific to any type of professional learning. Therefore, there is a need for more research into the factors that affect teacher transfer of learning. In particular, there is a substantial need for more research into the effect of having professional development workshops combined with a camp in which the teachers participate with their students in authentic engineering experiences because the GEAR UP Engineering Camp Professional Learning Experience is the only program of its kind that combines the teacher experience with the student experience.

CHAPTER III

PILOT STUDY

Introduction

During the summer of 2018, STEM teachers and students from different districts in the State of Utah participated in a five-day GEAR UP Engineering Camp on the campus of Utah State University. The main purpose of the camp was to increase student knowledge and interest in engineering. But an additional purpose of the camp was to help the participating STEM teachers incorporate engineering into their classrooms. The teachers had the opportunity to participate in engineering activities along with their students, rather than just acting as observers and chaperones. In addition to these experiences, the teachers participated in two professional development workshops in the evenings during the camp. One of the evenings was focused on the Three Dimensions of Science Learning and the Framework for K-12 Science Education. The second evening focused on the Engineering Design Process and giving the participating teachers time to prepare an engineering-related lesson plan. The combination of the engineering experiences and the professional development workshops was intended to be a professional learning experience for the participating STEM teachers.

During the following school year, the teachers were observed and interviewed in their own classrooms. The classroom observation was done by the student researcher, who observed the teachers while they were teaching a lesson related to engineering. The interview was conducted either before or after the observation by the same student researcher.

Purpose

The purpose of the pilot study was to examine the professional development workshops, the engineering experiences, the development of engineering lessons by the teachers, and the data collection methods in order to see if changes needed to be made before the full implementation of the research study. The professional development workshops, including the lesson planning time, needed to be tested to see whether it was beneficial to the participating teachers. Similarly, the engineering experiences needed to be tested to ensure that they were beneficial to the participating students as well as the participating teachers. The data collection methods needed to be tested to ensure that the data that was obtained during data collection was usable data. A secondary purpose was to get some preliminary data to inform the data collection and analysis for the research study.

Participants

Eight high school or middle school teachers from seven different school districts, and eight different schools, participated in the GEAR UP Engineering Camp and the professional development workshops. Of these eight teachers, all but one were science teachers. The other participating STEM teacher was a math teacher. Two of the teachers were female and the other six were male. One of the teachers was a first-year teacher and the others had been teaching for more than 2 years. Only one of the science teachers and the math teachers had more than 5 years of teaching experience. The teachers were not specifically asked how long they had been teaching so the information about the one teacher being a first-year teacher only came out during conversations during the professional development workshops.

Not all of the eight STEM teachers who participated in the professional development workshops continued until the end of the study. Two of the science teachers, one of whom was the first- year teacher, withdrew from the study before being interviewed and observed. Of the six remaining teachers, only five fully participated in the research study. One of the teachers participated in the interview but did not participate in the observation.

Program Description

During the GEAR UP Engineering Camp, the participating teachers were divided into four different groups, with one or two teachers per group, along with the student participants. These groups took turns participating in four engineering experiences including: using various methods of collecting stream data and water samples from a local river, using Sea Perch ROV submarines to collect water quality data and water samples from a local reservoir, using quadcopter drones with attached sensors to collect air quality data and a vertical temperature profile in the Engineering Quad, and learning more about the work that the Aggie Air group does using drones and thermal sensors. After completing all these experiences, the student groups selected one of the four areas to do more in-depth experiences. These more in-depth experiences included: going up a local canyon to measure stream data and collect water samples from different points along the river, using the Sea Perch ROV submarines to collect water quality data and water samples from a deeper reservoir, use simple air quality sensors to compare the air quality in different locations on camps, and using a computer program to analyze thermal data that had previously been collected by the Aggie Air students and faculty. Each group of students and teachers formulated research questions, collected and analyzed data to

answer those questions, and presented the results via research posters on the final day of the camp. After all activities were completed, the teachers were given materials including drones, subs, and sensors that they could use in their own classes.

In the evening of the first day of the camp, the teachers participated in one of the two professional development workshops. This workshop was focused on 3-dimensional science learning and the Framework for K-12 Science Education. First, the teachers participated in a discussion led by an education faculty member that focused on the Three Dimensions of Science Learning, which are practices, crosscutting concepts, and core ideas. This discussion also included the Framework for K-12 Science Education and how the teachers can apply it in their own classes. After the discussion, the teachers participated in a group activity which served as an example of how the teachers could apply 3-D science learning in their own classes. This activity was related to differences in rainfall in different parts of Hawaii. Finally, the participating teachers had the opportunity to reflect on what they had learned during the session.

In the evening of the third day of the camp, the teachers participated in the second professional development workshop. This portion of the professional development was focused on the engineering design process. The participating teachers were also given the opportunity to work on engineering related lesson plans that would be used in their classes.

Sea Perch Submarines

On the first day of the camp, the groups of students and teachers assembled simple Remotely Operated Vehicle (ROV) submarines using a kit that was provided to them. For the activities on the second and third days when the groups rotated through the

different activities, the teachers and students used the ROV submarines to collect water samples and water quality data from a shallow local reservoir. For the more in-depth activity on the fourth day of the camp, the groups that chose to participate in the Sea Perch activity used a university boat to get further from the shore at a deeper reservoir to collect more water samples and water quality data in the deeper water using the Sea Perch ROV Submarines. After completing the data collection, the students and teachers returned to a university computer lab, where they analyzed and interpreted the data to use for their posters with the help of the faculty and students who were leading the activity.

Stream Data

For the activity that the four groups rotated through on the second and third days of the camp, the Stream Data group used three different methods of measuring the flow of a local river near where it enters a reservoir. This group also collected water samples from the river and used different methods to test water quality. For the more in-depth activity on the fourth day, the teacher and student groups who had selected the Stream Data activity went up a nearby canyon and collected water samples and took river flow measurements at different locations along the river as it flowed toward the City of Logan. After completing the data collection along the river, the teachers and students returned to a university computer lab to analyze and interpret the data to use for their posters with the help of the faculty and students who were leading the activity.

Air Quality

For the air quality activity on the second and third days of the camp, teachers and students helped to collect and record temperature data at various elevations that was obtained using a drone. The students and teachers did not fly the drone, but observed it

being flown to different vertical heights and helped to record the time so that the temperature and altitude data could be organized after obtaining the data from the sensors. While the faculty member leading the activity was organizing the data, the teachers and students assembled simple air quality particulate sensors. These sensors did not have a numerical readout, but instead used different colored LEDs to show the differences in particulate measurements. On the fourth day of the camp, the Air Quality Group further divided into two smaller groups. One of the groups of teachers and students used the sensors to compare the particulate readings at different locations around the Utah State University campus. The other group did more in-depth measurements at different elevations using the drones. After collecting the data, the teachers and students returned to a university computer lab to analyze and compile the data to use for their posters with the help of the faculty and students that were leading the Air Quality activity.

Aggie Air

The Aggie Air activity for the second and third days of the camp involved taking a short tour of the Aggie Air shop where the teachers and students were able to see some of the work that was being done by the faculty and students in the Aggie Air group. The groups were then taken to another Aggie Air lab where they were able to see a live image from a thermal camera that the Aggie Air group was using to study the temperature in agricultural areas. The students were able to see themselves in the camera and do different things to try to change their temperature in order to change the image. After doing this, the teachers and students went to a computer lab where an Aggie Air faculty member showed them how to analyze the thermal images from the agricultural areas on

the computer. For the more in-depth activity on the fourth day, the teacher and student groups who had selected the Aggie Air group spent the entire time in the computer lab doing more in-depth analysis of the thermal image data with the help of the faculty and students who were leading the Aggie Air activity. The students and teachers then used this data to create their posters.

Professional Development Workshops

On the first evening of the camp, the teachers participated in a professional development workshop that was led by one of the GEAR UP faculty researchers and Graduate Student Researcher 1 (GSR1). The focus of the first evening of the workshop was on 3-dimensional science learning, which include science and engineering practices, disciplinary core ideas, and crosscutting concepts (National Research Council, 2012). Following this discussion, the teachers were divided into groups to participate in an activity which was meant to be a sample of something they could do in their own classrooms. This activity involved going through the different science and engineering practices in the context of a climate related problem in Hawaii. The teachers were asked to explain why annual rainfall can be different in different areas of the island. After completing this activity, the teachers shared their explanations with the rest of the group. The teachers were then given the opportunity to reflect on how to apply the 3-dimensions of science learning in their own classrooms.

On the third evening of the camp, the teachers participated in a discussion about one model of the Engineering Design Process (Appendix A) and how they could apply it in their own classroom. After the short discussion, the teachers were given the rest of the time to work on an engineering-related lesson plan that was similar to the camp activities.

Unfortunately, because of some logistical issues, the workshop on the third evening was cut short by about an hour. The participating teachers had to finish the lesson plan on their own time either before the end of the camp or shortly after the camp. Once finished, the teachers submitted their lesson plans to GSR1 so that the lesson plans could be analyzed to see how well the teachers had been able to apply what they had learned from the GEAR UP Engineering Camp.

Data Collection and Analysis

During the school year following GEAR UP Engineering Camp, GSR1 observed the participating teachers in their own classrooms teaching an engineering-related lesson. There was no specific rubric used to evaluate the observation, but instead, the student researcher took field notes related to the observed teachers' ability to apply what they had learned from the GEAR UP Engineering Camp. The student researcher had been trained to do observations through a qualitative research course as a part of his graduate program. Immediately before or after the observed lesson, the teachers were interviewed by the same student researcher. Only five of the teachers participated in both the interview and observation. A sixth teacher was interviewed but was not observed because he had already taught all his engineering-related content at the time of the interview and was unable to teach additional lessons before the end of the school year.

The interview questions were related to the teachers' experiences at the camp, what they had been able to use from the camp in their own classes, and what factors influenced whether they were able to use anything they had learned during the camp in their classes. Audio of the interview was recorded and transcribed. Preliminary data was obtained from listening to the interviews and looking at the observation field notes.

The qualitative data obtained as a part of the pilot study through interviews and observations was used primarily to test the research methodology before implementing it with the main research study. This included both the methods of data collection and data analysis. The pilot study data was also used to improve the engineering activities and the professional development workshops that were part of the camp.

Results

The results of the pilot study included the analysis of the lesson plans that the teachers submitted, the observation data, and the responses to the interviews questions. All eight of the participating teachers submitted lesson plans, but only six of the teachers participated in the interview, and only five of the teachers were observed in their classrooms teaching and engineering-related lesson.

Lesson Plans

The participating teachers each created an engineering-related lesson plan using the lesson plan template included in Appendix B. Because there was not sufficient time to finish the lesson plans before the end of the camp, some of the teachers submitted their lesson plan to the researchers either shortly after the camp or around the time that their lesson was observed. Because there was no specific protocol for analyzing the lesson plans during the pilot study, the results were subjective and based only on the opinion of the student researcher. These results showed that all the lesson plans submitted by the teachers included at least two or three of the engineering practices, although the presence of engineering was minimal in the lesson plan submitted by the participating math teacher.

Observations

As was the case with the lesson plans, there was no specific observation protocol, so there was not structure to the observational data. This data was based exclusively on field notes made by the observing researcher. Even these field notes had no organizational structure, so the observation data was also subjective and based only on the opinion of the observing researcher. The student researcher who was observing the lessons had also never done a teacher observation before, so the field notes mostly consisted of statements about the content of the lesson and the actions of the observed teacher.

Some of the field notes written by the observing researcher focused on the presence of the words *engineer*, *engineering*, or *engineering design* in the lesson. These notes included statements such as: "*the teacher used the word engineering specifically in the context of designing a solution with specific properties", "engineering and engineering design were never mentioned because the class was a math class, but he was still able to use the activity from the camp in his math class",* and *"the teacher divided students into groups of two or three and gave each student in each group a specific role (Electrical Engineer, Software Engineer, and Field Engineer)"*.

Other field notes written by the observing researcher focused on what the teachers did when the students asked for help or got stuck. These notes included: *"the teacher helped students when they needed help, but mostly left students to explore on their own", "helped the students do the calculations when they got stuck",* and *"walked around to different groups when they had questions"*.

However, most of the observation field notes focused on what the observed

teacher was asking the students to do. Some of these notes included: *"had the students use sonar sensors that they built and coded to map out stacks of books under the table in the front"* and *"had the students measure the normal melting point of ice to calibrate the temperature sensors"*.

The notes from the observing researcher focused on these particular topics to show whether or not engineering had been incorporated into the lesson. But, because there was no specific observation protocol or rubric, or even any idea of what form the engineering should be applied in the lesson, the field notes ended up being superficial.

Interviews

After the interviews were completed, recorded, and transcribed, the student researcher used in vivo coding to analyze the interviews in MAXQDA®. After the first round of coding, the student researcher used pattern coding to identify themes in the data. The results of this coding process are shown below in Table 1, which shows the coding phase, coding type, the code or theme, and the frequency of each code or theme.

The codes with a frequency of 1 were different enough from the other codes that they could not be grouped together during the first round of coding. However, during the second round of coding, the codes with smaller frequencies fit well into the overall themes. Because GSR1 conducted the interviews, he was able to hear the teachers' tone of voice and read their expressions, which he used to decide which codes with lower frequency should be included and which should be discarded. Only those that were included after this process appear in Table 1.

Table 1

Coding Table for Pilot Study

Coding Phase	**Coding Type**	**Code/Theme**	**Frequency**
Phase 1	In Vivo Coding	Kind of a whirlwind (Barriers)	2
		The core (Barriers)	1
		Teach the test (Barriers)	1
		They have to design something (Practical/hands-on)	1
		Extra time to process it (Benefits of the PLE)	1
		Good exhaustion (Benefits of the PLE)	4
		Both (Practical/hands-on)	2
		Professional learning community (Other People)	1
		Discouraged by bureaucracy (Barriers)	1
		Don't remember all the initial excitement (Barriers)	1
		Magical dreamland (Barriers)	4
		Don't have a space to do that one (Barriers)	1
		Different than a traditional typical classroom (Practical/hands-on)	2
		SEEd standards (Barriers)	5
		Set the foundation (Benefits of the PLE)	1
		Practical, for sure (Practical/hands-on)	8
		Solidified things (Benefits of the PLE)	2
		Teachers from other schools (Other People)	1
		Brainstorm with other people (Other People)	6
		How do I use this in the classes I'm teaching, right now? (Barriers)	8
		Those things stick more (Practical/hands-on)	1
		Time (Barriers)	12
		Engineering-type things (Practical/hands-on)	6
		Actually had students present (Other People)	7
		Apply it in the field (Practical/hands-on)	1
		See other teachers doing it (Other People)	4
		It's a little scary (Barriers)	2
		Gave us ideas (Benefits of the PLE)	3
		Very useful (Benefits of the PLE)	1
		All this other material (Barriers)	4
		Can't go into as much depth (Barriers)	3
		Rushed (Barriers)	3
		Extended hands-on learning (Practical/hands-on)	6
Phase 2	Pattern Coding	Barriers that Limit Learning Transfer	48
		Practical/hands-on	27
		Other People	19
		Benefits of the Professional Learning Experience (PLE)	12

There were several codes that had a substantially higher frequency than the other codes from the first round of coding. These codes included: *time* (12), *practical for sure* (8), *how do I use this in the classes I'm teaching right now* (8), and *actually had students present* (7). The codes *time* and *how do I use this in the classes I'm teaching right now* both fit under the theme *Barriers that Limit Learning Transfer*, the code *practical for sure* is a part of the *Practical/hands-on* theme, and the code *actually had students present* falls under the theme *Other People*. The only one of the themes that is not represented in these most frequent codes is the *Benefits of the Professional Learning Experience* theme, however this theme was present in the interview responses of all the participating teachers.

Barriers that Limit Learning Transfer. This theme is related to factors that can limit the teachers' transfer of learning from the professional learning experience to their classrooms. These factors can be related to the camp or can be things outside of the camp that have an effect on teacher transfer of learning. The factors mentioned by the teachers in the interviews for this pilot study included: lack of time, lack of space in the core curriculum, having to teach to standardized tests, bureaucracy, lack of excitement, the SEEd Standards, lack of confidence, and not being able to cover topics in much depth.

Regarding a lack of time, one of the participating teachers said, "*once the school year starts, it's kind of a whirlwind."* Another teacher said:

> *Well, I think part of it is time. Just having the time to be able to think about, "Okay. What can I do?" Because a lot of times, we could look for stuff on the internet and come up with stuff other teachers have done. But sometimes, that doesn't work and so you have to have time to be able to adapt it to your class,*

> *adapt it to the lesson you're doing. But I think time is the biggest thing. Like, I would love to do more labs it's just, it takes a lot of time to set them up and to get all the supplies, to do them in class. And, you know, at the same time, we're being asked to cover all these different learning objectives. We try to fit all that in and make it fun, by adding the hands-on experiences. So, for me, I just wish we had more time. That's, the primary thing. Is, the time to be able to stop, slow down, and go through the engineering-process with the kids and let them have time to explore. I wish I had time to add another day or two, where they could test their thing, and then redesign.*

Some of the teachers worried about how they were going to be able to apply the activities and the other things they learned from the camp. One teacher asked, "*How do I use this in the class I'm teaching right now?"* Another teacher said:

> *I mean some of the examples or some of the projects because they're mostly focused on environmental engineering. That some of those concepts… aren't physics or it's a stretch to try to reach them through a physics curriculum. So some of the projects,… examples that we learned, I wasn't able to like bring into the classroom. So I think, if possible, a bigger variation in the type of engineering projects that we have available, would help.*

The math teacher who participated in the camp said regarding some of what he learned at the camp, "*There's no way to use that in my math class.*"

Practical/Hands-on. This theme related to the teachers learning how to apply specific practices in their classrooms and the hands-on nature of the engineering activities from the Engineering Camp. The code *practical, for sure* was in response to a follow-up

question from the interview that was asked to some of the teachers which asked whether the teachers preferred professional development programs to focus on practical or theoretical. One teacher said, "*practical, for sure*" and several other teachers just responded with the word "*practical*" and then elaborated on why they preferred the practical over the theoretical. The teachers enjoyed having the hands-on engineering experiences at the camp but mentioned that one of the activities "*just wasn't hands-on enough.*" These hands-on activities from the camp helped the teachers to implement more "*extended hands-on learning*" and helped them to incorporate more of the "*engineering process… and making that more explicit.*"

Other People. This theme included anything related to interactions with the other participating teachers or with the students during the camp. The participating teachers enjoyed that the professional learning experience "*actually had students present*". Of this one teacher said, "*Having the students there is a big difference. I think that allows the opportunity to apply it immediately and reinforce what you're doing in the classroom.*" Another teacher commented that "*teachers need to see students doing*" the engineering activities in order to see how it can be applied in their own classrooms.

One of the participating teachers enjoyed that he "*got to know teacher from other schools that are in similar situations.*" He also enjoyed that he "*got to bounce ideas off of them, get feedback on various things, get strategies and ideas from them.*" Several of the other teachers also enjoyed the opportunity to "*brainstorm with other people*" and to be able to "*see other teachers doing*" engineering-related lessons.

Benefits of the Professional Learning Experience. This theme dealt with how the teachers benefited from participating in the professional learning experience. One

teacher said of the camp experience:

> *I thought it was very useful. I think it gave us ideas on how we can take activities or labs and make them more engineering-oriented. Because a lot of times, we have labs that are like cookbook, right? They just follow all the directions and do exactly, everyone does exactly the same thing.*

One of the participating teachers said that he didn't really learn new things from the camp professional learning experience but that the experience "*solidified things that [he] already had a view of as being important and being critical.*" Multiple teachers said that the GEAR UP Engineering Camp Professional Learning Experience "*gave some ideas to make [the lessons] more practical.*" One teacher also enjoyed that during the camp experience he had "*extra time to process*" what he had learned from the professional learning experience.

Discussion

It was clear from the results that some improvements needed to be made to the research study and the professional learning experience, including changes to some of the engineering experiences and to the professional development workshops. One of the themes that emerged from the data analysis was that the activities in the camp needed to be more hands-on. Most of the teachers specifically commented on two of the engineering activities from the camp that involved too much time sitting at a computer or listening to someone talk. These comments led to changes being made to those two activities to improve the quality and authenticity of the engineering experiences.

Only one of the teachers who was observed used an engineering activity that was done at the camp, but he was not able to use the drone that was given to him because he

said that he was unable to stabilize it. One of the other teachers was able to use the drone, but he did so before the interview, so that lesson was not observed. None of the other teachers used the materials that they were given at the camp. Because of this, the researchers decided that the teachers needed to be taught how to fly the drones and given the opportunity to do so during the camp. It was also decided that the researchers and the engineering professors leading the activities needed to help the teachers formulate lesson plans related to the camp.

It became clear from the data analysis that some changes needed to be made to the method of data collection and analysis in order to better answer the research questions. In the pilot study, the observations did not have any structured evaluation method. The only data from the observations was obtained from the field notes that were made by the student researcher. These field notes were not detailed enough, or descriptive enough to obtain meaningful data, or draw meaningful conclusions. So, the researchers created a rubric for the observations that were done with the teachers who participated in the 2019 GEAR UP Camp Professional Learning Experience. A similar rubric was created to evaluate the lesson plans that the participating teachers prepared during the professional development workshops.

In their responses to some of the interview questions, the teachers mentioned that they had both good and bad experiences at the camp. They could remember that there were good and bad things about the camp, but several of the teachers could not remember any specific details from the camp because the interviews took place at least five months after the Engineering Camp. This meant that some of that data was not usable. As a result of this, the researchers decided to divide the interview into two parts, one at the end of

the camp and the other after the classroom observation. Also, it was decided that all of the observations need to take place during the fall semester of the year following the camp so that the teachers can remember more specific details, and so that more meaningful data can be obtained. Despite all these issues, the preliminary results showed that the teachers enjoyed having a professional development workshop combined with the GEAR UP Engineering Camp for an overall professional learning experience, and that the participating teachers were able to transfer some of what they learned from the GEAR UP Engineering Camp activities and the professional development workshops about Three Dimensional Science Learning, the Framework for K-12 Science Education, and the Engineering Design Process to their own classrooms. This learning transfer was shown in the teachers' lesson plans, interviews, and observations.

Conclusions

Although the GEAR UP Engineering Camp Professional Learning Experience in 2018 was beneficial for the participating teachers, changes needed to be made to both the camp and the research design for the 2019 camp. In order to improve the data collection and analysis process, the semi-structured interview was split into two parts. Based on the results of this pilot study, it was decided that the first interview, consisting of the first two questions and related follow-up questions, would be conducted on the final day of the camp while the students were presenting their posters. The second part of the interview, which included the final three questions along with any follow-up questions, was then conducted in conjunction with the classroom observation (see Appendix G for the complete semi-structured interview protocol).

In addition to changing the interview process, it was clear that there needed to be

a more rigorous and structured method of evaluating the observed lessons and the lesson plans that the teachers submitted. To accomplish this, the researchers created an observation protocol and a lesson plan evaluation protocol. These protocols were created for use not only for the 2019 GEAR UP Engineering Camp, but for use in future GEAR UP Engineering Camp Professional Learning Experiences as well.

The interview data with the teachers also revealed that changes needed to be made to the professional development workshops. In preparation for the 2019 GEAR UP Engineering Camp, the researchers requested additional time with the teachers in order to allow for more lesson preparation time. The researchers also made the workshops more clearly focused on the Utah SEEd Standards, the Science and Engineering Practices, and the Engineering Design Process. The group activity done with the teachers was also modified to be more engineering-focused rather than science-focused.

The teachers also made it clear in their interviews that changes needed to be made to some of the engineering activities. These suggested changes focused mainly on making the Air Quality and the Aggie Air activities more hands-on. In order to accomplish this, the researchers worked more closely with the engineering faculty and students who were leading the activities and helped them to create a more hands-on experience for the students. For the Stream Data and Sea Perch Submarines groups, only minor changes were necessary. All these changes were intended to better help the teachers to apply engineering practices in their classrooms and help the researchers to obtain more usable qualitative data.

Overall, the pilot study resulted in some important changes to the GEAR UP Engineering Camp activities and the professional development workshop based on the

feedback from the participating teachers. These changes helped to improve the quality of the camp experience for the teachers and the students. Changes were also made to the methodology of the research based on the disorganized and incomplete data from the teachers' lesson plans and classroom observations. These changes made the research study more rigorous and helped to increase the quality of the collected data.

CHAPTER IV

METHODOLOGY

Because of NGSS or other similar standards such as the Utah SEEd Standards, K-12 science teachers are now expected to teach engineering in their science classes. Research has shown that many K-12 science teachers lack the engineering knowledge and self-efficacy to be able to teach these engineering practices in their classrooms. For this reason, it was necessary to conduct this qualitative research study.

Cresswell defines qualitative research as "an approach for exploring and understanding the meaning individuals or groups ascribe to a social or human problem" (Cresswell, 2014, p. 4). He continues, "Those who engage in this form of inquiry support a way of looking at research that honors an inductive style, a focus on individual meaning, and the importance of rendering the complexity of a situation." Because this research focuses on the experiences of the teachers at the GEAR UP Engineering Camp Professional Learning Experience, and because the researchers were more concerned with understanding that complex experience than with any numerical analysis, a qualitative approach was chosen for this research study.

This qualitative research study used a case study design using both a within-case analysis for each case and a cross-case analysis of all cases as described by Cresswell and Poth (2018). According to Cresswell and Poth (2018), "case study research involves the study of a case (or cases) within a real-life, contemporary, context or setting" (p. 96). This design was chosen because it is "suitable for exploratory, descriptive and explanatory research" (Yin, 2003, as cited in Ralston, Tretter, & Kendall-Brown, 2017, p. 91). This case study is bounded to include only those teachers who participated in the

GEAR UP Engineering Camp professional learning experience in the summer of 2019. A case is defined as “a concrete entity, such as an individual, a small group, an organization, or a partnership” (Cresswell & Poth, 2018, p. 96). In this research study, five different cases were chosen based on the subject that is taught by the participating teachers. These cases were: a first-year middle-school math teacher, a high school math teacher, a high school engineering teacher, two high school science teachers who also participated in GEAR UP 2018, and two high school science teachers who participated only in GEAR UP 2019. Each of these cases was analyzed individually, a within-case analysis, after which a cross-case analysis was performed. A cross-case analysis “involves examining themes across cases to discern themes that are common and different to all cases” (Cresswell & Poth, 2018, p. 322) and is used “when the researcher studies multiple cases” (Cresswell & Poth, 2018, p. 322). The qualitative data for this qualitative case study was collected through the interviews and observations of the teachers, as well as through the lesson plans that the teachers prepared during the camp.

Research Questions

This study was guided by the following research questions:

1. What factors influence transfer of learning for K-12 STEM teachers from an engineering focused summer workshop that includes student and teacher experiences to their classrooms?
2. How well are the participating STEM teachers able to transfer learning related to the Science and Engineering practices into their classrooms?
3. What is the effect of having a teacher professional learning experience combined with a student Engineering Camp on teachers’ transfer of learning?

Participants

This research study included eight K-12 STEM teachers from five school districts in the State of Utah, and one school district in West Wendover, Nevada. All these districts have participated in the GEAR UP Program in previous years as well. Of the eight participating teachers, seven were in-service teachers (although one had not been in a classroom yet at the time of the camp) and one was a pre-service teacher. Two of the participating teachers were math teachers, four of the teachers were science teachers, and one teacher taught engineering. The engineering teacher had a background in technology education, the science teachers had at least one degree in science or science education, one math teacher had a background in math education, and the other math teacher had a background in STEM and was in the process of getting a teaching certificate. The courses taught by the four science teachers included physics, chemistry, physical science, and biology. Four of the teachers were male and four were female. All the participating in-service teachers taught at the high school level except for one who was a first-year teacher at a middle school. The number of teachers participating in the research study was determined by the number of teachers who volunteered to come with their students to the GEAR UP Engineering Camp. The participating teachers were recruited for the study by the GEAR UP staff using a flyer which lists the expectations and benefits of participating in the camp (Appendix C). The number of participating teachers was limited to a maximum of 12, based on the needs of the camp and a desire to have a teacher to student ratio of approximately 5:1.

Two of the participating teachers from the 2019 Engineering Camp had participated in the GEAR UP Engineering Camp in the summer of 2018. Some changes

were made to the engineering experiences and to the professional development workshops, so these two repeat teachers were not exposed to the exact same experiences and content. These two repeat teachers, along with a third who had participated in other engineering-related professional development workshops, had some previous knowledge of the Next Generation Science Standards (NGSS), the Utah SEEd Standards, and the Science and Engineering Practices (SEPs) that are outlined in the standards.

Two of the teachers who participated in the Engineering Camp and Professional Development Workshops were not observed. One of the teachers was still in school and did not have a classroom to be observed, and the other was a first-year teacher who did not have time to implement the lesson plan sequence because of changes to his curriculum during the year. However, the first-year teacher did submit a lesson plan sequence to GSR1 before the end of the camp and participated in both interviews. The pre-service teacher participated in the workshop but did not submit a lesson plan sequence and was not observed or interviewed.

International Review Board

The IRB for this study was approved by the USU IRB office on September 20th, 2018. The camp portion of the study took place on the USU Campus with assistance from the GEAR UP staff and engineering faculty and students. The observations and the follow-up interviews took place in the classrooms of the participating teachers. A letter of informed consent (Appendix D) was sent to the participating teachers and signed copies were obtained at the camp. This letter of informed consent details what was expected of them as a part of the study, and that they were allowed to withdraw from the research study at any time without any reduction of the compensation that they received, or other

repercussions. The letter also informed the teachers how the data was obtained and stored, how the data was used by the researchers as a part of the study, and when the data will be destroyed. It also told the teachers what steps were taken to protect their identity including storage of the data in a secure location, limiting who has access to the data, and the use of pseudonyms. In addition, the participating teachers were given the contact information of the principal investigator and the co-investigator in case they have any questions about the study.

Program Description

In July 2019, teachers and students from various school districts throughout the State of Utah and one in the State of Nevada came to the campus of Utah State University (USU) to participate in the GEAR UP Engineering Camp. During the weeklong camp, the teachers participated along with their students in authentic engineering experiences and practices that were led by engineering professors and students from USU. These engineering experiences were based on the work in water quality, air quality, and other things related to environmental engineering that the engineering professors and students do themselves as a part of their research/education at Utah State University. Some of these activities may not have seemed related to engineering at first glance because the engineering professors are research engineers, not practicing engineers in industry, so the line between engineering and science was especially blurred. During the camp, the teachers and students were divided into four groups and took turns participating in four different engineering experiences which included: measuring stream data by placing sensors into a river at different points, measuring other data from the water using Sea Perch Submarines that the students and teachers built at the beginning of the camp,

measuring air quality data using sensors that were attached to copter drones, and assembling and flying small drones. This was done over two days of the camp (Tuesday and Wednesday). After participating in all four of the experiences, the students self-selected into one of the four groups by giving their top three choices. The teachers were then divided using self-selection among these groups as well. On the fourth day of the Engineering Camp, the teachers and students went with these new groups to participate in more in-depth experiences with the Sea Perch ROV Submarines, Stream Data, Air Quality, and Aggie Air groups. These experiences included: collecting stream data at different parts of the Logan River in Logan Canyon, going to a reservoir to take measurements in a deeper body of water using similar methods as were used previously with the Sea Perch ROV Submarines, taking more measurements of air quality using sensors, and building and modifying small drones and flying them around a course to see if the modifications helped the drones to fly faster. The experiences on Thursday were guided by research questions that the students and teachers formulated at the beginning of the activity. During the activities that day, the different groups collected data to answer the research questions. On Thursday evening, the students created research posters centered about the answer to their research questions and the research process they used to answer the questions. The students presented their posters on the last day of the camp (Friday) to professors and students from the College of Engineering, as well as others who were interested in the program. A summary of the division of the student groups is included below in Figure 1. The full camp schedule is included in Appendix E. A summary of the engineering experiences on Tuesday, Wednesday, and Thursday is also included below in Table 2.

The GEAR UP Engineering Camp professional learning experience allowed the teachers to not only have authentic engineering experiences but also allowed them to see the Science and Engineering practices being implemented with students through hands-on activities.

GEARUP Engineering Summer Program 2019												
Dates: July 8 - 12, 2019												
	Monday		Tuesday				Wednesday				Thursday	Friday
Teams and Topics	1 to 4		8 to 12		1 to 5		8 to 12		1 to 5		8 to 5	8 to 12
Overview of Program (all)	*											
Assemble Sea Perch Subs (all)		*										
Student Team #1			1	1	2	2	3	3	4	4	Team 1 -Reseach	Poster Session
Student Team #2			2	2	1	1	4	4	3	3	Team 2 -Reseach	Poster Session
Student Team #3			3	3	4	4	1	1	2	2	Team 3 -Reseach	Poster Session
Student Team #4			4	4	3	3	2	2	1	1	Team 4 -Reseach	Poster Session
	All		Team Activities									All
Air Quality / Drones	6 hours - Randy Martin (drones, vert. profiles, temp. profiles)											
AggieAir	6 hours - Cal Coopman / Alfonso Torres-Rua (aircraft data collection & payloads)											
Sea Perch Submarines	6 hours - Nancy Mesner/Cade Andrus (Robots collect stream data)											
GIS Stream Data	6 hours - Ryan Dupont/Patrick Strong (stream data along the watershed)											

Each Team (15 students & 3 teachers/chaperones)

Figure 1. GEAR UP Engineering Camp 2019 Group Division Schedule.

During each of the four authentic engineering experiences and the more in-depth experiences that were done on Thursday, which were all based on the engineering research of the engineering professors leading the activities, the teachers were able to go through different steps of one model of the Engineering Design Process (Appendix A), which they could then use in their own classrooms with their own students. The researchers and the engineering professors and students leading the activities encouraged the teachers to participate in the experiences with their students instead of just supervising or observing. Throughout the camp, the teachers were also encouraged to ask questions to help them better understand the engineering experiences so that they could better implement engineering activities in their own classrooms.

Table 2

Summary of GEAR UP Camp Activities

Group Name	Tuesday and Wednesday Activities	Thursday Activities
Sea Perch Submarines	• Used pebbles to balance and weight the subs • Collected samples and water quality data • Took pictures and video using attached camera	• Collected samples and water quality data from a deeper reservoir using boats to get away from the shore • Took pictures and video • Analyzed data in computer lab • Created research poster
Stream Data	• Measured flow of the river using three different methods • Collect and test water samples using various tools	• Measured flow of the river and collected water samples from different locations along the river in the canyon • Tested water samples • Analyzed data in computer lab • Created research poster
Air Quality	• Observed air quality presentation and demonstration of inversion • Assembled air quality sensors • Used sensors to measure air quality indoors and outdoors	• Used air quality particulate sensors to measure the particulate readings of different flames • Used air quality particulate sensors to measure the readings from different vehicles • Analyzed data in computer lab • Created research poster
Aggie Air	• Toured Aggie Air shop • Used authentic drone flight simulator • Learned about drone programming • Flew small quadcopter drones	• Assembled and flew quadcopter drones on an outdoor course • Made modifications to the drones and flew the course again • Created design poster highlighting modifications and results

Sea Perch ROV Submarines

On Monday, after the introductory presentations and logistical items were completed, the teachers and students assembled the Sea Perch Remotely Operated Vehicle (ROV) submarines from provided kits under the supervision of the engineering faculty and students who led the Sea Perch activity. On Tuesday and Wednesday, the different groups of students and teachers took the Sea Perch ROV submarines to a local reservoir. Before collecting any data or samples, the students and teachers used small bags of pebbles to make sure that the submarines would go down in the water and that the submarines would be balanced while underwater. After finishing these preparations, the students and teachers put their submarines in the water and drove them around underwater collecting water quality data, water samples, pictures, and video using the attached sensors, cameras, and other tools. Once the data and samples were collected, the faculty helped the students and teachers look at the data and make sure that the data was usable. Once the student and teacher groups had usable data, they returned to the campus where they analyzed the water quality data that they had obtained in a computer lab.

On Thursday, the students and teacher who had self-selected into the Sea Perch group went with the Sea Perch faculty and students to a deeper reservoir that was a little further from the campus of Utah State University. The students and teachers were able to go out further into the reservoir on small boats and use the ROV submarines to collect water quality data and additional water samples from the deeper water. Once the students and teachers had collected enough data to answer their research questions, which were limited to questions that could be answered by the data that was obtained during the activity, they returned to the computer lab on campus to analyze the data and complete

their research posters.

Stream Data

During the Tuesday and Wednesday portion of the activities, the groups of teachers and students were taken to where a local river flows into a reservoir and divided into even smaller groups at four different stations. These stations included three different stations that each focused on a different method of measuring the flow of the water stream in the river. The fourth station involved taking multiple small samples of water from the river and running several tests that checked for various types of substances and particulates and for overall water quality.

On Thursday, the teachers and students who had self-selected into this group were taken up nearby canyon to several locations along the river. At each location along the river as it flowed down the canyon, the teachers and students measured the flow of the water using the various methods and took additional water samples. The water samples were analyzed and tested using similar methods as in the previous portion of the activity. Once the groups had completed the testing, they returned to the computer lab on campus to analyze the water quality data in order to answer their research questions, which were limited to questions that could be answered using the data that was obtained in the planned activity, and then create their research posters.

Air Quality

For the first two days of the Air Quality activity, the teacher and student groups were further divided into two smaller groups. The first group listened to a presentation about air quality and inversions which included a demonstration of inversions and a scientific background and air quality measurements. The second group listed to a short

presentation about air pollution and then assembled simple air quality particulate sensors from using provided materials and detailed instructions. After the students and teachers had completed their sensors, they were able to walk around inside and outside and test the air quality in different situations. These situations included testing a truck's exhaust, testing the air after stomping on a carpet or kicking a tire, and testing the air above a candle flame, a rock crusher, and a lit cigarette under a vent hood.

For the Thursday activity, the teachers and students who had self-selected into the Air Quality group were divided into two smaller groups again based on their choice of research question. The first group used the air quality sensors to collect particulate readings from different flames. These flames included candles, candle warmers, a burning campfire, a smoldering campfire, burning crayons, a lit cigarette, and a lit cigar. The campfire was outside in a controlled environment and the other items were burned inside under a vent hood to prevent the students and teachers from breathing in any harmful fumes. The second group of students and teachers used the air quality sensors to measure the particulate readings from the exhaust of different vehicles that they found on the Utah State University campus with the permission of the drivers of the vehicles. The vehicles tested by this group included sedans and other smaller vehicles, pickup trucks, and diesel trucks. Once all the particulate readings had been collected, both groups returned to the computer lab to analyze the readings and complete their research posters.

Aggie Air

During the Tuesday and Wednesday Activities, the teachers and students were first given a short tour of the Aggie Air shop at Utah State University where the faculty and students of the Aggie Air group build and program drones. After this tour there was a

short presentation about some of the projects that the faculty and students in the Aggie Air group were working on at the time of the camp. Following the presentation, the students and teachers were further divided into three groups and rotated through three stations. In the first station, the teachers and students went to a computer lab and learned more about the programming of drones. In a different computer lab, the teachers and students were able to use a computer flight simulator using controllers that imitate real drone controllers. The third station involved a presentation about drone safety followed by flying small quadcopter drones in an indoor controlled environment. This third station had some technical difficulties at first because the controlled environment was too small for inexperienced drone pilots and the drones crashed multiple times. By Wednesday, the problems had been fixed and the students were able to fly drones at low altitude outside in a large open area near the engineering buildings.

For the more in-depth activities on Thursday, the teachers and students who had chosen to participate in Aggie Air built small quadcopter drones from a kit and flew them around a small course that was set up outdoors in a large open area near the engineering buildings. After flying the drones through the course, the teams of students and teachers were able to make some small modifications to the drones. When the modifications were completed, the teams flew the drones through the course again to test whether the modifications had improved the time or made the drones slower. After the second round of testing was completed, the students and teachers went to the computer lab to complete their research posters. The research posters were different for these teachers and students because it was more about design and redesign than about asking and answering a question.

Professional Development Workshops

On Monday, Tuesday, Wednesday, and Thursday evenings, the teachers spent approximately two hours with two of the GEAR UP researchers who were leading the professional development workshops. This workshop focused on helping the participating teachers learn more about the Science and Engineering practices (Figure 2 and Appendix F) and the Engineering Design Process (shown below in Figure 3) and about how to apply them in their own classrooms.

Science and Engineering Practices (SEPs)	
From the Framework for K-12 Science Education (NRC, 2012)	
1)	Asking question and defining problems
2)	Developing and using models
3)	Planning and carrying out investigations
4)	Analyzing and interpreting data
5)	Using mathematics and computational thinking
6)	Constructing explanations and designing solutions
7)	Engaging in argument from evidence
8)	Obtaining, evaluating, and communicating information

Figure 2. *Science and Engineering Practices. Adapted from the Framework for K-12 Science Education (National Research Council, 2012).*

The first night of the professional development workshop began with having the engineering professors who led the activities explain what the teachers were encouraged to do during the engineering experiences, and give them some examples of things they could do in their own classes that are related to those experiences. Next, the researchers reviewed the Science with Engineering Education Standards (SEEd), the Science and Engineering practices that are outlined in the SEEd Standards, and the engineering design process. The researchers then led a discussion on how they can be applied in the classroom. The discussion of the engineering design process centered on a simplified

model of the engineering design process (Appendix A) which was chosen by the researchers. Though other models exist, this model was developed to correspond with NGSS.

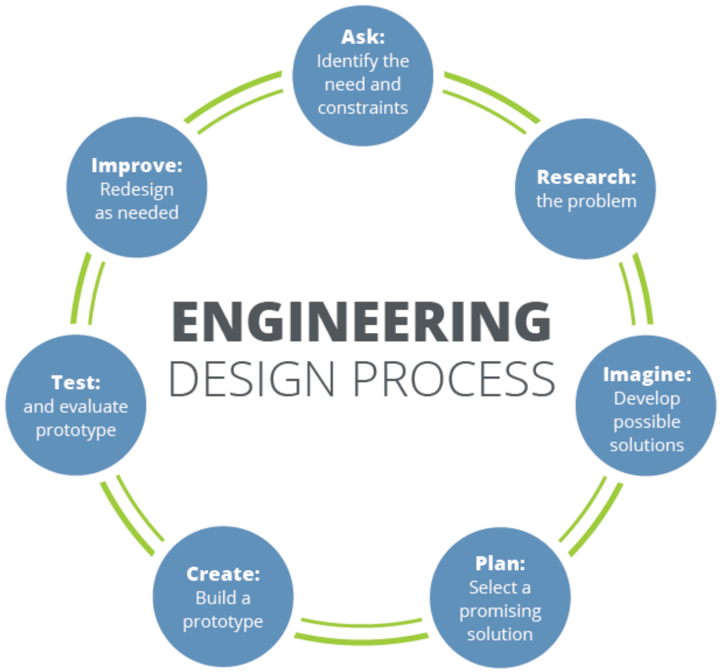

Figure 3. Simple Model of the Engineering Design Process. Obtained from teachengineering.org ("Engineering Design Process", n.d.)

After the discussion of the standards and practices, the teachers participated in an activity that was used as an example of how they can incorporate the Science and Engineering practices and the engineering design process into their classes. For this activity, the student researcher introduced a hypothetical open-ended design problem in which the teachers were asked to get into pairs and design a method of collecting water quality data and water samples from the deepest point of Bear Lake. The teachers were given a list of some of the specific parameters and could use online resources to help them define the parameters of the problem. The teachers were also given a hypothetical

budget and a list of materials that could be used on their design. They were also given the opportunity to use other materials which they found online with the approval of the student researcher who was leading the activity. To add an interesting twist to the activity, the teachers were told that in the context of the hypothetical problem, they were allowed to keep any of the budget that was not used for the materials and production of the design.

This activity lasted approximately 45 minutes, after which the teacher pairs presented their completed designs, including simple drawings, to the rest of the group. The student researcher then led a discussion about how this simple hypothetical design activity included many of the Science and Engineering Practices that are highlighted in the Utah SEEd Standards but was something that the teachers could do during a single class period. Hypothetical design activities, such as the one led by the student researcher, could also be done by the teachers without spending substantial time and money on materials or field trips. After this discussion, the teachers were asked to individually create a similar hypothetical design problem that they could use in their own classrooms and present it to the rest of the group. One of the teachers ended up expanding on this idea for their series of lesson plans.

On Tuesday evening, the student researcher reviewed the Science and Engineering Practices and led a discussion about how the practices relate to the Engineering Design Process. The student researcher then explained that the engineering design process is iterative and can involve a certain amount of failure. Two quotes from popular culture were used to illustrate the importance of failure and learning from failure in the engineering design process. The teachers then participated in a short discussion

about why it is important for them to help their students be able to learn from failure and keep pushing forward with their design.

For the rest of the time during the Tuesday evening workshop, as well as for the entire time during the Wednesday and Thursday evening sessions of the professional development workshop, the teachers had time to craft their lesson plans for a series of lessons from a template (Appendix B) that they would eventually teach in their own classrooms, one of which was observed by one of the researchers. The researchers leading the professional development workshop acted as resources during the lesson preparation time, helping the teachers to incorporate the Science and Engineering practices in the lessons that they were planning. The participating teachers also had the opportunity during this time to collaborate with each other to craft lesson plans, although most of the teachers ended up working on their own with minimal collaboration. There are several possible reasons for this. First, it was not explicitly stated to the teachers that they could work collaboratively on the lesson plans. The second possible reason is that the participating teachers were planning lessons in different subjects and were expected to plan an entire series of lessons instead of just a lesson for a single class period.

Table 3

Teacher Development Workshop Summary

Content/Activity	**Process**
	Monday Evening
Review of 3-D Science, Science and Engineering Practices, and Engineering Design Process	**<u>Welcome / Introductions (40 min)</u>** • Engineering Professors explained what the teachers and students will be doing during the activities • Explained how the teachers can help the students benefit from the engineering experiences • Explained how the teachers can benefit from the engineering experiences **<u>Presentation of Content</u>** • Briefly reviewed 3-D Science (5 min) • Reviewed Science and Engineering Practices and SEEd Standards (5 min) • Introduced Engineering Design Process (5 min)
Hypothetical Design Problem – Bear Lake	**<u>Group Performance (45 min)</u>** • Had small groups of 2 brainstorm and come up with solutions to the design problem **<u>Group Discussion (15 min)</u>** • Shared the solutions with the whole group • Discussed as a group from a teaching perspective the outcomes of engaging in engineering experiences **<u>Individual Performance (15-20 min)</u>** • Had each participant develop a design problem that they can use in their own classroom (transfer)
	Tuesday Evening
Review, Research, and Discussion	**<u>Introduction to TeachEngineering.org – (25-30 min)</u>** • Briefly reviewed the engineering design process again. • Introduced TeachEngineering.org and had the teachers browse the site. Had a small group discussion about what was found on TeachEngineering.org. Shared with the whole group.
Crafting Lesson Sequence	**<u>Lesson Plan Creation (90 min)</u>** • Allowed time for the teachers to work on their own plan for the lesson sequence.
	Wednesday Evening
Crafting Lesson Sequence	**<u>Lesson Plan Creation (90 min)</u>** • Allowed time for the teachers to work on their own plan for the lesson sequence.
	Thursday Evening (if necessary)
Crafting Lesson Sequence	**<u>Lesson Plan Creation (120 min)</u>** • Allowed time for the teachers to work on their own plan for the lesson sequence.

The structure of the series of lesson plans was intended to follow a similar format to that of the engineering experiences on the Thursday of the camp. In other words, the teachers should have planned to have their students ask research questions or define a problem, collect and analyze data, reach conclusions or solve problems, and communicate the conclusions or solutions using a poster or some other medium. The teachers did not have to recreate specific activities from the camp, but they could, if it fit into their core curriculum. At the conclusion of the last session of the professional development workshop, the teacher submitted their lesson plans to the researcher electronically so that suggestions could be made for improvement of the lesson before it was given in their classrooms.

A summary of the evening teacher development workshops is shown in Table 3, including the activities in which the teachers participated, the approximate amount of time the teachers had to complete each activity, and a short description of each activity. As seen in Table 3, the first evening session and the beginning of the second evening session were dedicated to discussion and activities related to the SEEd Standards, the Science and Engineering Practices, and the Engineering Design Process. The rest of the time on the second evening and the entire time during the other two evening sessions were dedicated to the teachers preparing their engineering lesson plans.

Data Collection

Overview

The qualitative data was collected through interviews and observations, and through the lesson plans that the teachers developed during the GEAR UP Engineering Camp. Data was collected both during and after the camp and was collected both on the

USU campus (at the camp) and in the individual classrooms of the participating teachers. The student researcher obtained the interview and observation data, which was stored in an IRB approved location for data storage.

Interviews

A semi-structured interview was used because it allowed for the freedom to ask follow-up questions relevant to the answers that teachers had given to the prepared questions. This interview was divided into two parts based on the results of the pilot study. However, the overall time commitment was the same as in the pilot study because the same questions were used. The first part of the interview was conducted at the end of the GEAR UP Engineering Camp while the students were presenting their research posters. The student researcher interviewed each teacher individually during that allotted time. Each of these interviews lasted approximately 10 minutes. The prepared interview questions for this part of the interview focused on the teachers' experiences at the GEAR UP Engineering Camp (Appendix G). These questions, which were based on the questions that were asked in the pilot study, included, "*Please share your thoughts about the GEAR UP 2 Engineering Camp*", and "*What are your thoughts about combining professional development with the GEAR UP 2 Engineering Camp for an overall professional learning experience?".* The two teachers who had participated in the 2018 GEAR UP Engineering Camp were asked "*How was this camp different from last year's cam?*". The question, "*How was this different from other professional development programs in which you have participated?*" ended up being asked to each of the participating teachers as a follow-up question. Additional follow-up questions related to the teachers' specific experiences at the Camp were also included.

Because of the results of the pilot study, it became clear that the interview needed to be split into two parts. Several teachers mentioned that they did not remember specific details or experiences from the camp because at least five months had passed since the camp. Having the interview questions that are only related to the teachers' experiences at the GEARUP Engineering camp at the end of the camp solved this problem.

The second part of the interview was conducted in the classrooms of the participating teachers immediately following the classroom observation. These interviews were each less than 20 minutes in length and focused more on what the teachers had done or planned to do in their classrooms based on their experience at the camp (Appendix G). These questions included, "*What experiences from the GEAR UP 2 Engineering Camp did you find most useful/beneficial for you in your teaching?"*, "*When considering the GEAR UP 2 Engineering Camp professional learning experience, what did you learn that you have used in your classroom?"*, and "*What are the most influential factors that determine whether you apply what you have learned from professional learning experiences such as the GEAR UP 2 Engineering Camp in your classroom?"*. In addition to the questions listed, the semi-structured interview format allowed for follow-up questions based on the responses of the teachers. All the questions, including the follow-up questions, helped to tie together the observation and the lesson plan data. Each of the questions included in the semi-structured interview protocol was created in order to answer one or more of the research questions (labeled as RQ1, RQ2, and RQ3 in Appendix G) using the teachers' responses to the specific interview questions.

Both parts of the interview were audio recorded. After all the interviews were completed, the recordings of the interviews were transcribed to facilitate data analysis.

The audio recordings have been stored in a secure location and will be deleted after the completion of the research study.

Observations

The student researcher went to the classroom of the participating teachers to observe them teaching a part of the lesson sequence, consisting of one class period, they prepared during the camp. The observed lessons incorporated at least a portion of the Science and Engineering practices outlined in the SEEd Standards. These observations took place during the Fall 2019 Semester or at the beginning of the Spring 2020 Semester. Most of the teachers chose which specific portion of the lesson they wanted to have observed. The purpose of the observation was to see to what extent the participating teachers had been able to transfer their learning related to the SEEd Standards and the Science and Engineering Practices from the GEAR UP Engineering Camp professional learning experience to their own classrooms.

For the teacher observations, GSR1 travelled to the individual schools of the participating teachers on a date and time that was most convenient to each participating teacher. GSR1 arrived before each class started and sat in an area of the class where he would not disturb the learning environment. During the observed lesson, GSR1 rated the observed teacher's application of the Science and Engineering Practices using a rubric (Appendix H). The researcher also took notes related to the classroom environment and the reasoning behind each of the ratings.

Lesson Plan

During the GEAR UP Engineering Camp, the participating teachers had time in the evenings to work on a sequence of lesson plans, based on the template in Appendix B,

which incorporated the Science and Engineering practices outlined in the Science with Engineering Education (SEEd) Standards. The purpose of collecting a lesson plan from the teachers was to see to what extent they have been able to transfer the learning about the Science and Engineering Practices into their own lessons. This series of lesson plans could incorporate specific activities that were done at the camp, although it was not a requirement since the participating teachers do not all teach the same subjects. Each teacher was able to craft a lesson sequence that fits in their core curriculum. Included in these lesson plans was a place for the teachers to write which of the 8 Science and Engineering Practices were incorporated into that portion of the lesson. These lesson plans were collected at the end of the camp. Another copy of the lesson plans was collected from each of the participating teachers when they were observed and interviewed in their own classrooms to see if any changes had been made to the lesson plan since the camp. Only one of the participating teachers made any substantial changes to the lesson plan sequence between the GEAR UP Engineering Camp and the observed lesson.

Data Analysis

Interviews

After all the interview data was collected and transcribed, the student researcher began the process of data analysis with the assistance of another coder, GSR3, who is another graduate student in the Engineering Education Department at Utah State University. GSR3 was trained in qualitative data analysis through a graduate course on qualitative research methods. In order to get additional practice and to make sure that both coders were familiar with the chosen coding methods, GSR3 analyzed the data from

the pilot study with GSR1. GSR1 also met with GSR3 before beginning the process of data analysis to familiarize him with the research study and answer any questions that he had.

It is important to have more than one person to analyze the qualitative data to make the data more valid and reliable. This data analysis consisted of doing a preliminary reading of the transcribed interview to get “a sense of the whole database” (Cresswell & Poth, 2018, p. 187). During this initial reading of the data, as well as through the entire coding process, the researcher and the other coder took notes in the form of analytic memos, which are “comparable to researcher journal entries or blogs – a place to ‘dump your brain’ about the participants, phenomenon, or process under investigation” (Saldaña, 2016, p. 44). These analytic memos were used to connect the three different data sources. The initial reading of the data was also done to look for emergent themes (Cresswell & Poth, 2018). All of this was done before any coding began.

For the first round of coding, both GSR1 and GSR3 read the interview transcripts again and began to code using In Vivo Coding in MAXQDA®. This program was used for every step of the coding process. According to Saldaña in *The Coding Manual for Qualitative Researchers*, In Vivo Coding is ideal for the first round of coding for interview transcripts because it is “a method of attuning yourself to participant perspectives and actions” (Saldaña, 2016, p. 73). In addition, he says that defaulting to descriptive coding for interview transcripts is one of the major mistakes made by researchers (Saldaña, 2016).

Between the first and second cycles of coding, code landscaping was done in MAXQDA® using the creation of a word cloud from the portions of data that were coded

during the first cycle of coding similar to the word cloud shown in Figure 4. This is used as a method of analyzing the frequency of specific words or phrases in the data (Saldaña, 2016). This frequency is especially useful since the first cycle of coding was done using In Vivo coding in which the codes come from the participants' own words.

Figure 4. Sample Word Cloud (Saldaña, 2013).

The second cycle of coding was done using Pattern Coding, which is done to group the first cycle codes "into a smaller number of categories, themes, or concepts" (Saldaña, 2016, p. 236). A sample of Pattern Coding is shown in Figure 5. After these themes were determined, they were used to answer the first and third research questions. During the entire process of data analysis of the interview data, the two coders coded independently and then met to come to an agreement on the codes. Both coders contributed to the codebook by creating a set of in vivo codes. The final codebook was a result of the consensus reached by the two coders. In case there was substantial disagreement between the two coders, then they agreed to consult with an arbitrator who would make the final coding decision, however there was no need for an arbitrator because the two coders were able to come to a consensus during both cycles of coding

through various meetings in which the two coders went through each interview and discussed each coded segment. After each coded segment was discussed, the coders came to an agreement on which codes were going to be applied to each coded segment. In many cases, the two coders had already used similar codes when coding individually, so they were able to reach a consensus without much difficulty.

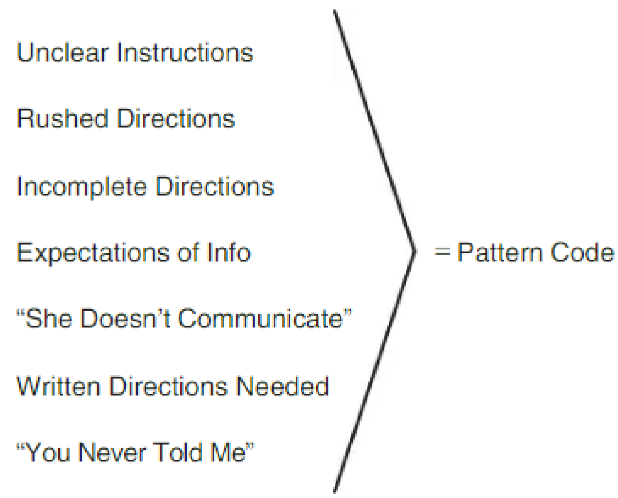

Figure 5. Sample of Pattern Coding (Saldaña, 2016)

Observations

The researcher evaluated how well the teachers were able to apply the Science and Engineering practices in the observed lesson based on a rubric (Appendix H). This rubric is loosely based on the Reformed Teaching Observation Protocol, RTOP (Piburn & Sawada, 2000). The elements of the RTOP that were incorporated in the rubric include the contextual background, the description of events, and the 0-4 scale. Because the rubric for the observation is specifically structured around the eight Science and Engineering Practices, the specific questions from the RTOP were not used. The rubric

that was used to evaluate the observations included space for the researcher to write about the context of the observed lesson, including details about the classroom, the teacher, and the learning environment. In addition, there are ratings of how well the observed teacher was able to apply the Science and Engineering practices in the observed lesson on a scale of 0-4, where 0 means that the Science and Engineering practice was not present and 4 means that there was substantial application of the Science and Engineering practice. There was also space included for the researcher to record specific events during the lesson that contributed to the ratings. The notes taken by the researcher in both the available spaces on the observation protocol were also considered as qualitative data to help triangulate the data. Both, the spaces for observer notes and the 0-4 rating system were taken directly from the RTOP, although the meanings of the 0-4 ratings were changed to fit the context of this research study. All of this helped to determine how well the participating teachers were able to apply the Science and Engineering practices outlined in the SEEd Standards in their own classes. This data provided the answer to the second research question.

Lesson Plans

After the lesson plans were completed, they were evaluated by the student researcher (GSR1) and another student (GSR2), who has experience in the K-12 environment in the State of Utah, using the same rating system as the observations (0-4 rating on each science and engineering practice with 0 meaning not present in the lesson and 4 meaning that there is substantial application of the Science and Engineering practice in the lesson) with space for notes on the reasoning for the rating (Appendix I) that were also used as analytic memos similar to the observation data. GSR2 was trained

in analysis of qualitative data through a graduate course on qualitative research methods. In addition to this, GSR1 met with GSR2 before the beginning of the analysis of the lesson plans to help familiarize her with the lesson plan evaluation protocol and the Science and Engineering Practices. A sample teacher lesson plan with a completed evaluation protocol is included in Appendix J.

Because the lesson plans were evaluated by more than one person, the interrater reliability was calculated using both the percentage agreement and Cohen's Kappa to ensure that the ratings were consistent. As with the observation data, the ratings from the lesson plan and the notes about the lesson plan were used to help determine how well the participating teachers were able to transfer the learning on the Science and Engineering practices from the context of the GEAR UP Engineering Camp professional learning experience to the context of their own classes. As a part of each individual lesson plan in the sequence, the teachers made a list of which of the SEPs they thought were incorporated into that individual lesson in the sequence. This list can be considered as a self-evaluation by the teachers of whether they were able to incorporate the SEPs into their lesson sequence.

Summary

This research study was done using a qualitative approach using a case study design. The qualitative data for this study was obtained through the lesson plans that the participating teachers prepared during the evening professional development workshops, through a classroom observation of the participating teachers while they enacted a portion of the lesson plan sequence from the camp, and through semi-structured interviews that were conducted on the last day of the camp and immediately after the classroom

observations. The lesson plan data was analyzed using the Lesson Plan Evaluation Protocol (Appendix I). The data from the observed lessons was evaluated using the Observation Protocol (Appendix H). The data obtained from the teachers' interview responses was analyzed by two coders using In-Vivo Coding and Pattern Coding (Saldaña, 2016).

Data was obtained from the teachers' lesson plans, the observed lessons, and the teachers' interview responses for the purpose of triangulation. Data was also taken from the analytic memos written by GSR1 and notes taken by both graduate student researchers who analyzed the teachers' lesson plans. In addition, each data source was analyzed separately for each of the five cases, then was analyzed collectively for the cross-case analysis.

The qualitative data obtained from the participating teachers' lesson plans, observations, and interviews was used to answer the research questions that guided the study. The lesson plans and observations were primarily used to answer the second research question, but also provided insight for the first and third research questions. The qualitative data obtained from the participating teachers' interview responses helped to answer primarily the first and third research questions, but also somewhat helped to answer the second research question. The teachers' responses to the third, fourth, and fifth interview questions and corresponding follow-up questions were particularly related to how the participating teachers' either were able to or were not able to transfer what they learned from the professional learning experience to their classrooms. The first two interview questions from the semi-structured interview (Appendix G) helped to answer Research Question 3. The fifth question from the semi-structured interview was used to

answer Research Question 1. In addition to interview questions 3 and 4 from the semi-structured interview protocol (Appendix G), GSR1 asked some additional follow-up questions which were also used to answer Research Questions 2 and 3. The process of data analysis for the cross-case analysis and triangulation is shown in Figure 6 below.

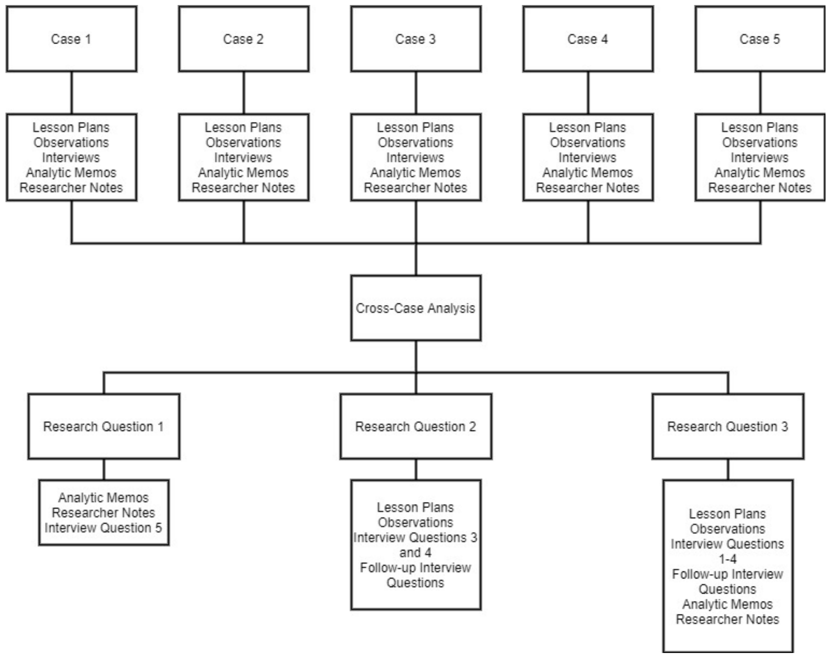

Figure 6: Flowchart of Cross-case Analysis and Triangulation

CHAPTER V

RESULTS

The purpose of this study was to examine transfer of learning of K-12 STEM teachers from the GEAR UP Engineering Camp professional learning experience to their own classroom. As a part of this study, the researchers investigated the factors that influenced the teachers' transfer of learning and determined how well the participating teachers were able to transfer their learning related to the Science with Engineering Education Standards (SEEd) and the Science and Engineering Practices (SEPs) from the Framework for K-12 Science Education. These SEPs (National Research Council, 2012) are:

1. *Asking Questions and Defining Problems*
2. *Developing and Using Models*
3. *Planning and Carrying Out Investigations*
4. *Analyzing and Interpreting Data*
5. *Using Mathematics and Computational Thinking*
6. *Constructing Explanations and Designing Solutions*
7. *Engaging in Argument from Evidence*
8. *Obtaining, Evaluating, and Communicating Information*

This research study was guided by the following research questions:

1. What factors influence transfer of learning for K-12 STEM teachers from an engineering focused summer workshop that includes student and teacher experiences to their classrooms?

2. How well are the participating STEM teachers able to transfer learning related to the Science and Engineering practices into their classrooms?
3. What is the effect of having a teacher professional learning experience combined with a student engineering camp on teachers' transfer of learning?

In order to answer these research questions, qualitative data was obtained by analyzing the lesson plans that the participating teachers had submitted, by observing the teachers in their own classrooms teaching a portion of the planned lessons, and by analyzing the teachers' responses to a series of interview questions. Throughout the process of data collection and analysis, GSR1 also wrote analytic memos, which were also analyzed using the same codes and themes as the interviews. The qualitative data obtained from the lesson plans and observations map most closely to Research Questions 2 and 3. The qualitative data obtained from the interviews map to all three of the Research Questions. The results of the data analysis of the lesson plans, observations, and interviews are shown in the following sections.

Lesson Plans

The lesson plan sequences that the teachers submitted were analyzed by the graduate student researcher (GSR1) with the assistance of GSR2, another graduate student in the Engineering Education Department with K-12 experience. Both graduate students evaluated the lesson plan sequence based on the Lesson Plan Evaluation Protocol (Appendix I) and rated how well each teacher was able to incorporate the Science and Engineering Practices (SEPs). After evaluating the lesson plans separately, the two graduate students met to come to a consensus on the ratings of the SEPs. The numerical ratings of GSR1 and GSR2, as well as the consensus ratings, are based on a

scale from 0 to 4, and the specific numerical values for each teacher are shown in Table 4. The table also includes the average rating among the teachers for each of SEP. In addition to the ratings, both graduate students took notes about the reasoning behind each of the ratings based on the content of the lesson plans.

Because there were two different graduate students rating the lesson plans, it was necessary to calculate the interrater agreement using both percentage agreement and Cohen's Kappa because there is not accepted best method of calculating interrater agreement. Using Excel, the percentage agreement was calculated to be 82% and the Cohen's Kappa was calculated to be 0.71. According to Graham et al., a percentage agreement between 75% and 90% is considered acceptable with a percentage higher than 90% percent being a high level of agreement (Graham et al., 2012). Graham et al. also suggests that a Cohen's Kappa between 0.61 and 0.81 is considered acceptable with a value above 0.81 being considered high agreement (Graham et al., 2012).

Some of the lesson plan sequences had some of the same Science and Engineering Practices represented in multiple lessons. For example, with regards to the lesson plan written by teacher 1, GSR2 wrote:

> *"Many of the science and engineering principals are implemented throughout these lessons, but the most frequent are engaging developing and using models including the FBDs (Practice 2), analyzing and interpreting data collected from different scenarios throughout the lessons (Practice 4), use of computational thinking calculations of net and balance forces as well as mass vs weight calculations (Practice 5). In each lesson students are asked to share a rationale for their conclusions allowing them to engagement in arguments from evidence*

(practice 7) and obtain and communicate information (Practice 8).”

In his notes for the lesson plan created by teacher 1, GSR1 wrote:

“Even though it was the expectation for the teachers to apply all of the 8 SEPs through the course of the entire lesson sequence and not necessarily to apply any of them in multiple individual lessons, this teacher was having the students ask questions or design solutions (SEP 1), using math (SEP 5), engaging in argument (SEP 7), and communicate information (SEP 8) on each day of the lesson sequence.”

Table 4

Teacher Lesson Plan SEP Application Ratings

Numerical Scale (0 = Not present in lesson, 1 = negligible application, 2 = limited application, 3 = moderate application, 4 = substantial application)

Science and Engineering Practices		1	2	3	4	5	6	7	8
	Rater								
Teacher 1	**Kate**	3	4	3	4	4	3	4	4
	Ryan	4	4	3	4	4	4	4	4
	Consensus	4	4	3	4	4	4	4	4
Teacher 2	**Kate**	2	4	0	0	4	3	0	0
	Ryan	1	4	0	0	4	2	0	0
	Consensus	1	4	0	0	4	2	0	0
Teacher 3	**Kate**	3	4	0	4	4	3	4	4
	Ryan	4	4	0	4	4	4	4	4
	Consensus	4	4	0	4	4	3	4	4
Teacher 4	**Kate**	4	4	4	4	4	4	4	4
	Ryan	4	4	4	4	4	4	4	4
	Consensus	4	4	4	4	4	4	4	4
Teacher 5	**Kate**	2	0	3	3	2	3	0	4
	Ryan	2	0	3	4	2	2	3	4
	Consensus	2	0	3	4	2	2	2	4
Teacher 6	**Kate**	0	4	2	0	4	2	1	1
	Ryan	0	4	2	0	4	1	1	1
	Consensus	0	4	2	0	4	2	1	1
Teacher 7	**Kate**	2	4	4	4	4	4	4	4
	Ryan	3	4	4	4	4	4	4	4
	Consensus	2	4	4	4	4	4	4	4
Average Rating	**Consensus**	2.43	3.43	2.29	2.86	3.71	3	2.71	3

Both math teachers had substantial application of SEP 5 throughout the lesson sequence, using mathematics and computational thinking. Of one math teacher, GSR2 wrote *"This lesson involves students in the application of mathematics and computational thinking (practice 5) as they practice graphing and using a coordinate plane."* She wrote something similar about the other math teacher, saying that "*the focus of this lesson is on using mathematical and computational thinking"*.

GSR1 had similar things to say about the math teachers. He wrote in an analytic memo while analyzing the lesson plans:

> *"Because the two math teachers have different standards (i.e. not the Utah SEEd Standards), it is unsurprising that both of their lesson sequences focused mainly on SEPs 2 and 5, which are more easily transferable to math. While they tried to incorporate some of the other SEPs, neither were able to do so to any substantial degree."*

The other teachers spread the application of the different SEPs over different individual class periods. GSR2 said about the lesson sequence created by teacher 4:

> *"Students are first asked to engage in understanding water poverty and asked to define the problem (Practice 1). They are then asked to create a design or model of their system and predict the outcome using physics and fluid mechanics formulas (relating to Practice 2 and 5). Students are provided with materials and are able to construct their solutions (Practice 6). After constructing their designs students carry out an investigation of their system and analyze the results (Practice 3 and 4). This information is share with the class (Practice 7,8)."*

Teacher 7 also spread the different SEPs over three class periods, focusing on

different SEPs each day. GSR2 wrote the following note about this lesson plan:

> *"In the first part of the lesson students are asked to create models (Practice 2) using free body diagrams. Additionally, students are then asked to use mathematics and computational thinking (Practice 5) to calculate force vectors. The bulk of the science and engineering practices are found in the second lesson where students are asked to design and conduct and experiments using the modified Atwood Machine. This involves students in Practice 3, 4, and 5. To wrap up this project students are asked in the final lesson to construct explanations for their results and to present them in the form of lab reports and presentation this engages students in Practices 6, 7, and 8."*

The lesson plan sequence created by teacher 3 also focused on different SEPs on different individual days of the lesson sequence. GSR1 wrote:

> *"This lesson sequence asked the students to create a plan of what to do with 400 acres of land. The first and third days focused on analyzing and interpreting data related to ecosystems (SEP 4). The second day focused on SEPs 7 and 8 by having the students read and engage in argument about a forest fire article. The focus of the last two days of the lesson sequence was on defining the 400 acre problem, coming up with a solution to the problem, and communicating the solution to the rest of the class (SEPs 1, 6, and 8)."*

Although it was made clear to the participating teachers that they were expected to incorporate all the 8 SEPs into their lesson plan sequence, there were some teachers who were unable to do so. As can be seen in Table 4 above, four out of the seven teachers received a rating of 0 on at least one of the SEPs, meaning the SEPs were not present in

the lesson plan sequence. Two of those four teachers only received a 0 rating on one SEP. Another teacher, who was one of the math teachers, received a 0 rating on two SEPs. The teacher who received a 0 rating on more than two of the SEPs, was not only a math teacher, so he had different State standards for his curriculum, but was also a first year teacher who had not yet been in a classroom of his own. GSR2 wrote of this teacher's lesson plan:

> *"While this lesson could be further expanded currently there is no evidence of students participating in investigations (Practice 3), there is no evidence of students analyzing or interpreting data (Practice 4), and there is no evidence of argument or communication on the part of the students (Practice 7 & 8)."*

GSR1 wrote of teacher 3's lesson plan, *"Although all the other SEPs have substantial application in this lesson sequence, there is no presence of planning and carrying out investigations (SEP 3)."* Teacher 3 did not even list SEP 3 in any parts of the lesson plan as being applied in the lesson. In GSR2's notes about this teacher's lesson, there is no mention of SEP 3, indicating that it was missing from the lesson plan sequence.

Teacher 5 was also missing one of the SEPs, having received a rating of 0 for SEP 2 in the consensus rating between GSR1 and GSR2. GSR2 said of this lesson plan sequence, "*It does not appear that students are not asked to create a model of their robot or the ecosystem where they are measuring the water so Practice 2 is not included.*" GSR1 wrote an analytic memo while rating this lesson plan sequence. He said:

> *"While all the other SEPs are at least present to a small degree in this lesson plan sequence, the lesson plan does not ask the students to develop or use a model. I*

find this particularly odd because this teacher expanded on one of the activities from the GEAR UP camp. One would think that if the activity was used in the GEAR UP camp, it would include all of the SEPs since the activities are intended to be models of lessons that the teachers can use in their own classrooms."

The math teacher who received a 0 rating on two of the SEPs also received relatively low ratings on all but two of the other SEPs. GSR2 said of this lesson plan sequence, "*The lessons in this grouping are short and include little detail on how students will engage in science and engineering practices.*" In the notes for GSR1's ratings of this lesson plan sequence, he wrote, "*In this lesson sequence, the teacher does not have the students ask questions or define problems, resulting in a rating of 0 on SEP 1.*" He also wrote "*The teacher also missed out on the opportunity to have the students analyze and interpret data (SEP 4) as a part of the 3-point shot portion of the lesson plan sequence.*"

All the teachers except two listed all eight Science and Engineering practices as being included in at least one portion of the lesson plan sequence. One of the teachers listed seven of the eight SEPs. The other teacher seemed to have confused the Science and Engineering Practices (SEPs) with the steps of the model of the engineering design process that was presented to the teachers. This one teacher listed which of the steps of the engineering design process were present in his lesson plans. While the engineering design process is related to the Science and Engineering practices (SEPs), there is no direct way to correlate the individual steps of the engineering design process with individual SEPs.

Observations

During the school year following the camp the teachers were observed in their own classrooms teaching a portion of the lesson plans that they had submitted at the camp. The classroom observation was done by GSR1. He evaluated the observed lesson based on the Observation Protocol (Appendix H) and rated how well each teacher was able to incorporate the Science and Engineering Practices. The numerical ratings for each teacher's observed lesson were based on a scale from 0 to 4, and the numerical values of each teacher's SEP score are shown in Table 5. In addition to the ratings, GSR1 took notes explaining the reasons for the SEP ratings of the observed lessons.

Table 5

Teacher Observation SEP Application Ratings

Numerical Scale (0 = Not observed in lesson, 1 = negligible observed application, 2 = limited observed application, 3 = moderate observed application, 4 = substantial observed application)

Science and Engineering Practices	1	2	3	4	5	6	7	8
Teacher 1	4	4	4	4	4	4	0	4
Teacher 2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Teacher 3	3	4	0	2	3	4	0	4
Teacher 4	0	4	0	0	0	4	0	0
Teacher 5	1	0	1	3	0	1	0	0
Teacher 6	1	2	2	4	4	2	1	2
Teacher 7	4	2	4	3	1	1	0	0

The ratings from the observations are different from the ratings of the lesson plans for several reasons. There was only one observer, whereas there were two graduate student researchers evaluating the lesson plans. The observations also only represented a snapshot of the overall lesson plan. This meant that some SEPs might not have been present in the observed portion of the lesson even though they were present in the overall lesson plan. The teachers were also able to make modifications to the lesson plans between the camp and the implementation.

Teacher 2 did not participate in the observation, but GSR1 wrote an analytic memo of his interactions with the teacher, which took place with the teacher directly via email and through the GEAR UP office, the GEAR UP site coordinator at his school, and his school administrators. The analytic memo reads:

> *"While this first-year teacher was more than willing to communicate with me shortly after the camp, it has been difficult to get in touch with him to schedule the observation and interview. I tried to communicate with him through his email and through GEAR UP channels, but all I heard was that he was busy and did not have time for the observation. After I finally asked the teacher if he would be willing to just do the second part of the interview via video call, I finally received a response. The teacher said that his curriculum had been changed mid-semester and that he would not be able to fit the lesson that he had planned into his course. He also said that because he was a first-year teacher he just did not have the time to put the lesson plan into action with all the other work he had to do."*

All the other six participating teachers who had created a lesson plan during the camp participated in the observation. Because the observed class was only a portion of

the planned lesson sequence, it was not expected that the teachers would incorporate all 8 SEPs into a single lesson. One teacher was able to incorporate all the SEPs in his lesson, but only two of the SEPs were substantially incorporated into the lesson. Another teacher was able to incorporate all but one of the SEPs with substantial application. Of this teacher, GSR1 wrote:

> *"The students designed a system to measure friction. The students were given the opportunity to choose on which surfaces they were going to measure the friction, including a table that had been sprayed with oil. The students put the system together to make a physical model to measure friction. Before creating the system, the students were asked to plan how they were going to measure friction, (i.e. using weights, which surfaces, what kind of weights, etc.). The students used the data collected (i.e. weight necessary to move an object from rest on a table) to calculate the friction force of the chosen surface on the object. The designed system was tested. If it didn't work, the students had to redesign in order to successfully measure friction force. The students compiled the collected data in a graph and then were asked to share the design and results with the class."*

Teacher 3 had substantial application of SEPs 2, 6, and 8 in the observed lesson, and at least limited application in SEPs 1, 4, and 5. About this teacher's application of SEP 1, GSR1 wrote:

> *"The problem was given to the students along with the main parameters. The teacher gave the students questions that they should be asking themselves about their design. It could have been better if the teacher gave the students freedom to develop their own questions about the problem and about their proposed*

solution."

Regarding the application of some of the other SEPs in Teacher 3's lesson, GSR1 wrote:

"The students were asked to create a model of the forest that they are supposed to manage and how they are going to manage it. This was done in order to understand the problem and help the other students to understand their solution. The students read an article about what kinds of things can be done with forest lands. The teacher then had the students use a small grid of graph paper (1 grid square = 1 acre) to design what they would do with each acre of the 400-acre wood."

In the observed lesson taught by Teacher 4, there was substantial application of SEPs 2 and 6, but none of the other SEPs were present in the observed lesson. GSR1 wrote the following about the application of SEP 2 and SEP 6 in the lesson: "*The students used written models that they had developed in a previous class to build a prototype of the gravity fed water system*." This prototype was built "*to solve a hypothetical problem of water poverty by designing a method of transporting water*."

For the observed lesson, Teacher 5 took her students on a field trip to a local wetland and replicated the Sea Perch ROV submarine activity that was done at the GEAR UP Engineering Camp. Only SEP 4 had more than negligible application. Of this this lesson, GSR1 wrote:

"This portion of the lesson plan focused on the activity of using the subs that they had previously built to collect data, after which the data was analyzed and interpreted. The other SEPs were not present in this activity but were

incorporated into other days of the lesson sequence."

Teacher 6 was the only participating teacher who had modified the lesson plan that he had created during the camp before implementing it in his classroom. Instead of the basketball activity from his lesson plan, Teacher 6 used small rovers that he had learned about in a different teacher development program and obtained from a large technology company for use in his class. The students used the rovers to "drive along a parabolic path to reach a specific goal point along the x-axis" which was drawn on the floor in a large room. Because this teacher was a math teacher, it was unsurprising that both SEP 4 and SEP 5 had substantial application in the observed lesson. GSR1 wrote a note in his observation protocol about these two SEPs. He said:

> *"The students gathered the data of the input values and took notes about the parabolic path and where the rover ended up along the x-axis in a table that was provided to them at the beginning of the class. The students had to interpret the data that was obtained and put into the table in order to get the rover to go between the small cones along the x-axis."*

Teacher 7's observed lesson consisted of the students using a Modified Atwood Device. This lesson had substantial application of SEP 1 because, "*the teacher began by having the students come up with questions that they can ask using the Modified Atwood Device (MAD)".* This lesson also had substantial application of SEP 3. Of this SEP, GSR1 wrote:

> *"He then asked the students to figure out how they could collect the data that they would need to answer the questions using the MAD. He asked the students to tell them what their plan was for the investigation to make sure they understood what they were doing and why they were doing it."*

Of the two SEPs that were missing from this lesson, GSR1 wrote, "*There was not enough time in a single class for the students to engage in argument (SEP 7) or to communicate the information from the investigation (SEP 8)".* There also would have been more than negligible application of SEP 5 and SEP 6 except, "*the students ran out of time*", so they were not able to complete the calculations and answer the questions they had asked at the beginning of the class.

Interviews

After both interviews were completed (at the end of the camp and after the observed lesson), recorded, and transcribed, the graduate student researcher (GSR1) and another graduate student (GSR3) used in vivo coding to analyze the interviews in MAXQDA®. After the first round of coding, the graduate students used pattern coding to identify themes in the data. After each round of coding, the two graduate students met to come to a consensus on the codes and themes. The resulting codes and themes that were agreed on by both GSR1 and GSR3 are shown below in Table 6, which shows the coding phase, coding type, the code or theme, and the frequency of each code or theme.

In between the first and second rounds of coding, GSR1 also created a code cloud (Figure 7) using MAXQDA®. This more visual representation of the qualitative data was helpful in the transition to the second phase of coding where themes were identified based on the codes from the first round of coding because Table 6 was not compiled until after the second round of coding. This code cloud showed which of the codes appeared most in the participating teachers' interview responses. The codes that had the highest frequency appear larger than the codes with lower frequencies.

Figure 7. Code Cloud After First Round of Coding

There were fourteen of the codes identified in the first round of coding that had a frequency of 1. The codes were kept because they were different enough from the other codes. However, these codes ended up fitting into the themes identified during the second round of coding. Some of these lower frequency codes were also emphasized by the individual teachers in whose interviews the codes appeared. Because GSR1 was the researcher conducting the interviews, he was able to identify these codes based on the tone of voice and other visual cues from the interviewed teachers. There were five codes with a frequency greater than ten including: time (20), how to incorporate (18), SEEd standards (14), collaboration with other teachers (14), and hands-on (14).

Table 6

Coding Table for First and Second Rounds of Coding of Interview Data

Coding Phase	Coding Type	Code/Theme	Frequency
Phase 1	In Vivo Coding	How to incorporate (Implementation)	18
		Engaging students more (Implementation)	6
		Teacher confidence (Implementation)	7
		SEEd standards (Implementation)	14
		Written up example (Implementation)	6
		Super easy to incorporate (Implementation)	1
		Putting in work (Implementation)	7
		Stick with them (Implementation)	1
		Lesson planning (Implementation)	9
		Apply engineering concepts (Implementation)	6
		Hypothetical experiments (Implementation)	3
		Collaboration with other teachers (Interaction with other people)	14
		Interacting with students (Interaction with other people)	7
		Time with the professors (Interaction with other people)	2
		Work with other teachers (Interaction with other people)	1
		Hands-on (Quality of the Camp)	14
		It was a blast (Quality of the Camp)	1
		Resources to talk to (Quality of the Camp)	2
		Change to improve (Quality of the Camp)	4
		Fun for the students (Quality of the Camp)	2
		Worn out (Quality of the Camp)	4
		It's effective (Quality of the Camp)	1
		I learned a lot of things (Quality of the Camp)	1
		Forget about it a week later (Quality of the Camp)	1
		Understand how the students react (Quality of the Camp)	4
		See science and engineering in action (Quality of the Camp)	3
		New perspectives and opportunities (Quality of the Camp)	7
		The professors weren't prepared (Quality of the Camp)	5
		Finishing project (Quality of the Camp)	1
		Sitting and listening (Quality of the Camp)	4
		We got involved (Quality of the Camp)	4
		See different ways (Quality of the Camp)	3
		Skewed idea of classrooms (Quality of the Camp)	1
		Realistic experience (Quality of the Camp)	1
		Practical stuff helps the most (Practical)	5
		Don't have time (School Environment)	20
		Flexibility (School Environment)	1
		Resources are a problem (School Environment)	2
		Focus on the one (School Environment)	1
		Teachers have a lot on their plate (School Environment)	2
		Administration is a big, big part of it (School Environment)	1
		Class size (School Environment)	1
Phase 2	Pattern Coding	Implementation	60
		Interaction with Other People	25
		Quality of the Camp	59
		Practical	6
		School Environment	14

For the second round of coding, after the themes were identified, the interviews were coded again using the themes as codes. In Table 6, the codes from the first round of coding are accompanied by their primary corresponding theme in parentheses. However, some of the codes from the first round, such as *time*, ended up fitting into multiple themes depending on the context.

Theme 1: Implementation

One of the major themes that was identified in the interview data was Implementation, or in other words, anything related to the teachers implementing what they learned at the camp into their own classrooms. This includes things that either help or hinder the ability of the teachers to implement what they had learned from the camp, such as those described by the following codes: *how to incorporate, engaging students more, teacher confidence, SEEd Standards, written up example, super easy to incorporate, putting in work, stick with them, lesson planning, apply engineering concepts,* and *hypothetical experiments*. Although it is not listed as being under this theme in Table 6, in certain contexts the code labeled as "time" was also related to the Implementation theme.

One topic that was discussed by multiple teachers in their answers to the interview questions was how the camp activities and professional development workshops had helped them to incorporate the SEEd Standards and the Science and Engineering Practices in their own classrooms. Teacher 1 said of the camp experience, "*I think it's effective because we can see how we might apply it what the kids are learning to our own classes.*" Teacher 2 commented, "*I thought it was good too because it made me think of how to utilize the things that we're learning in the camp and apply them to the*

classroom." Teacher 3 enjoyed how the camp activities allowed her to see "*potential problems that can happen*" before attempting to teach a similar lesson in her own classroom. One of the math teachers, Teacher 6, said of the camp activities, "*I was trying to think about what I would try to do with my class if I was doing the same thing.*" The engineering teacher, Teacher 5, said of the camp experience, "*I learned a lot of what I could do with the students as well as the different activities I could include in my curriculum.*" One of the teachers who had participated in the 2018 camp and the 2019 camp, Teacher 7, talked about the benefits of learning about the SEEd Standards in professional development workshops. He said, "*I think having a better understanding of what they are and how to incorporate them from the evening classes, yeah, was very helpful.*"

Several of the participating teachers, including both math teachers, mentioned that the camp activities and the professional development workshops helped them to engage their students more in their own classrooms. Teacher 6 said that for him it was, "*hard to get some of these types of activities where … the students have more fun and engage a little bit more in our type of module.*" But he also said that being able to be more engaged himself in the engineering activities helped the students to be more engaged. The other math teacher, Teacher 2, said that he was going to be, "*implementing exciting and real-world problems into my lessons instead of just standing up and lecturing*". He also said that these problems would, "*get the kids thinking about it in a fun way.*" Teacher 7 said that, "*engaging students more is one of the benefits from the camp that I got.*"

Two of the participating science teachers mentioned that a lack of confidence has sometimes prevented them from implementing engineering, or at least specific

engineering lessons into their classrooms. Two of the teachers specifically mentioned a lack of confidence with using the drone that they were given after participating in the GEAR UP Engineering Camp. Teacher 1 said that she was, "*a little intimidated by*" the prospect of doing an activity using the drones because she was "*not really comfortable with the drones yet.*" Teacher 3 said that she was "*trying to get more comfortable*" with the drones so "*if there's glitches*" she would "*know what to do.*" She said that she did not, "*have enough experience with them to implement them effectives.*" Teacher 3 also mentioned that she was *"nervous implementing some of these things*" related to engineering in general and not just in using the drones. She said, "*I probably need a little bit more … training so I'd feel a little bit more comfortable doing some of, because some of it's just not my expertise. I'm not an engineer.*" Teacher 7 mentioned that the evening professional development workshops had helped him to gain more confidence. He said, "*I think it helped, especially just being more comfortable with explaining the process, having gone through a couple of different examples, with planning lessons and looking at how you can, I guess, teach or present those type of lessons.*"

Five of the participating teachers referred to SEEd Standards in their interview responses. Teacher 3 mentioned that it was helpful to, "*just talk … a little bit more about implementing the SEEd standards*". She also said in her interview response:

> *"I was hoping to kind of get a little bit more in-depth with the SEEd standards and kind of like really explore it … I don't know if the way that I'm doing it is still what they envision engineering in my science class."*

Teacher 7, who had participated in both the 2018 and 2019 GEAR UP Engineering Camps, talked about how the 2019 camp helped him to better understand the

SEEd Standards. He said:

> *"I feel like this year, and it might be that I had more exposure in between the camps of the science and engineering and SEEd standards, but I feel like that was a lot more clear for me this year of what they were and sort of how to fit them in. But again, I'm not sure if that was through the workshops or through just more exposure in between."*

Teacher 7 also said that the professional development workshops helped him with, "*Tying in the SEEd standards… trying to… pull several different* science and *engineering practices into each lesson.*" He said that the 2019 workshops had helped him with implementing, "*the science and engineering practices and making lessons more effective.*" Between the 2019 Engineering Camp and the second part of the interview with this teacher that coincided with the observation, this teacher switched to a different school. He mentioned that the professional learning experience of the GEAR UP Camp was especially helpful for him considering the change in schools. He said:

> *"So something that's new for me this year is I am also teaching middle school science. And so going back and looking through the SEEd standards and the information we got at the camp that you do courses on how it structured the different science and engineering practices was very helpful in me going this year."*

Both participating math teachers talked about how as math teachers "*the standards are different"*. Teacher 6 said regarding the evening professional development workshops, "*But a lot of it I felt was very science-focused, and so we were looking at science standards that were coming up, which is important, because those standards are*

changing.” Both math teachers thought that even though they have different standards, the discussion about the SEEd Standards was still beneficial for them. Teacher 5 commented, “*There was some things that we did that wouldn't apply to my classes. It's just not part of what the state wants us to teach. And so whatever I could apply, I try to include in my curriculum.*”

Teacher 3 talked about how beneficial it was “*getting the handout of the new SEEd Standards*” during the evening professional development workshops. She said, “*I haven’t had as much time to read it, but the times I’ve looked at it…that was a great resource.*” She also talked about how it was beneficial for her to spend time during the professional development workshops doing an “*overview of… the science and engineering… practices.*”

Several of the participating teachers talked about how useful it was to have written out resources as well as a “*having a format, a template was very helpful*” to use while they were planning their lessons during the evening workshops. Teacher 3 mentioned that it would have been nice to get an example lesson plan incorporating the engineering experiences from the camp activities. She asked, “What does it look like in a lesson?”. Teacher 7, another one of the participating science teachers said, “*I think having an experience with teachers where we're able to see a lesson plan in action and see like some specific examples of how the science and engineering practices are tied into like a short lesson is beneficial.*” Teacher 7 also said that it would have been beneficial for him to have written lesson plan for the hypothetical engineering design activity that was done in the evening workshops. He said:

> *“I think almost having it a written up example of like that activity, have it written*

up and almost shown how you would format that example lesson plan, where you're tying all the objectives and then how they're met I think would have helped sort of bridge a gap between us doing the activity and then us making the lesson plan a little bit to see what the lesson plan for that activity would look like."

Teacher 2, the first-year math teacher also mentioned that having a written-up example was useful for him. He said:

"And I think that was something that you guys are really good was you gave us the models, the hands-on, and got us excited about the actual, you know, the school part of it, the science behind it, the math."

While the one engineering teacher, Teacher 5, said that incorporating the things she had learned into her curriculum would be "*super easy*", most of the other teachers said that they would need to put in work in order to incorporate what they had learned from the professional learning experience. Even Teacher 5 said that it would take some work for her to use the activities from the GEAR UP Engineering Camp in her classroom. She said, "*I'm trying to make it fit. And so I got the tools from the USU GEAR UP, and I'm still trying to figure out how to use them. So I just need to look it up and get it to work.*"

Teacher 6, who was one of the math teachers, mentioned that in order to incorporate what he had learned from the professional learning experience he would need to change his "*thought process*". Teacher 7 said that he would need to be creative to apply what he had learned from the GEAR UP Engineering Camp professional learning experience in his classroom. He said, "*So I think the creativity of, I guess, coming up with new lessons, so having to time it up, but also the energy or creativity to come up with new*

ideas or new applications."

Teacher 6, who was the more experienced math teacher, mentioned that the professional learning experience had "*big science focus, and so it was a stretch for me.*" He continued. "*I mean, that was beneficial in a way that I had to stretch*". Teacher 6 also said in response to a follow-up question:

> *"I think that if you're at least open enough and you're willing to be creative and work with other people to break down those barriers, I think almost -- possible. It's just taking that time and putting in that work, because sometimes you do have to get creative with how you can get around something to give a better learning experience to the student."*

Teacher 2 also talked about how difficult it can be to apply the things he had learned at the camp into his math class. He said:

> *"It can get hard to come up with things that way. That's probably my biggest challenge, because I want to -- it's hard to make math fun sometimes. Really, it can be a challenge for me. And so I'm constantly wrapping my brain to try and come up with new things that way."*

Several of the teachers also enjoyed having time to plan their engineering related lesson sequence while they were at the GEAR UP Engineering Camp. Teacher 7, who had also participated in the 2018 camp, talked about how the 2019 camp was more beneficial for him because he enjoyed, "*having a concrete lesson finished, and then also seeing, having a plan for where it fits into the curriculum.*" Teacher 2 especially appreciated having the time to create a lesson plan and being able to learn about "*the process of lesson planning was really helpful*". Teacher 3 said that although she

appreciated having time to create the lesson plan, "*some of the lesson planning was a little long*".

Four of the participating teachers discussed how the GEAR UP Engineering Camp professional learning experience had helped them to apply engineering concepts with their own students. Teacher 1, who had participated in both the 2018 and 2019 camps, said that in the 2019 camp she, "*learned more about how to apply the engineering concepts, designing, testing, that it doesn't always have to be like a lab experience.*" Teacher 7, who had also participated in both camps, talked about how he had been able to apply engineering concepts in his class. He said:

> *"So far this year, in other classes we did it. In a biology class, we did a little sort of engineering project where they were given some materials and… a budget. And then it was to build a tower that would hold some different weights. And so they… did a lesson… where they were given a task or a challenge and then had to work together and come up with a design of solution constructed."*

Teacher 4 was able to use "*the ideas of the project*", referring to the engineering experiences from the camp, in her classroom. She also found that the professional development workshops were useful because she was able to learn more about the engineering design process. She said:

> *"Just the engineering design process in general, I used that last year, but I was able to learn more about it, go more in-depth with the engineering design process and use in pretty much every lesson that I had with them."*

Two of the participating science teachers found that the hypothetical design activity from the professional development workshops was useful for them. Teacher 1

said:

"You don't have to have all this lab equipment and stuff. You can actually do hypothetical experiments and have kids design things that maybe they're not going to build that they can, at least, plan on using different resources. And I think that's a good part of the engineering process, just that brainstorming and coming up with hypotheticals, planning before you start, you know."

Teacher 3 enjoyed the hypothetical design problem from the professional development workshop because GSR1 "*presented…the problem and had… the groups work on the solution.*" She specifically commented on how this hypothetical helped her to learn about developing and using models. She said:

"With engineering, or like, modeling and the different parts of it, it's not necessarily you always have to have some type of like, they're constructing this massive model with like, different material. That a model can also be on paper. … And so, that was the way that I incorporated modeling, and hopefully that's what the core is getting after."

Summary. All the participating teachers discussed different factors that either helped or hindered their implementation of what they had learned from the GEAR UP Engineering Camp Professional Learning Experience to their classrooms. These factors included a learning more about the SEEd Standards at the camp, a lack of confidence in teaching engineering, having time for lesson planning at the camp, having a written up example, and having the example of the hypothetical design problem during the professional development workshops. These factors mentioned by the teachers could be considered as features/characteristics of the learner (Agyei & Voogt; Barnett, 2005,

2014) and as features of the task (Barnett, 2005). The teachers also mentioned that even with some factors that hindered their implementation, they just needed to be creative and put in enough work to be able to transfer what they learned from the camp into their own classrooms. The teachers said that because of the camp experience they were more able to apply engineering concepts and better incorporate the Utah SEEd Standards and Science and Engineering Practices (SEPs). The data included in this theme helps to answer Research Questions 2 and 3.

Theme 2: Interaction with Other People

Another major theme that was identified by the coders was *Interaction with Other People*. This theme relates to the participating teachers' interactions with students, other teachers, and engineering faculty at the camp, as well as the participating teachers' interaction with other teachers in their own schools or districts that happen outside of the camp.

The majority of the teachers mentioned that they would have liked more collaboration with the other participating teachers from any discipline while working on the lesson plans instead of working individually. Teacher 1 said, "*We would have liked maybe more collaboration. So instead of having our individual units maybe working together on just one or two lesson plans*". She continued, "*But we like to collaborate with each other because, you know, we get tunnel vision sometimes, and so it's nice to hear other people's ideas.*" Teacher 2 also commented about having more collaboration. He said:

> *"I think being a new teacher, it might have been useful also to maybe have some more collaboration with some of the other teachers. And I got that with like the*

ones I was sitting next to. But to just maybe have a little bit more of an open-ended talking session, maybe to just bounce ideas off of other teachers just to kind of help me feel like I had some more ideas that way."

Teacher 3 mentioned that she wanted, "*teachers collaborating and talking about ways that you could use some of these engineering things*". In addition to collaborating on lesson plans, Teacher 3 also suggested that the teachers could be divided into smaller groups to discuss the standards. She said:

"Split us into groups and … talk about how you'd do that in your lesson and brainstorm and come together. Maybe even like collaborating, like do a lesson plan as a group and do one on your own. Because to me, I learned I love collaborating with other teachers to see how they do things. And this one, we did the lesson plans, but it's just me. And so I was like, "I don't know if this is the best way of doing it. And could there be other ways of doing it? Is this effectively reaching the SEEd standards that this state envisions, or is this how I'm interpreting it?" And so that's where I still have been trying to understand those standards."

Teacher 4 mentioned that she enjoyed the professional development but would have liked more collaboration with the other participating teachers to "*share ideas and work as a group*". She continued:

"I think it could be a little more… group work would maybe be better so we can exchange ideas more, so we can cooperate with each other and I think it would be more beneficial for us, as teachers. Other than just lesson, well, individual lesson plans. Because we do that on a daily basis."

Teacher 6 also commented on how useful collaboration with the science teachers would have been for him in particular as a math teacher. He said:

> *"I wish we had some collaboration time with other teachers, during that time. We only had to create … a couple lesson plans but one of them was … collaborating with a teacher and we came up with a lesson-plan, together… where we combined our two subjects … and be able to just bounce ideas off … others. … Even if we partnered up and had maybe make one really good lesson instead of making a whole unit. … Because I felt that I was just kind of rushed that I had to get this whole unit done instead of… to really think out the whole process of it. What are the things you're going to need? What are some of the barriers you're going to have? And how could you get around it? And be able to talk to somebody else and have them help you. … I think that would have helped a ton. Even as a math teacher, I would have loved to… talk to one of the physics teachers and see how we could have made a collaborative lesson that would have fit both of us that we could have combined. I think that would be cool too."*

Multiple teachers discussed how much they enjoyed "*interacting with students*" during the GEAR UP Engineering Camp. Teacher 5 said that she "*really connected with [her] students"* and that she "*really loved working with the students*". However, multiple teachers mentioned that they would have like more time with the students during the camp. Teacher 3 said that it was "*hard… to get to know [her] students as much*". Teacher 6 said, "*It would've been nice to have some of that … downtime to … connect with them*." Teacher 1, who had also participated in the 2018 camp said:

> *"I would have liked it if it had a little more time to play with the kids just to get to*

know them a little bit better, because it seems like they got to go do an activity and we were, you know, doing teacher class. So I liked how, last year, how we had one night where we just got to play with the kids like basketball, volleyball, and stuff. So maybe just have one night where we could do that to get to know the kids better and build relationships with them."

Teacher 6 suggested that it would have been beneficial to have the engineering faculty that were leading the engineering experiences come to the professional development workshops and work with the teachers. He said:

"I would have loved to have some time with some of the professors and talk to them about how they designed their experiences each day and just be able to collaborate with them a little bit and see what are the things, as scientists, that they're looking for so that we train our students better so that, if they want to go in that field, that we know kind of how things break down and how they design their days."

He also said:

"The only thing I would've liked is … if one of the PD nights, if we had 20 minutes with a couple of the professors, and just go through what their process is… And like just so when I'm doing, even in a different discipline, when I'm doing a hands-on project or an engineering project, I understand how someone that does it for a living, at a research-level, how they go about that whole process and what they look for and things, I think that would've been cool, just a little bit more one-on-one question/answering time with the professors."

Summary. All the participating teachers discussed interacting with other people

during their answers to the interview questions, particularly during the first part of the interview that focused on the GEAR UP Engineering Camp experience. The participating teachers discussed the benefits of having students present, wished they would have had more time with the students, wanted more collaboration with the other participating teachers, and wanted to interact more during the professional development workshops with the engineering professors who led the activities. The data that fits in this theme helps to answer Research Question 1.

Theme 3: Quality of the Camp

The theme with the second highest frequency was related to the quality of the camp. This theme included anything related to the camp, including both aspects of the GEAR UP Engineering Camp that the teachers liked and aspects of the camp that the teachers suggested should be changed for future camps. Any comments related to the camp activities, the professional development workshops, or just the camp experience in general, fall under this theme.

One of the most frequently mentioned topics by the teachers related to the quality of the GEAR UP Engineering Camp was, “hands-on”. However, the teachers talked about “hands-on” in two different contexts. Some of the teachers were referring to the “hands-on” engineering activities of the camp or the professional development. But some of the teachers also commented on how the camp had helped them to do more “hands-on” activities in their own classes. The two teachers who had participated in both the 2018 camp and the 2019 camp both mentioned when asked about the differences between the two camps that some of the engineering activities were more “hands-on”. Teacher 1 said:

“So I think it was a lot better than last year, especially the Aggie Air portion. This

is more hands-on. I feel like the projects the kids were able to do were a lot more what you want as far as like science and engineering practices, because they were able to build the drones and then collect some data. We changed designs. It's a much more -- last year, they couldn't really do any of that. So it was more like they come up with hypothetical experience. So this year, they're actually able to conduct real experiments or engineering projects."

Teacher 7, who had also participated in the 2018 camp said:

"So the changes to some of the activities I think were good. The Aggie Air one specifically, it was nice to be more hands-on, and I think the students enjoyed that. One of the differences with that one though is I feel like that one almost moved slightly too much away from the data."

Teacher 7 also commented that the "hands-on" activities in which he was able to participate at the GEAR UP Engineering Camp helped him with "*tying in more hands-on projects and attaching those to learning objectives and different practices.*" He continued, "*I think engaging students more is one of the benefits form the camp that I got.*"

Teacher 2 enjoyed the GEAR UP professional learning experience because of the "hands-on*"* nature of the camp experience that made it different from other professional developments in which he had participated. He continued:

"With professional development, you talk about it, but you don't necessarily get the application part of it. Yeah, you can act it out or whatever, but you don't really get the experience of the students until you take it back and try to implement it."

Teacher 5, "*really loved going out, testing things, and seeing the student-side of*

PD." She said that she enjoyed the camp because she likes "*the actual physically doing things*" and that she "*really connect[ed] to activities*". About the camp activities, she said:

> *"Because I do things very physically, and so I like to actually see them, hear them. It's harder for me to just get a concept and talk about it. I'd like to actually do activities. And so that really stuck to me."*

In response to question 4 from the semi-structured interview (Appendix G), both math teachers mentioned that they had been able to use "*more hands-on activities and exploratory activities*". Teacher 6 said:

> *"For me, it's been trying to add more practical application and more exploratory. For a lot of my stuff, the negative was -- because I was forced to try to expand my way of thinking or how I could approach a topic or a subject matter to make it more exploratory and where I'm doing less talking and the students are doing more of the work."*

Teacher 2 also talked about being able to use hands-on activities in his math class. He said:

> *"The hands-on activities to learn certain things have been super helpful too. I've been taking that same model, obviously, not necessarily the exact same things we did, but you know, trying to -- because I'm teaching sixth-grade math and seventh-grade math, so I just try to create models and relate it to real-life situations and having them understand it more in a realistic manner than just, you know, solve for X or why do we need to solve for X."*

Multiple teachers commented during the first interview about things that they had

enjoyed, and things that they thought had room from improvement from the GEAR UP Engineering Camp activities and the professional development workshops. Teacher 1, who participated in both the 2018 and 2019 camps said she enjoyed the 2019 camp. She said:

"I feel like I knew what more to expect. So yeah, it was fun that way. So I mean a lot of things were familiar, and it was good for me to see the changes that you guys made to the camp to improve it. So it was definitely apparent that you guys took our feedback and tried to improve things."

Teacher 2 spoke about how the camp was a good experience for him, and that he could also tell that the students enjoyed the camp. He said:

"It was a blast. I really enjoyed it. There's a lot of great things and I could see the excitement in the students. I think the way that the professors interacted with the students was awesome. They got to really kind of understand what it's like to work with the professors firsthand. And the professors really kind of opened up and got to know them too. It was fun for the students."

Teacher 2 also commented on how useful the professional development workshops were for him, even though he is not a science teacher. He said:

"As a future teacher, I liked it because there's a lot of things that I feel like I-- even though I am teaching math, I felt like I could still utilize some of the things that they did, some of the practices, just some of the techniques that they used with the students to help them get on that same level of understanding and excitement. So for the teaching side, I think it was really good. I mean, if I was teaching science, obviously, I think it would be even more useful. But still, with

math, it's still pretty fun. I think it's useful."

Teacher 2 also commented on how great it was to have the students present, as opposed to other professional developments where there are no students, because the teachers were able to "*understand how the students react*" to the activities and that the teachers were also able to "*see the pros and cons right away.*" Teacher 5 commented that it helped her "*to learn like what the students are actually getting out of"* the engineering activities. Teacher 4 said that the activities were beneficial for the kids, but also for the teacher because they, "*were able to watch them and get ideas from their projects.*" Teacher 3 also commented on how having students present made it different from other professional developments in which she had participated. She said:

> *"The difference is that you're seeing students do projects and you're with them as they're like doing it. And so that part is different, because a lot of times, with PD, you're just having teachers. You don't work with students and you don't see their reactions as they're doing the activity. And seeing like students in action a lot of times in like professional development, you talk about outcomes of what you want to do, but you don't really see it at the same time. So that part is nice to kind of see like you're learning about it but then you can actually see it done."*

Several other teachers also talked about other things that made the GEAR UP Engineering Camp professional learning experience different from other professional developments in which they had participated. One of the main things that was mentioned by multiple teachers was that in most professional development programs, the participating teachers just listen as other people talk, whereas in the GEAR UP Camp they were actually able to participate in activities. Teacher 2 said that in most

professional developments "*you kind of get talked at and you might take some of it, but a lot of times you kind of forget about it a week later*" and that most professional development workshops have "*kind of a skewed idea of what classrooms really are.*" He also said, "*it's hard to utilize the things that you learn in a lot of professional developments. I feel like this one gives you a reason to.*" Teacher 4 said that "*other professional development programs are just lectures*" where the participating teachers "*just listen and take notes*". Teacher 5 said:

> *"So other PDs that I've had is mostly the winter and summer CTE where they have just classes all day and you just notes in classes. I've never really been to a PD with students. So, usually, I'm sitting in a classroom for eight hours straight, going over PD. And I really loved going out, testing things, and seeing the student-side of PD."*

Teacher 5 also said this camp was different because she, "*felt like [she] was very involved in all of the activities*", but was still able to have ideas about how to make the activities better when applying them in her class. She said that she really "*enjoyed being with the students and doing those experiences.*" Teacher 4 said, "*we got involved more than other professional development, so that was good.*" Teacher 7 commented:

> *"From my perspective as a teacher, I get a lot out of it also. I think going around with students and helping be a part of the process as they, you know, try to come up with questions and ideas and look at problems and solutions, I guess, outside of a classroom setting and more like out in the field."*

Teacher 1 also benefitted from having the graduate student and faculty member who were leading the professional development present while the teachers were working

on their lesson plans. She said, "*we had you guys as resources to talk to. So a lot of times, I think they give us PD with a whole bunch of stuff and they say, 'Okay, guys, now go do this'*." She spoke about the faculty member in particular when she said, "*He had a lot of knowledge about the new core and also integrating the crosscutting concepts and stuff. So he was a useful resource. So when we were doing our lesson prep, he was helpful.*"

Two of the teachers also mentioned that the GEAR UP Engineering Camp helped them to "*see different ways of going at topics*". Teacher 3 said:

> *"I've never really thought about doing like, the problem and having a solution, and letting the students just figure stuff out. And so, I liked that, and that's what I was trying to do with… the problem … like this one. Trying to … give them the problem, let them just kind of struggle with it a little bit, and then, give them the requirements that they aim for. But, I liked that part. That was good. And then… I just liked seeing like, different ways of applying information. Of… having a hands-on approach and making it applicable to them. I liked that part of the engineering camp."*

Despite all the good things the teachers had to say about the camp, they did have some things that they said could be improved. Three of the teachers mentioned that they didn't think the faculty and students leading the activities were completely prepared. Teacher 3 noticed problems with the Aggie Air group. She said, "*I know they fixed the AggieAir one and connect the coding. It was a little rough for my students, because the drones were broken. And so we just sat. And then the coding, they only have one computer.*" Teacher 1 mentioned that the Aggie Air group could be improved. She said:

> *"I think the programming is good to bring in, but we were thinking maybe have*

the kids do some other--learn how to program a little bit on their own, maybe give them a little Arduino kit that they could take home and then they could do some simple programming. So I mean they don't have to be taught how to program a drone but just program something simple for the drones that's similar to this, but you have more--it's more complicated."

Teacher 7, who had also participate in the 2018 Engineering Camp also talked about the Aggie Air experience. He said:

"Whereas last year, it was pretty much all I did was look at like the maps and data. This one, there's very small exposure to programming. I felt like that was not very clear or didn't have very clear objectives of what they were supposed to get out of the programming section of it, and then they didn't really experience any like data besides like the short PowerPoint presentation of the graphs of the plot."

Teacher 1, who also participated in both the 2018 and 2019 Engineering Camps, talked about how the air quality activity could be improved. She said:

"And they got to fly the drones and collect data, it's just analyzing the data when we were there, it was just--the professor had all the data and he was crunching the numbers. So I think the kids could do more of that like in a computer lab. That would be good. And some of the, you know, some of the computations were a little complicated, and so I think some of the kids got a little lost."

Teacher 1 also mentioned that there were issues with the Sea Perch activity regarding the calculations. Speaking about the faculty member leading the activity, this teacher said, "*I felt like she could have spent a little more time explaining the importance*

of figuring the coefficient of extinction--the extinction coefficient." Teacher 7 said that "*the professors weren't as prepared for the data part.*"

The other negative aspect of the camp that was mentioned by multiple teachers was that participating in the camp activities during the day, and the professional development workshops at night, "*made for a super long day*." Teacher 2 mentioned that, "*the kids were pretty worn out*" and that the teachers were, "*pretty beat by that late at night.*"

Summary. The teachers had both positive and negative things to say about the GEAR UP Engineering Camp experience. Most of the quotes from the teachers related to the quality of the camp came in response to the first and second questions from the semi-structured interview (Appendix G). These results help to describe the participating teachers' perceived benefit, which was a main feature of the task in Barnett's study (Barnett, 2005). This theme also relates to aspects of the camp that help to increase the motivation of the teachers to transfer the learning based on the possible benefits to their own students, similar to the study from Van Duzor (Van Duzor, 2011). This theme is particularly helpful in answering Research Question 3 which asks about the effects of combining the teacher and student experiences on teacher transfer of learning.

Theme 4: Practical

Although this theme did not have as high a frequency as some of the other themes, it was mentioned by more than half of the teachers in their responses to the interview questions. This theme is specifically related to the evening professional development workshops that took place at the GEAR UP camp, as well professional development workshops in general.

Teacher 6, one of the participating math teachers, said:

"I think it's more of the practical. I think it's easier to relate. I mean, if you touch on the theoretical of why it would work, it's always good to understand it, but I think the practical stuff helps the most, at least for me."

Teacher 3, one of the science teachers, said that she wants to see "*how it's actually done*" versus how she is "*reading it and interpretation and that part*". She continued:

"I guess I would like to see it -- how it's done in a classroom setting. I'm seeing like, "Okay, so here's -- " You had some great idea, and just to see like, how it would go into a class setting. Because you had the projects, and then the different stuff. I guess it's just seeing overall how do you fit it into an actual lesson in the classroom, and that part. But you learn as you do."

Teacher 7, who was one of the two participating science teachers who had also participated in the 2018 camp, said that, "*the practical experience of almost seeing different types of activities or seeing different labs is helpful to be able to use those in lessons.*" `Teacher 2 said that he enjoyed the camp and the professional development workshops as compared to other professional developments in which he had participated because, "*it made it more of a realistic experience that way.*"

Summary. All of these quotes from the teachers were in response to a follow-up question in the interviews that asked whether the teachers thought that it was more important in professional development to focus on the practical, meaning how to actually implement things in their classrooms, or the theoretical, meaning the background of why those things work. None of the participating teachers who were asked this question

responded that the theoretical was more important, although some said that both the theoretical and the practical are important in a professional development workshop. This theme helps to answer Research Questions 1 and 3.

Theme 5: School Environment

The last of the five themes that were identified by the coders in the interview data was *School Environment*. This theme is related to the teaching environment at the participating teachers' own schools and is not directly related to the GEAR UP Engineering Camp, or Utah State University. This includes things such as: *time, resources, administration,* and *class size*.

One thing that every participating teacher mentioned at least once was the constraint of time in various contexts. One of the contexts that was mentioned by multiple teachers was time constraints in their own schools. Teacher 2 said that time was a constraint because "*teachers… have a lot on their plate*". Teacher 3, one of the participating science teachers, said:

> *"I think some of the barriers is just teacher workload, the stress of being a teacher. Because like, I have -- I teach three preps. I have three classes. Two of them, I didn't teach last year. And I'm teaching biology with an interactive notebook, and so, it's completely different."*

She also said:

> *"I'm stretched out thin with my lesson prep. Like, I prep every day, and so there's times where I would really love to spend and think about these more activities to do, but I'm cut for time as a teacher. And that's a barrier that you don't have control over."*

Teacher 6 teaches at a school that has a different teaching model than most traditional high schools. He spoke about how this model affects his time when he said:

> *"Our school is very different. We have about half the time to teach the same content as, like, our neighboring high schools because of our model. And so, like, for today's activity, I had to restructure my whole term to allow this day to happen, which was a bit of work."*

Teacher 6 also spoke in more depth about how time was a constraint for him because of the teaching model. He continued:

> *"I think, for me, it's the time I had in class and the time to create lesson plans. For our model, my entire curriculum is already online and available to student for the entire year. So I have students in term 1, term 2, term 3, and term 4. So to make adjustments, it has to kind of be … during the summertime. And so I think that when you have professional development, if it's happening in a year, you have to have a way to catalog it to make that change. At least for me, it's hard to make a go-to professional development in October and then, in November, make a change, because I already have students who moved on and I can't change it. Because to me, that's not equitable or fair. And so that's my biggest challenge is to catalog it and then put that time in during the summer of changing the whole course and adding that piece."*

He also spoke about how there are constraints, not only on his time, but on the time of the students, when he said:

> *"It's just being able to have enough time to allow them to have that discovery. Because I don't want to have a discovery thing and then, within our time*

constraints, have them not have enough time to discover what they need to discover."

Teacher 1, who was one of the two teachers who had also participated in the 2018 GEAR UP Engineering Camp, talked about how beneficial it was to have plenty of time during the 2019 camp because:

"It takes time to put lessons together and think about, 'Okay, what are the concepts that I want to teach? What are the learning targets? How am I going to present it? How am I going to add hands-on activities in there? How am I going to integrate the engineering concepts?'"

When talking about incorporating specific activities from the camp into her classroom, Teacher 1 also said that "*time is a big factor*". She continued:

"We don't always have a lot of time to do full labs. So, there was one teacher, she teaches an engineering class. So she could spend, you know, weeks working on a project. We can't really do that because we have to cover all this core stuff."

Teacher 7, who had also participated in the 2018 camp, as well as the 2019 camp, talked about the differences in the amount of time they had at each camp. He said:

"I think part of it was I think having time to actually work on putting the lesson together. I think, the first year, that was a struggle because it was almost like homework during a time when we didn't have time to do it."

Having the time at the camp was important for him because, when asked what things could prevent him from applying what he learned at the camp to his own class, he said, "*I guess time would be a big one as having time to actually plan it out and, you know, yeah, figure out how to implement it into the curriculum.*"

When asked what some of the barriers are to being able to apply what she had learned from the camp in her own class, Teacher 4, one of the participating science teachers, said, "*So time was one. Even though we have long classes because we're on a block schedule, we have hour and 30 minutes scheduled for class. But some projects take longer. So time was one of them.*"

Two of the participating teachers, when asked about what factors influence whether they are able to apply what they learn from professional learning experiences (question 5 from the Semi-structured interview protocol in Appendix H), spoke about the lack of materials and other resources. Teacher 1 said:

> *"Well, our lab department, like we have a lot of old equipment that doesn't really work. So we're working on upgrading that. So I think just resources right now are a little bit of a problem, but I anticipate that we'll be able to overcome that in just a couple of years."*

Teacher 4 also spoke about resources. She said:

> *"So financially, we got a grant for STEM, and so I had to get that approved to administration. And then I was waiting for the materials to get here, some of the supplies. I'm still waiting for some of the supplies to get here. So the time of the supplies, that was kind of an issue, because we were working on a different project. That's why I had to postpone the lesson plan, because we were working on a 3D print project, so we had to wait for the materials."*

Teacher 4 also mentioned two other things related to the school environment in her response to question 5: administration and class size. She said, "*Administration, too. We were able to -- they are investing more this year. Since the professional development*

and other trainings that I went through, the school is investing more. So administration is a big, big part of it." When talking about class size she said:

> *"That would be barriers? Class size. Because last year I had, my STEM class, I had 7 students, and then this year, I have 25. So I feel like it's a lot harder to work with a big class, with a large number of students. It's a lot harder to work with five or six groups other than one or two groups. That is a big barrier. So next year, I'm planning on splitting my class into two so I have a smaller size. So that is my biggest barrier is class size."*

Summary. All of the participating teachers mentioned aspects of their school environment, mostly in the context of how it affects what they are able to teach, and how well they are able to apply what they learn in professional learning experiences, such as the GEAR UP Engineering Camp, in their own classes. The data included in this theme describes features of the context (Barnett, 2005) and characteristics of the school environment (Agyei & Boogt, 2014) that can either help or hinder transfer of learning. Many of these quotes were from the teachers' responses to question 5 from the semi-structured interview, although some were just discussed in response to other questions. This theme is particularly related to the first research question.

Summary of Qualitative Results

To summarize the qualitative data obtained from the lesson plans, observations, and interviews, Table 7 shows the principal codes and themes for each teachers' lesson plan, observation, and interview. The themes and codes listed under the lesson plans and observations in Table 7 come from the researchers' notes and analytic memos, not from the lesson plans or observed lessons. This table does not show all the codes/themes that

are present in each teacher's lesson plan, observation, or interview because the resulting table would be much too long to be considered a summary of the qualitative results.

The *Implementation* theme is one of the principal themes in 20 of the 21 data sources (i.e. lesson plans, observations, and interviews). The only data source in which *Implementation* is not one of the principal themes is the observation of Teacher 2 because Teacher 2 was not observed. It was a major theme in the lesson plans and observations because these documents are a physical representation of the participating teachers' implementation of what they learned from the GEAR UP Engineering Camp Professional Learning Experience. Each of the teachers discussed implementation thoroughly in their interview responses as well because the fourth interview question from the semi-structured interview (Appendix G) asked about what the teachers had been able to implement in their classes from what they had learned at the Engineering Camp.

The *Quality of the Camp* theme is a principal theme in 7 out of 21 data sources but is one of the principal themes in all 7 teacher interviews. It was one of the main themes of the interviews because that is where the participating teachers were able to discuss what they enjoyed about the GEAR UP Engineering Camp and what they wanted to see changed in future camps.

The theme, *School Environment*, is one of the principal themes in 10 of the data sources but is present in most of the interviews as well as several of the observations. This theme was common in the classroom observations and the teacher interviews because the classroom observations took place at each participating teachers' own school. The school environment was noted as part of the contextual background of the observed lessons. Things related to the school environment were also mentioned frequently in the

interviews because the teachers were asked about factors that affect whether they can apply what they have learned from professional learning experiences into their classrooms. Almost all mentions of the school environment came in the responses to this question.

Interaction with Other People is a principal code in the majority of the teacher interviews. This theme was not one of the principal themes in the lesson plans and observations because it came mostly in response to the first and second questions in the semi-structured interview. The teachers suggested more collaboration time with the other teachers and more down time with the students in the evenings.

Although the theme, *Practical,* is not listed as one of the principal themes in any of the data sources, it was present in most of the teachers' interviews because it was in response to a follow-up question that asked whether professional development workshops should focus on the practical application in the classroom or on the theoretical background. The teachers agreed that while the theoretical background is important, the focus should be on the practical application, or how to apply what is being learned in the classroom.

Table 7

Summary of data and codes

	Principal Codes/Themes (note: Themes (from coding round 2) listed in italics to distinguish from codes (from coding round 1))		
	Lesson Plans	**Observations**	**Interviews**
Teacher 1	• SEEd Standards • Hands-on • *Implementation*	• SEEd Standards • Hands-on • Apply engineering concepts • *Implementation* • *School Environment*	• Don't have time • How to incorporate • *Interaction with other people* • *School Environment* • *Implementation* • *Quality of the Camp*
Teacher 2	• Engaging students more • Hands-on • *Implementation* • *School Environment*	(Teacher 2 was not observed) • Don't have time • *School Environment*	• Hands-on • How to incorporate • Lesson planning • *Quality of the Camp* • *Implementation*
Teacher 3	• SEEd Standards • Lesson Planning • Hypothetical experiments • *Implementation*	• SEEd Standards • Hypothetical experiments • Apply engineering concepts • *Implementation* • *School Environment*	• Collaboration with other teachers • Teacher confidence • SEEd Standards • Hypothetical Experiments • *Interaction with other people* • *Implementation* • *Quality of the Camp*
Teacher 4	• SEEd Standards • Hands-on • Apply engineering concepts • *Implementation*	• Hands-on • Apply Engineering Concepts • *Implementation* • *School Environment*	• Hands-on • Apply engineering concepts • We got involved • *Quality of the Camp* • *Interaction with other people* • *Implementation* • *School Environment*
Teacher 5	• Super easy to incorporate • Apply engineering concepts • *Implementation*	• Super easy to incorporate • *Implementation* • *School Environment*	• Hands-on • How to incorporate • We got involved • *Quality of the Camp* • *Interaction with other people* • *Implementation*
Teacher 6	• Engaging students more • Lesson planning • *Implementation*	• Engaging students more • See Science and Engineering in action • *Implementation* • *School Environment*	• New perspectives and opportunities • Don't have time • *Quality of the Camp* • *Interaction with other people* • *Implementation*
Teacher 7	• Apply engineering concepts • Engaging students more • SEEd Standards • *Implementation*	• Apply engineering concepts • SEEd Standards • *Implementation* • *School Environment*	• SEEd Standards • Don't have time • Hands-on • Lesson planning • *Quality of the Camp* • *Implementation* • *School Environment*

CHAPTER VI

DISCUSSION, CONCLUSIONS, IMPLICATIONS, AND RECOMMENDATIONS

Because of the Next Generation Science Standards (NGSS) and other state standards based on NGSS, such as the Utah Science with Engineering Education (SEEd) Standards, K-12 science teachers across the country are now being asked to teach engineering in their science classes. Studies have shown that these teachers do not have the engineering background knowledge nor the self-efficacy to teach engineering in their classes (Ambrose et al., 2010; Ames, 2014; Banilower et al., 2013; Bybee, 2014; Johnson & Cotterman, 2013, Lederman & Lederman, 2013).

In order to bridge this gap, teachers were invited to come with their students to the campus of Utah State University for the 2019 GEAR UP Engineering Camp. For the students, the camp was intended to increase knowledge of and interest in engineering, but for the teachers, the camp was intended to be a professional learning experience that would help them learn how to teach engineering to their students. This professional learning experience included participating in authentic engineering experiences, which were crafted by engineering professors based on their research, with the students and participating in evening professional development workshops led by two researchers from Utah State University.

Researchers collected an engineering related lesson plan sequence from each teacher at the end of the camp, interviewed the participating teachers, and observed the teachers enacting a portion of the lesson plan sequence in the teachers' own classrooms. The lesson plans, interviews and observations were qualitatively analyzed in order to answer the following research questions:

1. What factors influence transfer of learning for K-12 STEM teachers from an engineering focused summer workshop that includes student and teacher experiences to their classrooms?
2. How well are the participating STEM teachers able to transfer learning related to the Science and Engineering practices into their classrooms?
3. What is the effect of having a teacher professional learning experience combined with a student engineering camp on teachers' transfer of learning?

This research study was primarily qualitative, specifically a case study using cross-case analysis, which included the following five cases: *a first-year middle school math teacher, a high school math teacher, a high school engineering teacher, two high school science teachers who participated in the GEAR UP Engineering Camp both in 2018 and in 2019, and two high school science teachers who participated in only the 2019 GEAR UP Engineering Camp*.

The cases were chosen by GSR1 based on the subject taught by the different teachers. The cases were further divided because the first-year middle school math teacher had a much different experience from the other math teacher due to him never having been in his own classroom prior to the GEAR UP Engineering Camp. The science teachers were also divided into two different cases because two of the teachers had also participated in the 2018 GEAR UP Engineering Camp, making their experience different enough from the experience of the other science teachers to warrant being a separate case.

Case 1: First-year Middle-School Math Teacher

One of the teachers (Teacher 2) who participated in the GEAR UP Engineering

Camp in 2019 and the related research study had been offered a job just before the start of the camp teaching math at a middle school in a more rural area of the State of Utah. However, before getting a job as a teacher, he had worked as a GEAR UP site coordinator in the same rural district, so he had no prior experience in his own classroom.

Because the Utah SEEd standards do not apply to math teachers, and because this teacher had no substantial previous experience in the classroom, any learning transfer from the Engineering Camp to his classroom required substantial cognitive effort which would qualify as high road transfer (Johnson et al., 2011). The context of teaching in a middle-school math classroom is also substantially different from the context of participating in the GEAR UP Engineering Camp professional learning experience, which makes learning transfer for this teacher far transfer. This is consistent with the research done by Barnett in that the lack of similarity of the task to the context of this teacher's classroom limited transfer of learning (Barnett, 2005).

Because of this, having any level of application of the Science and Engineering Practices (SEPs) for this teacher can be considered as substantial learning transfer. It is no surprise that this teacher was able to have substantial application of SEP 5 in the lesson plan sequence because it is specifically related to using mathematics. Having substantial application of SEP 2 was only slightly unexpected for this teacher because, although creating and using models is more closely tied to science and engineering rather than math, it is still something that is more easily transferable to a math class than some of the other SEPs. Having any level of application of SEP 1 and SEP 6, especially when it is specifically related to the engineering side of defining problems and designing solutions, shows that there has been at least some learning transfer taking place.

While it would have been better for the teacher to have applied the other SEPs to any degree at all, having some application of half of the SEPs shows that progress was made. Progress would have been more obvious if the teacher had participated in the observation, but as was mentioned in the previous chapter, due to some unexpected changes to his curriculum, and the pressure of being a first-year teacher, this teacher was unable to enact the lesson plan sequence in his class. The inability of this teacher to enact the lesson plan actually brings up some important points. Although the camp professional learning experience was beneficial to this teacher, he was not able to fully incorporate the things that he had learned from the camp because too much was being expected of him as a first-year teacher. Besides the normal stresses and time constraints of being a first-year teacher, his administration had changed his curriculum during the middle of the school year, so he was unable to fit in the lesson that he had planned. This lack of availability of time is one of the characteristics of the learner mentioned in the literature (Agyeit & Voogt, 2014). The lesson sequence this teacher had planned also worked best if he was able to collaborate with another teacher and, once again, because as he put it, he had "*too much on his plate*", he did not have the time, even outside of his prep time, to make the necessary arrangements for such a collaboration.

Although this teacher was not observed enacting his planned lesson, he was able to participate in both parts of the interview, with the second part being conducted via video conferencing. One of his main points in the first part of the interview was how beneficial the lesson planning portion was to him since he had never been in a classroom and did not have any substantial educational training. He enjoyed being able to participate in the professional development workshops with other teachers but would

have preferred being able to work with some of the more experienced teachers to create a lesson plan collaboratively.

Because the second part of the interview with this teacher did not take place immediately after the enactment of his lesson plan, the second part of the interview was more focused on how he had been able to apply what he had learned from the camp to his class overall, rather than to a specific lesson. According to his answers to the interview questions, the thing from the camp that he was able to apply most substantially to his class was using hands-on activities. Because hands-on activities are not as common in math classes as they are in science classes, he said that it did take effort on his part to do these kinds of activities in his class.

Although it would have been ideal to have more substantial learning transfer of the Science and Engineering Practices from the GEAR UP Engineering Camp to this teacher's classroom, there is evidence that learning transfer took place. Because this teacher had several barriers inhibiting more substantial learning transfer, such as a lack of time, too much pressure, and a heavy workload, which was added to even further by his administration, any amount of transfer of learning could be considered as substantial for the teacher.

Case 2: High School Math Teacher

Teacher 6, the other math teacher who participated in the GEAR UP Engineering Camp in 2019 had more experience in teaching, although not by a substantial amount. This teacher had been teaching math for about a year and a half at the time his class was observed. This teacher's experience was different from that of the other math teacher, not only because of having taught for more than a year, but because of the teaching

environment of the high school in which he taught. The school where this math teacher works has a different teaching model than most other schools in the area. Because of this different teaching model and the fact that he is a math teacher, any learning transfer for this teacher can also be considered high-road far transfer. This is consistent with the research done by Agyei & Voogt which showed that characteristics of the school environment can limit learning transfer (Agyei & Voogt, 2014).

In his interview he described how he has to have his entire curriculum for the year firmly planned out, ready, and posted online before the start of the school year because the students in his class are allowed to move ahead. Because of this, each of his students could potentially be at a different point in the course at any point during the semester. So he feels that introducing any new material that he might learn from a professional learning experience during the middle of the school year would be unfair to the students who had moved further in the course. For this reason, it was beneficial for him to not only learn more about the SEEd Standards and the Science and Engineering Practices, but also to be able to create a lesson plan enacting some of the practices while he was at the camp.

As was the case with the other math teacher, there was substantial application of both SEP 2 and SEP 5. However, this teacher also had limited application of two of the other SEPs and negligible application on two other SEPs. This lower level of application was evident from the teacher's submitted lesson plan. Therefore, he was able to apply six of the eight SEPs to at least some degree. Once again, any level of application of the other SEPs shows that some learning transfer had taken place. Unfortunately, this teacher's original lesson plan sequence was not detailed enough to show any evidence of

more substantial learning transfer.

However, between the engineering camp during the summer and the day when the teacher enacted the lesson plan in his class, he made some substantial modifications to the lesson. As can be seen from the higher SEP ratings from this teacher (Teacher 6) for the observation than for the lesson plans, these modifications made by the teacher made the lesson more substantially aligned with the Science and Engineering Practices. This shows that with additional effort input after the camp was over, this teacher was able to more substantially apply what he had learned from the camp in his class even though, like the other math teacher, the SEEd Standards do not apply directly to him because the State of Utah has different standards for math teachers.

One of the major themes that was present in this teachers' interviews was the need for interaction with other people. He specifically mentioned that it would have been beneficial for him to have been able to meet with the professors who were leading the engineering activities and have them tell him more about their process of teaching engineering as well as more about their process of doing engineering research. This one-on-one interaction with the engineering professors might have helped him to create a better lesson plan and to have more application of the SEPs in his observed lesson. Even though this was only mentioned by one of the teachers, GSR1 agreed with this teacher that it might be beneficial for all the participating teachers. It would give the teachers another practical example of how to teach engineering to students, so it is being considered for future camps.

He also mentioned that it was useful for him to be able to interact with the students during the Engineering Camp, but he wished that he had been able to interact

more with the students doing the fun activities instead of having so much time with just the teachers in the professional development workshops. He also suggested that more of the time in during the workshops be spent on collaborating with other teachers and creating a single lesson plan instead of creating a lesson sequence individually.

The other major theme from this teacher's interviews was how much he had been able to use hands-on activities and what he called "*discovery*" in his class. He said that because he had participated in both the engineering activities and the professional development workshops, he had been able to have the students ask more questions and discover more things on their own rather than him just explaining everything to them. In other words this teacher was better able to transfer learning because the camp professional learning experience allowed him to have concrete experiences and reflective observation through the engineering activities and an opportunity for abstract conceptualization in the workshops (Kolb, 1984).

Although it was not particularly clear from the lesson plans that this teacher created, with some additional time and effort after the camp was over, he was able to substantially transfer what he had learned from the context of the Engineering Camp professional learning experience to the different context of his math class. Not only did his observed lesson receive higher ratings, but they also had more of the engineering aspects of the SEPs (i.e. defining problems and designing solutions).

Case 3: High School Engineering Teacher

One of the participating teachers (Teacher 5) was a high school engineering teacher who had been teaching engineering for 3 years prior to the camp. The GEAR UP Engineering Camp professional learning experience was much different for this teacher

than it was for all the other participating teachers. Because she was an engineering teacher, and the school at which she worked had a traditional teaching model, learning transfer was low road and near transfer because it did not require substantial cognitive effort on her part and was in a similar context. The similarity of the task, one of the features of the task mentioned in the literature (Barnett, 2005), helped this teacher to better transfer learning from the camp to her class. In fact, the lesson sequence that the teacher planned at the GEAR UP Engineering Camp, a portion of which was observed by GSR1, was an expansion of the Sea Perch ROV Submarine activity from the camp. The portion of the lesson sequence that GSR1 observed involved a field trip to a wetland preserve area near her school that was an extension of Utah State University.

When looking at both the lesson plan ratings and the observation ratings, the ratings of the engineering teacher (Teacher 5) were substantially lower than the ratings of teachers 1, 3, 4, and 7 who were all science teachers. At first glance, it would seem that this teacher was not able to transfer what she had learned from the GEAR UP Engineering Camp professional learning experience to her own class, which is surprising considering low road near transfer does not require as much effort as high road far transfer. However, looking more deeply at the data, it is apparent that the problem lies not with the teacher's ability to transfer what she had learned from the camp, but in the Sea Perch ROV Submarine activity from the camp. After analyzing the lesson plan sequence and observing the field trip, GSR1 evaluated the Sea Perch activity from the camp and realized that the level of application of the Science and Engineering Practices in the activity from the camp was similar to the level of application in the lesson plan sequence and the observation. The engineering activities from the camp were not designed based

on the SEPs so it is not surprising that the Sea Perch activity did not substantially apply the SEPs. Part of the reason for the activities not being based on the SEPs is that the engineering professors were not trained in the SEPs before crafting the engineering activities. Therefore, the low ratings are not an indication of a lack of learning transfer by this teacher.

During the second part of the interview, this teacher mentioned that before she enacted the lesson that she had planned at the GEAR UP Engineering Camp during the professional development workshops, she was able to use several of the other activities from the camp. In other words, she indicated that she was able to substantially transfer what she had learned from the camp in the form of direct application with some expansion of the camp activities, although no evidence of substantial transfer was present in the lesson plan and observation ratings. Although the particular lesson that was observed did not have high ratings, the other activities that she described having done, or was planning to do, would have higher ratings of application of the Science and Engineering Practices.

One of the major themes from this teacher's interview was how much she enjoyed having the hands-on activities and actually being able to get involved rather than sitting and listening like is done in most other professional developments in which she had participated. She mentioned that she learns better by doing, which fits with the model of experiential learning (Kolb, 1984) on which the camp experience for the teachers was designed. It was particularly beneficial for her to have students present while doing the engineering activities to be able to see how she might change things in the activities based on how the students reacted at the camp.

While most of the science and math teachers mentioned that they were able to implement more hands-on engineering lessons in their curriculum because of their experience at the Engineering Camp, the engineering teacher mentioned during her interview that she had been able to incorporate more math and science in her class as a result of participating in the activities and the professional development workshops.

Even though this teacher's lesson plan and observation ratings were low compared to the participating science teachers, the ratings were comparable to the ratings that GSR1 gave to the Sea Perch activity. It was also apparent to GSR1 during both parts of the interview that this teacher had been able to transfer what she learned about the Science and Engineering Practices from the GEAR UP Engineering Camp Professional Learning Experience to her class.

Case 4: High School Science Teachers Who Also Participated in GEAR UP 2018

Two of the science teachers who participated in the 2019 GEAR UP Engineering Camp had also participated in the 2018 Engineering Camp. Both teachers had been teaching for over 5 years making them the most experienced teachers who participated in the 2019 GEAR UP Engineering Camp. Both teachers had been teaching science at the high school level, although one of the teachers had been teaching at a school where younger students also attended the same school. During the summer of 2019, this teacher had also switched jobs, so the observation of his classroom in Fall 2019 was in a different school than the observation associated with the 2018 GEAR UP Camp.

Because both these teachers had also participated in the 2018 Camp, they had already participated in the four engineering activities and had participated in the evening professional development workshops. This meant that they had previous experience with

the SEEd Standards, the Science and Engineering Practices, and the Engineering Design Process. Because of this previous experience, it is possible that transferring learning from the camp to their classrooms would not require as much cognitive effort, so it could be considered as low road transfer. However, the context of their science classrooms is still substantially different from the context of the Engineering Camp.

Because these two teachers had also submitted lesson plans for the 2018 Camp, GSR1 was able to compare both teachers' lesson plans from 2019 to their lesson plans to 2018, although GSR1 did not go back and use the evaluation protocol that was used for the 2019 lesson plans on the previous year's lesson plans. The lesson plans that the teachers submitted in 2018 were also not for an entire lesson sequence like the 2019 lesson plans but were for a single lesson. Although both teachers were observed during the 2018-2019 school year and the 2019-2020 school year, the observations were not done using the same evaluation protocol either, so a direct comparison of the ratings was not possible. However, there was a limited amount of data from the observation notes that were taken by GSR1 who conducted the observations. Both, the comparison of the lesson plans, and the comparison of the observation notes from the two years, showed that the two teachers who participated in both the 2018 and 2019 camp were better able to apply the Science and Engineering Practices in their lessons after the 2019 camp than after the 2018 camp. In particular, the two teachers were better able to apply the engineering parts of SEPs 1 and 6 because their lesson focused on solving problems and not just asking and answering questions. There are several possible explanations for this change.

One possible explanation for the improved application of the Science and Engineering Practices after the 2019 Engineering Camp is that, based on the results of the

pilot study that was done in conjunction with the 2018 Camp, GSR1 and the faculty member from the college of education who led the professional development workshops made changes to the workshops and helped the engineering professors make changes to the engineering activities. One of these changes was to make the content of the workshops more focused on the Utah SEEd Standards, the Science and Engineering Practices, and the Engineering Design Process, including the group activity which was focused on engineering in 2019 whereas the 2018 activity was more science focused. The other major changes that were made to the 2019 camp were related to making the engineering activities, the Air Quality and Aggie Air groups in particular, more hands-on. Because of these changes, it is possible that the teachers were able to learn more about, and have better examples of the SEEd Standards, the SEPs, and the Engineering Design Process, and were therefore more able to transfer that learning to the context of their own classrooms.

Another possible explanation for the teachers' improvement in the application of the SEPs from the 2018-2019 school year to the 2019-2020 school year is that the repetition of the engineering activities, and the content of the workshops, led to an increased mastery of the subject and more foundational knowledge on the part of the teachers, which helped to increase their learning transfer (Bransford et al., 1999; Caffarella, 2002). Because of this additional experience, these two teachers had a better understanding of the original learning (Agyei & Voogt, 2014).

Because these teachers had also participated in the previous camp, in addition to being asked during the interview about the quality of the 2019 Camp, they were also asked about how the 2019 Camp was different from the 2018 Camp. Both teachers

commented on how the camp activities had improved and become more hands-on. They also both mentioned that they enjoyed having more time to work on lesson plans. However, they both also talked about how there might have been too much time to work on the lesson plans individually when that could have been spent collaborating with the other participating teachers. Both teachers also mentioned that the changes to the Aggie Air activity could have gone a bit too far away from the data and from the students doing work on the computer. Clearly, a balance needs to be found in all the engineering activities between being hands-on while still helping the students to learn the underlying scientific principles and engineering problem solving.

When asked about what factors affect their ability to apply what they have learned from the camp into their own classes, both teachers said that the biggest factor was time. So even though these teachers have more experience than the first-year teacher, they still do not necessarily have the time that they need for optimal learning transfer. This lack of time is one of the characteristics of the learner as mentioned in the literature (Agyei & Voogt, 2014). One of these two teachers also mentioned a lack of satisfactory materials. She talked about how the materials at her school were getting old, but that she hoped they would be able to get new materials. Unfortunately, both the teachers' time, as well as the materials and resources to which the teachers have access, are mostly out of the control of the those running professional learning experiences. The only thing that can be done about the lack of time and resources is to give the teachers time for lesson planning during the camp, as was done at the GEAR UP Camp, and give the teachers materials that can be used for the lessons. Those running the GEAR UP Camp did provide the teachers with aerial drones and the ROV submarines that were used at the camp to help the

teachers to be able to use some of the activities from the camp without a substantial financial burden. However, both these teachers had received the drone and submarine after participating in the 2018 Camp, but neither had been able to use the drone or the submarine in their classes. Therefore, providing materials without providing ideas of how the teachers can use them in their own classes was not beneficial to the teachers.

Both teachers also mentioned in their responses during the second part of the interview that they had used, or planned to use, more engineering activities in the 2019-2020 school year than they had during the 2018-2019 school year. This, along with the increase in the level of application of the Science and Engineering Practices from 2018-2019 to 2019-2020, clearly show that these two teachers were able to transfer what they had learned from the GEAR UP Engineering Camp to their own classrooms.

Case 5: High School Science Teachers Who Participated Only in GEAR UP 2019

The other two science teachers who participated in the GEAR UP Engineering Camp Professional Learning Experience had not participated in a prior camp. Although one of these science teachers taught at a smaller school in the State of Nevada, and the other teacher taught at a larger school in the State of Utah, it was decided that their experience at the camp was similar enough to be considered in a single case. This was because the size of their classes was similar, and because although the SEEd Standards are for the State of Utah, the science teacher acknowledged that the standards in the State of Nevada are similar, so she was able to apply what she had learned to her class. Because neither of these teachers had participated in a previous camp, and because their science classrooms are substantially different from the context of the Engineering Camp, the transfer of learning for these two teachers can be considered high road far transfer.

Despite the need for more substantial cognitive effort, it is clear from the lesson plans alone that both teachers were able to transfer what they had learned in the GEAR UP Engineering Camp Professional Learning Experience to their classrooms. One of these teachers received a rating of 4, meaning substantial application, on six of the eight SEPs and a rating of 3 on another SEP. The other teacher's lesson received a rating of four on all eight SEPs. Because the observed lesson was only a small piece of the overall lesson sequence, the ratings on the observations of these two teachers were lower. However, one of the teachers still received a rating of 4 on two SEPs, along with two ratings of 3. The other teacher received a rating of 4 on both SEPs that were present in the observed lesson, although it was clear from the context of the observed lesson that the other SEPs had either been covered on a previous day or would be covered on a subsequent day of the lesson sequence.

Both teachers enjoyed being able to participate in the engineering activities, and having a concrete experience (Kolb, 1984), instead of just observing, or just sitting and listening as they do in other professional development workshops. One teacher benefitted from the hands-on engineering activities and mentioned in the second interview that she was able to incorporate more engineering activities because she got ideas from the activities at the camp after reflective observation (Kolb, 1984). The other teacher appreciated having the hypothetical engineering design problem during the workshop. In fact, her lesson plan and observed lesson centered on a hypothetical design problem related to environmental impact of land usage. Both of these teachers focused their lesson plans on the engineering parts of SEPs 1 and 6, because both of the lesson plans focused not on asking and answering questions, but on identifying and solving problems.

Also, in their interview responses, both teachers expressed a desire to have had more time to brainstorm and collaborate with the other participating teachers. Even though both teachers had substantial application of the Science and Engineering Practices in their lessons and observations, it is possible that there would have been even more application of the SEPs in their class overall if they had been able to collaborate and share ideas with the other participating teachers.

Both teachers also mentioned in their interview responses during the second interview some barriers that could prevent them from applying what they learned in the GEAR UP Engineering Camp to their classes. One teacher mentioned that she lacked confidence in being able to teach some of the engineering activities, particularly related to the drones because she did not have enough experience with them. The other teacher commented on a lack of materials and other resources. This teacher had to postpone the observed lesson because she had to wait for the materials for a previous lesson.

In their interview responses, both teachers mentioned that they had either been able to, or were planning to, incorporate more engineering activities besides the lesson plan sequence that they had created during the GEAR UP Engineering Camp. This, along with the high SEP application ratings on both teachers' lesson plans and their observed lesson, showed that a substantial amount of transfer of learning took place for these teachers.

Cross-Case Analysis

The previous sections all related to the analysis of the individual cases separately, but it was also important to look at all the cases together and identify the common themes throughout all the qualitative data, including the lesson plans, observations, and

interviews of all participating teachers. The SEP application ratings for the lesson plans and the observations were also be compared across all cases, although there were not enough participants to have sufficient statistical power to analyze the ratings quantitatively (Oehlert, 2010).

When looking at the SEP ratings of all the teachers' submitted lesson plan sequences, seen in Table 4 in the previous chapter, some interesting trends emerge. For SEP 2 (developing and using models) and SEP 5 (using mathematics and computational thinking), all teachers' lesson plans received a rating of 4 except for the engineering teacher. It was not surprising that the math and science teachers were able to do well on these two practices, but it was a surprise for the engineering teacher to be the only teacher who did not receive a rating of 4 because her lesson was an expansion of the Sea Perch Submarine activity from the GEAR UP Engineering Camp. It is possible this happened because the Sea Perch Submarine activity from the camp was not originally designed with the eight Science and Engineering Practices in mind. In fact, none of the activities from the camp were designed around the SEPs, partially because the researchers were not directly involved in creating the camp activities, with the exception of a slight involvement on the part of GSR1 in the redesign of the Aggie Air activity based on the results of the pilot study.

Another interesting trend is that the lesson plans from the four participating science teachers received ratings of 4 for substantial application on at least six of the SEPs, with two of the teachers receiving seven ratings of 4 and one teacher receiving eight ratings of 4. The two math teachers and the engineering teacher only had a rating of 4 on two of the SEPs each. It is possible that the science teachers had the highest

application ratings of the eight SEPs because the professional learning experience of the GEAR UP Camp was specifically designed to help science teachers be able to better teach engineering in their science classes.

The final interesting trend in the SEP ratings of the teachers' lesson plans is that SEP 1 (asking questions and defining problems) and SEP 3 (planning and carrying out investigations) have the lowest average ratings across the seven participating teachers. Although no statistical analysis was done, it is reasonable to conclude that more time should be dedicated in the professional development workshops to helping the teachers apply these SEPs. Changing the engineering activities to show examples of applying SEPs 1 and 3 more clearly might also benefit the teachers.

Some interesting trends also emerged when comparing the SEP application ratings of all teachers' observed lesson, seen in Table 5 in the previous chapter. Only one of the teachers applied SEP 7 (engaging in argument from evidence) in their observed lesson and it was only negligible application. Because the ratings were not similarly low on the lesson plans for all participating teachers, it is reasonable to assume that this SEP was applied in one of the other parts of the lesson sequence that was not observed by GSR1. Similarly, the teachers' ratings for SEP 8 (obtaining, evaluating, and communicating information) were also much lower for the observations than for the lesson plans. Again, it is probable that SEP 8 was present in other parts of the lesson which were not observed. It is interesting that only one of the teachers chose to incorporate SEP 7 to any degree in the lesson that was observed by GSR1 and only half of the teachers who were observed incorporated SEP 8. Unlike SEPs 7 and 8, the ratings for SEP 1 and SEP 3 were low in both the observations and the lesson plans. This

confirms that there should be additional emphasis in future professional learning experiences on how the teachers can apply these practices in their classrooms.

Regarding the qualitative data obtained from the teachers' interview responses, shown in Table 6 in the previous chapter, it is unsurprising that the two themes with the highest frequency are *Quality of the Camp* and *Implementation*, because these were the main subjects of the interview questions in the first and second parts of the interview, respectively. The *Interaction with Other People* and *School Environment* themes had a smaller frequency than the other themes because they emerged from the teachers' responses to only one specific interview question each. All the participating teachers mentioned interaction with other people during the first part of the interview in response to the second interview question (Appendix G). The *School Environment* theme emerged in response to question 5 which was asked during the second part of the interview.

Because the SEEd Standards were so new at the time of the camp, having just been approved in June 2019 by the Utah State Board of Education, many of the teachers had no exposure to the Standards before the camp. All the participating teachers, including the two math teachers, appreciated learning more about the Standards at the GEAR UP Engineering Camp. Even though the standards are different for the math teachers, they benefitted from learning about the SEEd Standards and reported that they had been able to apply some of what they had learned from the camp in their own classes within the scope of the state standards for math. For the science and engineering teachers, learning more about the SEEd Standards through abstract conceptualization (Kolb, 1984), and how to apply them during the professional development workshops, helped them to better implement the SEEd Standards and SEPs in their own classes. However, this was

not the only thing that the teachers were able to learn from the camp and apply in their own classes. Several teachers were better able to incorporate engineering and engineering design in their classes because of participating in the engineering activities and the professional development workshops. Some of the teachers were better able to engage with their students because of what they learned at the camp. Others reported that they had used more hands-on activities because of the camp experience. Other participating teachers were able to get ideas from the camp for other activities and projects that they could do in their classes. Multiple teachers used the example of a hypothetical design problem from the professional development workshop to create their own hypothetical design problem that fit better into their curriculum.

Learning transfer for the engineering teacher was, according to her, “super easy” because of the similarity of the task (Barnett, 2005). For the two math teachers, transferring what they had learned from the camp took more effort because of the difference in the standards. For the four participating science teachers, a certain amount of effort was required. Teachers had to change their way of thinking, be more creative and stretch in order to transfer what they had learned from the GEAR UP Engineering Camp Professional Learning Experience into their classes. Having time during the camp to prepare a lesson sequence helped the teachers to transfer what they had learned to their own classrooms, but the teachers thought that there might have been too much time given to them to work on their lesson plans.

All the participating teachers agreed that interacting with the students during the camp made the GEAR UP Engineering Camp Professional Learning Experience more beneficial to them. The teachers were able to see the engineering being taught to their

students through the hands-on engineering experiences. This would not be possible at most professional development programs because there are not students present. At most professional developments, the teachers listen to the presenters and might have some activities to practice the principles being taught with the other teachers, but they do not have the opportunity to see it being taught to students. Multiple teachers also enjoyed being able to interact with the students outside of the classroom.

When asked about the camp experience, the teachers had some suggestions on how to improve the experience for the teachers and for the students in future camps. Most of the suggestions were related to having more interaction with other people. They wanted more time to interact with the students doing the fun activities. Having more time with the students would not seem to directly affect the teachers transfer of learning, however, several teachers mentioned that it was difficult for them to work on the lesson plans in during the evening workshops because the days had been so long already. It is possible that allowing the teachers to participate in some of the fun activities with the students and reducing the lesson planning time during the evenings would help them to not be so exhausted and be better able to create quality lesson plans and transfer what they learned from the camp to their classrooms.

Almost all the participating teachers wanted more of an opportunity to collaborate with the other participating teachers instead of spending so much time working on their own on the lesson plans. There are several reasons why the teachers were given so much time to work on their lesson plan sequences. First, the results of the pilot study showed that the teachers had not had enough time in that camp to plan their lessons so the amount of time was increased, but it appears from the data that the researchers went too far and

allowed too much time for lesson planning. The second reason so much time was given to the teachers to plan their lesson sequence was because they were expected to plan multiple lessons, whereas in the previous camp they were only asked to plan a lesson for a single class period. It is clear that the changes were beneficial in that the teachers had more time to plan their lessons so they could be completed before the start of classes in the fall, however it is also clear that the teachers would benefit from being able to brainstorm with the other teachers and collaborate on one or two lesson plans instead of a full lesson sequence.

It was clear from the interview data that all the participating teachers enjoyed participating in the GEAR UP Engineering Camp Professional Learning Experience, partially because it was so different from other professional developments in which the teachers had participated. Having the opportunity to participate in the concrete experience (Kolb, 1984) of the engineering activities with their students, and also being able to reflectively observe (Kolb, 1984) engineering being taught to their students using hands-on activities, helped contributed to the teachers' ability to transfer what they learned from the camp to their classes. The teachers did however benefit from the teacher professional development workshops in the evenings of the camp, which were more similar to the traditional style of professional learning. Having the teachers participate in the engineering experiences and the professional development workshops allowed the teachers to follow the Kolb's model of Experiential Learning. The teachers were able to have concrete experiences through the engineering activities and were given time for reflective observation, abstract conceptualization, and active experimentation during the professional development workshops. Therefore, it was beneficial for the teachers to have

their teacher experience (the professional development workshops) combined with the student experience (the engineering activities) for an overall professional learning experience.

However, there were several suggestions from the teachers to improve the camp experience for future participating teachers, which would help to improve their transfer of learning. These changes included some changes to the engineering activities as well as changes to the professional development workshop. The changes related to the activities included allowing the students participating in the Aggie Air group to do some simple programming, allowing the students participating in the Air Quality group to do at least some of the data analysis, and having the professors more prepared for the data analysis in the Sea Perch and Stream Data groups. The issue with these activity-specific suggestions is that future camps will not include the same engineering activities. There were however some more general suggestions for the engineering activities and the professional development workshops that could be applied to future GEAR UP Engineering Camps. First, some of the teachers suggested that while the activities had become more hands-on, they had gone too far away from the data. This means that activities in future camps should have a balance between the hands-on engineering and the data collection/analysis. Second, most of the teachers suggested that the teacher development workshops should be limited to two of the evenings instead of four. They also suggested that the lesson planning should be limited to one or two lessons and should be collaborative instead of individual work. These changes are being considered for future camps to improve the teacher experience and, more importantly, increase the teachers' transfer of learning to their own classes.

Most of the participating teachers agreed that a professional learning experience such as the GEAR UP Engineering Camp should focus on the practical aspects of teaching, such as how to actually implement the SEEd Standards and Science and Engineering Practices in their classes. The other teachers felt that it was also important for them to learn about the educational theory in order to have a solid foundation before learning the more practical ways of implementing in their classrooms. Even those teachers who preferred a focus on practical implementation did not specifically say that it was bad to include some theoretical aspects in a professional learning experience. Therefore, including some theoretical background while still focusing on the practical application seems to be the best thing to do in a professional learning experience. The GEAR UP Engineering Camp activities already focus on practical application and the professional development began with a small amount of theoretical background followed mostly by a focus on practical application. Because it aligned with the way the teachers wanted it to be, the GEAR UP Camp Professional Learning experience will continue to focus on the practical application of the SEEd Standards, the Science and Engineering Practices, and the Engineering Design Process and only spend a short time on the theoretical background knowledge at the beginning of the professional development workshops.

All of the participating teachers spoke in their interview responses about aspects of the environment of their own schools that affect whether they are able to apply what they have learned from professional learning experiences to their classes. They spoke about not having enough time during the school year to prepare new lessons as well as not having enough class time to fit more engineering activities in their curriculum. They

spoke about sometimes not having sufficient resources and about how sometimes their classes have too many students to make some engineering activities feasible. Sometimes the administration can also affect what the teachers do in their classrooms and can either encourage or hinder the teachers' transfer of what they learned in professional learning experiences. Unfortunately, unlike the aspects of the camp that the participating teachers mentioned, the GEAR UP researchers, as well as those who run other professional development programs, have no control over the teachers' school environment.

Conclusions

Research Questions

The qualitative data obtained from the participating teachers' lesson plans, observations, and interviews helped to answer the research questions which had guided the study.

Research Question 1. The first research question was related to factors that influenced the participating teachers' transfer of learning from the GEAR UP Engineering and was primarily answered through the teachers' interview responses, although the data from the teachers' lesson plans and observations also revealed some factors. Some of these factors are things that the researchers can control and change to improve the teachers' transfer of learning. Other factors are outside of the control of the researcher and can only be changed by school administrators and policymakers.

Factors that influenced the teachers' transfer of learning which can be controlled by the GEAR UP team are all related to the quality of the GEAR UP Engineering Camp Professional Learning Experience. One of the factors is the degree to which the engineering activities, which the teachers participated in during the camp, are related to

the Science and Engineering Practices so that the teachers have better examples of what they should be doing with their own students. Another factor is the content, length, and collaboration of the evening professional development workshops. The data showed that focusing the professional development workshops on the Utah SEEd Standards, the Science and Engineering Practices, and the Engineering Design Process helped the teachers to better transfer what they learned from the Camp into their classes. The length of the professional development workshops, specifically the amount of lesson time, also influences the teachers' transfer of learning. In the pilot study, the teachers did not have enough time to work on their lessons, so the researchers requested more time with the teachers. The teachers who participated in the 2019 Engineering Camp made it clear that there was too much lesson planning time and that planning an entire lesson sequence was too much work for the time given them. It was also clear that in working on fewer lesson plans, the teachers would have time to collaborate with each other in creating the lessons rather than working individually. The other factor that can be somewhat controlled by the GEAR UP Team is the discipline of the teachers that are recruited for the camp. Because the Utah SEEd Standards and the Science and Engineering Practices are the main focus of the GEAR UP Engineering Camp Professional Learning Experience, the participating teachers should be limited to science or engineering teachers who are held to these standards. Although the math teachers who participated in the camp were able to benefit from the camp experience, they have different standards to which to teach. These math teachers were able to use more hands-on activities to engage their students better, but they were not able to apply the full scope of the Science and Engineering Practices because that is not required of them.

There were other factors that influence teacher transfer of learning over which the GEAR UP researchers have no control. However, even though the researchers have no control over these factors, they can be accounted for in professional learning experiences. A major factor was the teachers' time, both in class and outside of class. In order for teachers to transfer what they learn from a professional learning experience to their own classrooms, the data showed, similar to the results in Agyei and Voogt (2014), teachers need sufficient time. Time is necessary for the teachers both to process what they have learned and to create or change lesson plans that apply what they have learned. The teachers also require some flexibility in their classroom time in order to fit these new or modified lesson plans into their curriculum. In order to account for the teachers' lack of time, the teachers were given lesson preparation time during the camp. However, only the school administrators and policymakers can give the teachers more time and flexibility. The administration in the participating teachers' schools and districts was another factor that was found to affect transfer of learning of the participating teachers. This echoes the results of other research that showed that support from superiors is necessary for successful transfer (Agyei & Voogt, 2014; Johnson, 2009; Thomas, 2007).

Another factor which the researchers do not have control that was found to affect the participating teachers' transfer of learning was the resources available to the teachers in their classrooms. Although the researchers do not have control over all resources available to the teachers, it was possible to provide the teachers with some resources, such as the Sea Perch ROV Submarines and quadcopter drones that were used during the GEAR UP Engineering Camp Activities. Another factor related to the school environment is the number of students in the teachers' classes. Although this also cannot

be controlled by the GEAR UP researchers, it is possible to help the teachers learn how to do engineering activities with larger groups during professional learning experiences such as the GEAR UP Camp.

Research Question 2. The second research question was related to how well the participating teachers were able to transfer what they learned related to the Science and Engineering Practices into their classrooms. This question was primarily answered through the teachers' lesson plans and observations, although the third and fourth questions from the semi-structured interview were also intended to answer this research question.

It is clear from the high SEP Application Ratings shown in Table 4 in the previous chapter that all four of the participating science teachers had substantial transfer of learning of the Science and Engineering Practices from the camp to their lesson plans. The two science teachers who had participated in the 2018 and 2019 GEAR UP Engineering Camps were much more able to apply the Science and Engineering Practices in their lesson plans that were created during the 2019 camp than in their 2018 lesson plans. Because the other two participating science teachers also had high SEP ratings for their lesson plans, it is reasonable to assume that the changes made to the camp and the professional development workshops after the pilot study helped the teachers to better transfer their learning from the GEAR UP Engineering Camp Professional Learning Experience.

The two math teachers had lower SEP Application Ratings for their lesson plans, but since they have different curriculum standards, any level of application of the SEPs shows that transfer of learning has taken place. Because the context is substantially

different, and because the transfer of learning required substantial cognitive effort, the math teachers had high road far transfer of learning. The transfer of learning of the participating engineering teacher is not clearly exhibited in the SEP Application Ratings of her lesson plan. Her lesson plan was an extension of the Sea Perch Submarine activity from the Engineering Camp, so this alone makes it clear that transfer took place, even if it was low road near transfer. The relatively low ratings for this lesson, compared to the lessons created by the science teachers, are most likely caused by the fact that Sea Perch Submarine activity, as well as the other engineering activities, was not designed to follow the Science and Engineering Practices.

The results from the observations show similar results. The science teachers showed substantial transfer of learning of the Science and Engineering Practices, which can be seen from their high SEP Application ratings. One of the math teachers was not observed, but the other actually had higher ratings for the observation than for the original lesson plan because he modified his lesson plan before the observation. This shows that with more time and more effort, the math teacher was more able to transfer what he learned about the Science and Engineering Practices into his classroom. The engineering teacher's observed lesson had similarly low SEP Application Ratings for the same reasons as the lesson plan. The observed lesson also involved a field trip, and some logistical problems occurred which cut the students' time short. This was another reason for the low scores in the engineering teacher's observed lesson. Although the observations only covered a portion of the overall lesson sequence that the teachers had planned during the GEAR UP Engineering Camp, it is actually a better representation of how well the teachers were able to transfer what they learned from the camp into their

classroom because it actually shows what they did, and not just what they planned. Ideally, the entire lesson sequence would have been observed, but because the teachers were from various schools and districts, that was not possible at the time of the observations.

In addition to the qualitative data obtained from the lesson plans and observations, some of the teachers' interview responses also helped to show how well the participating teachers were able to transfer what they had learned from the GEAR UP Engineering Camp Professional Learning Experience to their own classrooms. All the participating teachers reported being able to transfer at least some of what they learned for use in their classes. This transfer ranged from using specific activities from the camp, or at least getting ideas from the camp to use in their own classrooms, to being able to better apply the Science and Engineering Practices or the Engineering Design Process throughout their curriculum instead of just in one class. Combined with the qualitative data from the lesson plans and observations, this interview data shows that there was substantial transfer, especially for the participating science teachers, from the GEAR UP Engineering Camp Professional Learning Experience to the teachers' own classrooms.

Research Question 3. The third research question was related to the effect on teacher transfer of learning when combining a teacher professional learning experience with the GEAR UP student engineering camp. This question was answered primarily through the first and second questions in the semi-structured interview, and through the lesson plan and observation data, although some of the teachers' responses to the third and fourth interview questions and the follow-up questions also helped to answer this research question.

The data from the teachers' responses to the interview questions regarding the camp showed that, overall, the participating teachers reported that combining the teacher professional learning experience with the student engineering camp helped the teachers to transfer what they had learned from the camp to their classrooms. The hands-on nature of the engineering activities helped the teachers to use more hands-on activities in their own classes. Participating in the engineering experiences, instead of just sitting and listening, helped the teachers to learn what engineering is, and how it can be applied in their classrooms. Being able to see how the students reacted to the engineering experiences at the camp helped the teachers to know how to modify the activity if they decided to do it in their own classes. Having the example of the hypothetical design problem during the professional development workshops helped the teachers to develop other hypothetical design problems which fit their curriculum. These problems helped them to realize that they do not necessarily need to take a field trip with their students, or bring in expensive materials, to teach engineering to their students.

The teachers also suggested several changes to the camp, which may have an even more substantial effect on the teachers' transfer of learning in future camps. These changes included balancing the hands-on activities and design with data collection and analysis. The teachers suggested that the lesson planning time did not need to be so long, and that it should be collaborative instead of an individual project. The teachers also suggested that only one or two lessons should be planned at the camp, instead of an entire sequence of lessons. The researchers are planning on making these changes to future camps to help improve the transfer of learning of the teachers who participate in future camps.

Implications

This research found that there are some factors that influence whether teachers are able to transfer learning from a professional learning experience such as the GEAR UP Engineering Camp to their classrooms. Some of these factors can be controlled by the researchers at Utah State University or any other university that also combines a teacher and student experience. Other factors are controlled by administrators and policymakers. While these factors can be accounted for by the researchers, there needs to be some change at the policymaker and administrator level to allow teachers more time to reflect on what they have learned, more time to prepare lessons by taking some other responsibilities off their plate, and more time and flexibility in their class to implement new lessons that apply things they have learned from professional learning experiences. If the teachers are unable to transfer what they learned from a professional learning experience to their own classrooms, then there was no purpose in having the teachers attend the professional learning experience. Educational researchers can help to implement the necessary changes by communicating with the policymakers and administrators and influencing them to make the changes.

It is also clear from the results of this research that professional learning experiences should be restricted to only the specific discipline to which the learning applies. While the professional learning experience of the GEAR UP Engineering Camp was beneficial to the two math teachers who participated, it would have been more effective if all the participating teachers had been science teachers. A separate professional learning experience using the same model could be created for math teachers, and other experiences could also be created for other disciplines. These new

professional learning experiences could focus on the applicable State Standards for each discipline and any other discipline-specific teaching practices that need to be taught to the teachers. The portion of this professional learning model that can be implemented in other disciplines is not the subject matter, which should change based on the individual discipline, but the idea that teachers can see the teaching practices and the standards being taught to their students, and can participate in related activities to have the experience for themselves.

The success of the GEAR UP Engineering Camp Professional Learning Experience provides a model for other universities to implement similar programs. Many other universities have already started student outreach engineering camps, or similar outreach programs to get students interested in engineering. These other camps can follow the model of the GEAR UP Engineering Camp Professional Learning Experience and combine a teacher experience, including one or more professional development workshops, with the student-focused camp.

There are multiple professional development opportunities available to science teachers who are looking for help in implementing engineering in their science classes. Some of these opportunities are the traditional type of professional development in which the teachers sit and listen to speakers who talk about the standards and teaching practices (Ghosh et al., 2019; Lakin et al., 2019). Other programs allow teachers to participate in engineering research or other engineering experiences with engineering faculty and graduate students on university campuses (Krishnamoorthy et al., 2019; Lavelle et al., 2019; Smith & Lohani, 2019; Veety et al., 2019). The key to the success of the GEAR UP Engineering Camp Professional Learning Experience is having the professional

development workshops and allowing the teachers to participate in authentic engineering experiences with their students, instead of having separate experiences. Therefore, there are two keys to any other university implementing a similar professional learning experience. The first is having teachers participate with students in engineering experiences so that they can not only experience engineering, but also see it being taught to their students. The second is having short engineering-focused professional development workshops that include examples of how the participating teachers can implement engineering in their own classrooms, and sufficient lesson preparation time in which the teachers can collaborate on the creation of engineering-related lesson plans.

Even though the GEAR UP Engineering Camp Professional Learning Experience was focused on engineering, schools, districts, and state boards of education can implement professional learning experiences in other disciplines that combine the teacher experience with a student experience that allows the teachers to see what is being taught to them in action with students. This will help the teachers to transfer more of what they have learned from the professional learning experience into their classrooms. It is possible that there may be additional cost to these programs when adding students, however, the benefit to the participating teachers would most likely outweigh the cost.

Recommendations

Because this study is part of a 7-year project, and because there are other GEAR UP Engineering Camps that are run at Utah State University, there will still be additional research related to the teachers who participate in the camps. The improvements suggested by the teachers for future camps are part of the same grant as the camp that was the subject of this research (GEAR UP 2). The camp that has been run on the newer

GEAR UP grant (GEAR UP 3) did not have any professional learning aspect for the teachers who came to the camp. So, the professional development workshops and teacher participation in the engineering activities still need to be implemented with the suggested improvements in the future camps that are part of the newer GEAR UP grant. The GEAR UP group at Utah State University also runs other camps that are not specifically related to engineering. In order to have the camp activities be more related to the SEEd Standards and the SEPs, teachers who have previously participated, as well as education faculty who are familiar with the Standards, could assist the engineering professors in the planning of the camp activities. The professional learning model from this research, consisting of combining the teacher professional development with the student-focused camp, could be modified, and used in these other camps as well.

With teacher professional learning being included in these other camps, it would be possible to obtain qualitative data from a larger group of teachers in various disciplines. For these future camps, the data can be obtained from lesson plans, observations, and interviews, although observing all lessons that are planned by the participating teachers, rather than just a portion of them, would provide more complete data. After enough camps have been run with a similar model of combining the teacher experience with the student experience, it might even be possible to have a large enough number of participants to do some statistical analysis. In addition to this, longitudinal research should be performed with teachers who have participated in the all the camps to track whether the transfer of learning is sustained or increased over time.

Although this research was focused on the teachers, future research could include the students of the participating teachers to see if the positive effects of the camp on the

teachers help their students to increase their knowledge of, and interest in engineering, similar to the research that has been done involving students who have participated in the GEAR UP Camp. The students who participated in the engineering camp and are also in the classes of the participating teachers could also be asked about how well their teachers were able to transfer what they learned from the camp to their classrooms. These students could also be asked about how their experience in the classroom compared to their experience at the engineering camp.

Future research could also compare the teachers’ transfer of learning from professional learning experiences that combine the teacher experience and the student experience to the transfer of learning from traditional professional development experiences. This could be done by having some teachers participate only in a professional development workshop based on the evening professional development workshops that were a part of the camp, and other teachers participate in the full professional learning experience of the camp. Both groups of teachers could then be interviewed and observed to see if there is a difference in their transfer of learning.

More research needs to be done related to transfer of learning that is specific to teachers. Most of the research on transfer of learning is specifically related to students transferring what they learn in school to their eventual workplace, or related to people who already have a job, transferring what they learn in workplace training. There are unique challenges that are present in transfer of learning for teachers, and teachers are required to participate in a number of professional development programs on a regular basis. More research is needed to better understand these challenges.

In addition to future research being conducted at Utah State University, other

universities could use the same model of combining the teacher professional learning experience with a student-focused camp experience to create their own camps. These universities could obtain even more data from their participating teachers which could then be compared to the data obtained at Utah State University.

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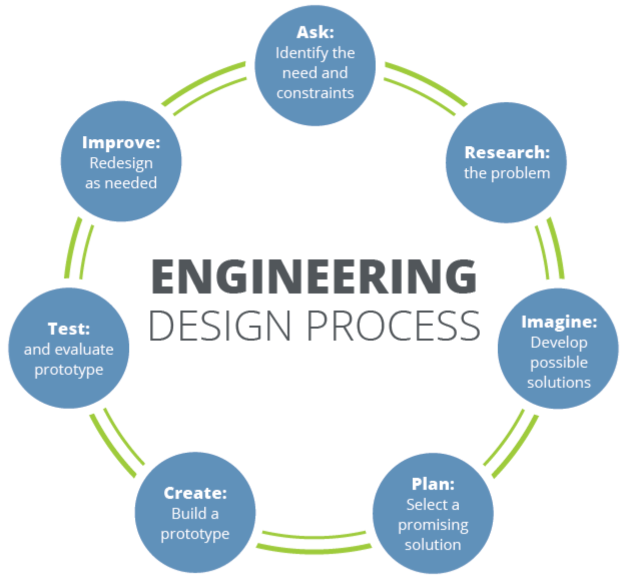
APPENDICES

APPENDIX A

A SIMPLIFIED MODEL OF THE ENGINEERING DESIGN PROCESS USED DURING THE TEACHER PROFESSIONAL DEVELOPMENT WORKSHOPS

Engineering Design Process

A Simplified Model of the Engineering Design Process



1. **Ask**

   Questions that need to be asked include (but are not limited to):
   - What is the problem that needs to be solved?
   - What are the constraints of the problem?
   - Who is it for?
   - What is the overall goal?

2. **Research**

   Find resources (experts, books, reputable websites, etc.) to learn more about the problem and possible solutions that may already exist or could be adapted for the problem.

3. **Imagine**

   Brainstorm possible solutions to the problem with a team. Be creative and don't dismiss ideas.

4. **Plan**

   Based on the needs and constraints, select the most promising solution.

5. **Create**

   Build a prototype of the selected design.

6. **Test**

   Evaluate the prototype. Does it work? Does it fit all the constraints? Can it be improved?

7. **Improve**

   Improve the design and revisit previous steps. Make changes as necessary.

This process is iterative. The entire process can be repeated, or individual steps can be revisited as needed, until the best design or solution is found.

APPENDIX B

TEMPLATE FOR PARTICIPATING TEACHERS' ENGINEERING RELATED LESSON PLANS

Science and Engineering Performance Lesson Plan	
Grade **Topic –**	**Title**
SEED Standards(s):	
Lesson Objective:	
Student Science and Engineering Performance (5-E Model, GRC Model, etc.)	
Science Essentials (NRC, 2012)	
Science and Engineering Practices	
Crosscutting Concepts	
Disciplinary Core Ideas	

APPENDIX C

GEAR UP ENGINEERING CAMP 2019 TEACHER RECRUITMENT AND TEACHER EXPECTATIONS

Engineering Camp 2019

July 8th to 12th

Teacher Participants

USU IRB Protocol Number: 9506

Expectations of Teachers:

- Work and guide a group of high school students throughout the week
- Identify connections from the content of the week with your core curriculum and begin to identify how you can integrate the engineering and science experiences when you return to the classroom
- Using the week's experiences create 1 sequence/series of lessons on a concept shared during the camp. Identify a science and engineering component that will be integrated and taught no later than December 2019. Plan for approximately 3-5 days of instruction, one of which will be observed by Gear Up researchers
- Following enactment in your classroom, participate in an interview with Gear Up researchers regarding the implementation of your professional learning

Benefits for Teachers:

- Develop practical and conceptual understanding of Science and Engineering practices for use within their classrooms
- Learn how various models of the cycle of engineering practices can be used for classroom instruction
- Stipend for time and effort
- Experience science and engineering curriculum that can be adapted within schools
- Receive science and engineering equipment reflecting lesson sequences that intended for fall delivery

APPENDIX D

LETTER OF INFORMED CONSENT FOR TEACHERS PARTICIPATING IN THE GEAR UP ENGINEERING CAMP PROFESSIONAL LEARNING EXPERIENCE AND RELATED RESEARCH

Office of RESEARCH and GRADUATE STUDIES
UtahStateUniversity
INSTITUTIONAL REVIEW BOARD

Page 1 of 2
Protocol #9506
IRB Approval Date: September 20th, 2018
Consent Document Expires: June 2021
IRB Password Protected per IRB X

v.8.3: May2019

Informed Consent

USU GEAR UP II Engineering Camp

Purpose

You are invited to participate in a research study conducted by Kurt Becker, a professor in the Department of Engineering Education and Max Longhurst in the School of Teacher Education and Leadership at Utah State University. The purpose of this research is to find out more about teacher professional learning. You have been asked to take part because of your participation in a professional development (PD) experience in connection to the USU GEAR UP II Engineering Camp project. There will be approximately 8 total participants in this portion of the research. This form includes detailed information on the research to help you decide whether to participate in this research. Please read it carefully and ask any questions you have before you agree to participate.

Procedures

Your participation will involve being observed in your own classroom by one of the student researchers while teaching a lesson(s) that is related to what you learned in the PD from the USU GEAR UP II Engineering Camp. This observation will be followed by one semi-structured interview of no more than 60 minutes. The observation and interview will take place during the Fall 2019 academic year. You will also be interviewed at the end of the camp regarding your overall GEAR UP Camp experience. You will be invited to review interview transcripts and observation data to ensure accuracy. If you agree to participate, the researchers will also collect audio recordings of the interviews for transcription and analysis. The observation will not be recorded. We anticipate that 8 people will participate in this research study.

Risks

This is a minimal risk research study. That means that the risks of participating are no more likely or serious than those you encounter in everyday activities. The foreseeable risks or discomforts include minor disruption to classroom instruction, stress from being observed, loss of preparation time due to interviewing, or inadvertent loss of confidentiality. In order to minimize those risks and discomforts, the researchers will sit at the back of the classroom and refrain from any interruption to classroom instruction that is not necessary for the observation. In order to minimize the risks and discomforts of the interview, the researcher will limit the interview to no more than 60 minutes, will offer breaks during the interview, and will conduct the interview at a time convenient to the participating teachers. All data will be kept in a secure, restricted-access location. If you have a bad research-related experience or are injured in any way during your participation, please contact the principal investigator of this study right away at kurt.becker@usu.edu.

Benefits

Participation in this study may directly benefit you by accessing effective models of instruction practice that enhance student learning in your classroom. More broadly, this study will help the researchers learn more about influential factors that lead to improvements in education professional learning and may help future teachers and students across the state or nationally.

Confidentiality

The researchers will make every effort to ensure that the information you provide as part of this study remains confidential. Your identity will not be revealed in any publications, presentations, or reports resulting from this research study. However, it may be possible for someone to recognize your particular interview responses.

We will collect your information through audio recordings during semi-structured interviews. This information will be securely stored in a restricted-access folder on Box.com, an encrypted, cloud-based storage system. All names

will be given numeric identifiers and pseudonyms will be inserted upon transcription. This form will be kept for three years after the study is complete, and then it will be destroyed.

It is unlikely, but possible, that others at Utah State University or the federal funding officials may require us to share the information you give us from the study to ensure that the research was conducted appropriately. We will only share your information if law or policy requires us to do so. If the researchers learn that you are abusing or neglecting others, state law requires that the researchers report this behavior to the authorities.

Voluntary Participation & Withdrawal

Your participation in this research is completely voluntary. If you agree to participate now and change your mind later, you may withdraw at any time by notifying the research staff during the interview and the interview will end. If you choose to withdraw after we have already collected information about you, your data will be destroyed upon your request. If you decide not to participate, the services you receive from your association with GEAR UP II will not be affected in any way. The researchers may choose to terminate your participation in this research study if you fail to respond to requests for interviews. Your termination of participation will be sent in writing via email.

IRB Review

The Institutional Review Board (IRB) for the protection of human research participants at Utah State University has reviewed and approved this study. If you have questions about the research study itself, please contact the Principal Investigator at (435) 797-2078 or kurt.becker@usu.edu. If you have questions about your rights or would simply like to speak with someone other than the research team about questions or concerns, please contact the IRB Director at (435) 797-0567 or irb@usu.edu.

Dr. Kurt Becker Principal Investigator (435) 797-2078; kurt.becker@usu.edu	Dr. Max L. Longhurst Co-Investigator (435) 797-7093; max.longhurst@usu.edu

Informed Consent

By signing below, you agree to participate in this study. You indicate that you understand the risks and benefits of participation, and that you know what you will be asked to do. You also agree that you have asked any questions you might have and are clear on how to stop your participation in the study if you choose to do so. Please be sure to retain a copy of this form for your records.

______________________________	______________________________	____________
Participant's Signature	Participant's Name, Printed	Date

APPENDIX E

FULL SCHEDULE OF GEAR UP ENGINEERING CAMP

<table>
<tr><th></th><th></th><th></th><th>Teams 1-3</th><th>Teams 4-6</th><th>Teams 7-9</th><th>Teams 10-12</th><th>Teachers</th></tr>
<tr><td rowspan="15">Monday, July 8</td><td>10:00-11:00</td><td>1 hr</td><td colspan="5">Arrival & Check In at LLC</td></tr>
<tr><td>11:10-12:00</td><td>50 min</td><td colspan="5">Lunch: The Junction</td></tr>
<tr><td>12:10-12:30</td><td>20 min</td><td colspan="5">Opening Survey - ENGR 3rd Floor</td></tr>
<tr><td>12:30-12:50</td><td>20 min</td><td colspan="5">Engineering Camp Expectations/Orientation - ENGR 103</td></tr>
<tr><td>12:50-1:00</td><td>10 min</td><td colspan="5">Break</td></tr>
<tr><td>1:00-2:30</td><td>1.5 hrs</td><td colspan="5">Introductions to Air & Water - ENGR 103</td></tr>
<tr><td>2:30-4:00</td><td>1.5 hrs</td><td colspan="5">Engineering Activity #1 - ENGR 103, 205
Nancy Mesner, Ryan Dupont, Randy Martin, Cal Coopmans & Kurt Becker</td></tr>
<tr><td>4:00-5:00</td><td>1hr</td><td colspan="5">Get To Know You Games</td></tr>
<tr><td>5:10-6:00</td><td>50 min</td><td colspan="5">Dinner: The Marketplace</td></tr>
<tr><td>6:00-6:15</td><td>15min</td><td colspan="4">Change for Swimming</td><td rowspan="3">Professional Development
Max Longhurst
ENGR 221</td></tr>
<tr><td>6:20-6:30</td><td>10 min</td><td colspan="4">Load Bus - TSC Roundabout</td></tr>
<tr><td>6:30-8:30</td><td>2 hrs</td><td colspan="4">Canoe/Paddle Boarding - 1st Dam</td></tr>
<tr><td>8:30-9:00pm</td><td>30 min</td><td colspan="5">Load Bus Return to LLC</td></tr>
<tr><td>9:00-10:00</td><td>1 hr</td><td colspan="4">Clean Up/Social Hour/Healthy Snack</td><td>Set up Healthy Snacks</td></tr>
<tr><td>10:00-10:30</td><td>30 min</td><td colspan="5">Get ready for bed</td></tr>
<tr><td></td><td>10:30</td><td></td><td colspan="5">Lights Out</td></tr>
<tr><td rowspan="12">Tuesday, July 9</td><td>7:00-7:45</td><td>45 min</td><td colspan="5">Breakfast: The Junction</td></tr>
<tr><td>8:00-9:00</td><td>1 hr</td><td rowspan="2">Air Quality/Drones
Randy Martin
(EL 221)</td><td rowspan="2">Flying Aggies
Cal Coopmans
(Aggie Air Shop)</td><td>Meet at EL 235 B</td><td>Meet at EL 235 B</td><td></td></tr>
<tr><td>9:00-12:00</td><td>3 hrs</td><td>Sea Perch Submarines
Nancy Mesner
(2nd Dam)
Load bus at TSC</td><td>GIS Stream Data
Ryan Dupont
(Water Lab)
Load bus at TSC</td><td></td></tr>
<tr><td>12:00-1:00</td><td>1 hr</td><td colspan="5">Lunch: The Marketplace</td></tr>
<tr><td>1:00-2:00</td><td>1 hr</td><td>Meet at EL 235 B</td><td>Meet at EL 235 B</td><td rowspan="2">Flying Aggies
Cal Coopmans
(Aggie Air Shop)</td><td rowspan="2">Air Quality/Drones
Randy Martin
(EL 221)</td><td></td></tr>
<tr><td>2:00-5:00</td><td>3 hrs</td><td>GIS Stream Data
Ryan Dupont
(Water Lab)
Load bus at TSC</td><td>Sea Perch Submarines
Nancy Mesner
(2nd Dam)
Load bus at TSC</td><td></td></tr>
<tr><td>5:00-6:15</td><td>1.25 hrs</td><td colspan="5">Campus Scavenger Hunt
End on Engineering Quad</td></tr>
<tr><td>6:30-7:30</td><td>1 hr</td><td colspan="5">Dinner: The Marketplace</td></tr>
<tr><td>7:30-9:30</td><td>2 hrs</td><td colspan="4">Volleyball, Basketball, Board Games - ARC</td><td>Professional Development
Max Longhurst</td></tr>
<tr><td>9:30-10:00</td><td>30 min</td><td colspan="5">Walk to Housing</td></tr>
<tr><td>10:00-10:30</td><td>30 min</td><td colspan="4">Get ready for bed/Healthy Snack</td><td>Set up Healthy Snacks</td></tr>
<tr><td>10:30</td><td></td><td colspan="5">Lights Out</td></tr>
<tr><td rowspan="12">Wednesday, July 10</td><td>7:00-7:45</td><td>45 min</td><td colspan="5">Breakfast: The Junction</td></tr>
<tr><td>8:00-9:00</td><td>1 hr</td><td>Meet at EL 235 B</td><td>Meet at EL 235 B</td><td rowspan="2">Air Quality/Drones
Randy Martin
(EL 221)</td><td rowspan="2">Flying Aggies
Cal Coopmans
(Aggie Air Shop)</td><td></td></tr>
<tr><td>9:00-12:00</td><td>3 hrs</td><td>Sea Perch Submarines
Nancy Mesner
(2nd Dam)
Load bus at TSC</td><td>GIS Stream Data
Ryan Dupont
(Water Lab)
Load bus at TSC</td><td></td></tr>
<tr><td>12:00-1:00</td><td>1 hr</td><td colspan="5">Lunch: The Marketplace</td></tr>
<tr><td>1:00-2:00</td><td>1 hr</td><td rowspan="2">Flying Aggies
Cal Coopmans
(Aggie Air Shop)</td><td rowspan="2">Air Quality/Drones
Randy Martin
(EL 221)</td><td>Meet at EL 235 B</td><td>Meet at EL 235 B</td><td></td></tr>
<tr><td>2:00-5:00</td><td>3 hrs</td><td>GIS Stream Data
Ryan Dupont
(Water Lab)
Load bus at TSC</td><td>Sea Perch Submarines
Nancy Mesner
(2nd Dam)
Load bus at TSC</td><td></td></tr>
<tr><td>5:00-6:00</td><td>1 hr</td><td colspan="5">Small Group: Poster Session - Choose Groups (ENGR 3rd Floor)</td></tr>
<tr><td>6:00-7:00</td><td>1 hr</td><td colspan="5">Dinner: The Marketplace</td></tr>
<tr><td>7:00-9:30</td><td>2.5 hrs</td><td colspan="4">Bingo/Karaoke - ESLC 130</td><td>Professional Development
Max Longhurst
ENGR 221</td></tr>
<tr><td>9:30-10:00</td><td>30 min</td><td colspan="5">Walk to Housing</td></tr>
<tr><td>10:00-10:30</td><td>30 min</td><td colspan="4">Get ready for bed/Healthy Snack</td><td>Set out Health Snacks</td></tr>
<tr><td>10:30</td><td></td><td colspan="5">Lights Out</td></tr>
</table>

Thursday, July 11	7:00-7:45	45 min	Breakfast: The Junction				
	8:00-10:00	2 hrs	Group Choice	Group Choice	Group Choice	Group Choice	Air Quality - EL 221 Sea Perch - Hyrum Reservoir-TSC
	10:00-12:00	2 hrs					Flying Aggies - Aggie Air Shop GIS Stream- Logan Canyon-TSC
	12:00-1:00	1 hr	Lunch: The Marketplace				
	1:00-3:00	2 hrs	Group Choice	Group Choice	Group Choice	Group Choice	Air Quality - EL 221 Sea Perch - EL 227
	3:00-5:00	2 hrs					Flying Aggies - Aggie Air Shop GIS Stream - EL 227
	5:00-6:15	1.25 hrs	Small Group: Poster Session (ENGR 3rd Floor)				
	6:30-7:30	1 hr	Dinner: The Marketplace				
	7:30-9:30	2 hrs	Small Group: Poster Session (ENGR 3rd Floor)				Professional Development Max Longhurst
	9:30-10:00	30 min	Walk to Housing				
	10:00-10:30	30 min	Get ready for bed/Healthy Snack				Set out Health Snacks
	10:30		Lights Out				
Friday, July 12	7:00-7:45	45 min	Breakfast: The Junction				
	7:45-8:30	45 min	Check out of the LLC				
	8:30-10:00	1.5 hrs	Poster Session - ENGR 103				
	10:00-10:45	45 min	Closing Remarks/Survey				
	10:45-11:00	15 min	Walk to The Marketplace				
	11:00-11:45	45 min	Lunch: The Marketplace				
	11:45-12:00	15 min	Load Bus & Goodbyes				

APPENDIX F

SCIENCE AND ENGINEERING PRACTICES FROM THE FRAMEWORK FOR K-12 SCIENCE EDUCATION

NGSS Science Practices

A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. (NRC, 2012)

1. Asking Questions and Defining Problems

Science begins with a question about a phenomenon, such as "Why is the sky blue?" or "What causes cancer?," and seeks to develop theories that can provide explanatory answers to such questions. A basic practice of the scientist is formulating empirically answerable questions about phenomena, establishing what is already known, and determining what questions have yet to be satisfactorily answered.

2. Developing and Using Models

Science often involves the construction and use of a wide variety of models and simulations to help develop explanations about natural phenomena. Models make it possible to go beyond observables and imagine a world not yet seen. Models enable predictions of the form "if … then … therefore" to be made in order to test hypothetical explanations.

3. Planning and Carrying Out Investigations

Scientific investigation may be conducted in the field or the laboratory. A major practice of scientists is planning and carrying out a systematic investigation, which requires the identification of what is to be recorded and, if applicable, what are to be treated as dependent and independent variables (control of variables). Observations and data collected from such work are used to test existing theories and explanations or to revise and develop new ones.

4. Analyzing and Interpreting Data

Scientific investigations produce data that must be analyzed in order to derive meaning. Because data usually do not speak for themselves, scientists use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Sources of error are identified and the degree of certainty calculated. Modern technology makes the collection of large data sets much easier, thus providing many secondary sources for analysis.

5. Using Mathematics and Computational Thinking

In science, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks, such as constructing simulations, statistically analyzing data, and recognizing, expressing, and applying quantitative relationships. Mathematical and computational approaches enable predictions of the behavior of physical systems, along with the testing of such predictions. Moreover, statistical techniques are invaluable for assessing the significance of patterns or correlations.

6. Constructing Explanations

The goal of science is the construction of theories that can provide explanatory accounts of features of the world. A theory becomes accepted when it has been shown to be superior to other explanations in the breadth of phenomena it accounts for and in its explanatory coherence and parsimony. Scientific explanations are explicit applications of theory to a specific situation or phenomenon, perhaps with the intermediary of a theory-based model for the system under study. The goal for students is to construct logically coherent explanations of phenomena that incorporate their current understanding of science, or a model that represents it, and are consistent with the available evidence.

7. Engaging in Argument from Evidence

In science, reasoning and argument are essential for identifying the strengths and weaknesses of a line of reasoning and for finding the best explanation for a natural phenomenon. Scientists must defend their explanations, formulate evidence based on a solid foundation of data, examine their own understanding in light of the evidence and comments offered by others, and collaborate with peers in searching for the best explanation for the phenomenon being investigated.

8. Obtaining, Evaluating, and Communicating Information

Science cannot advance if scientists are unable to communicate their findings clearly and persuasively or to learn about the findings of others. A major practice of science is thus the communication of ideas and the results of inquiry—orally, in writing, with the use of tables, diagrams, graphs, and equations, and by engaging in extended discussions with scientific peers. Science requires the ability to derive meaning from scientific texts (such as papers, the Internet, symposia, and lectures), to evaluate the scientific validity of the information thus acquired, and to integrate that information.

APPENDIX G

SEMI-STRUCTURED INTERVIEW PROTOCOL

GEAR UP 2 Participant Interview Protocol (Completed by Researcher)

School: ____________________ Date: _________.

Teacher: _______________ Grade/Subject: __________.

Years of Teaching:_______. Interviewer:________________.

Introductory Questions:	Running Notes/Observations:
1. Please share your thoughts about the GEAR UP 2 Engineering Camp? (Interview 1, RQ3) 2. What are your thoughts about combining professional development with the GEAR UP 2 Engineering Camp for an overall professional learning experience? (Interview 1, RQ3) 3. What experiences from the GEAR UP 2 Engineering Camp did you find most useful/beneficial for you in your teaching? (Interview 2, RQ3) 4. When considering the GEAR UP 2 Engineering Camp professional learning experience, what did you learn that you have used in your classroom? (Interview 2, RQ3) 5. What are the most influential factors that determine whether you apply what you have learned from professional learning experiences such as the GEAR UP 2 Engineering Camp in your classroom? (Interview 2, RQ1)	
Follow up question #1:	Running Notes/Observations:
Follow up question #2:	
Follow up question #3:	
Follow up question #4:	
Emergent Questions:	

APPENDIX H

OBSERVATION PROTOCOL FOR OBSERVED LESSONS

GEAR UP 2 Observation Protocol (Completed by Researcher)

School: ____________________ **Date:** _________.

Teacher: _______________ **Grade/Subject:** __________.

Years of Teaching: ______. **Observer:** ________________.

Contextual Background

A brief description of the lesson, the classroom setting, and any other important details about the teacher or the classroom.

Ratings

How well has the teacher applied the Science and Engineering practices in this lesson? (practices specific to engineering are underlined)

(0 = Not present in lesson, 1 = negligible application, 2 = limited application, 3 = moderate application, 4 = substantial application)

1. Asking questions and <u>defining problems</u> 0 1 2 3 4
2. Developing and using models 0 1 2 3 4
3. Planning and carrying out investigations 0 1 2 3 4
4. Analyzing and interpreting data 0 1 2 3 4
5. Using mathematics and computational thinking 0 1 2 3 4
6. Constructing explanations and <u>designing solutions</u> 0 1 2 3 4
7. Engaging in argument from evidence 0 1 2 3 4
8. Obtaining, evaluating, and communicating information 0 1 2 3 4

Description of Events

A brief description of events that contribute to the ratings above.

APPENDIX I

TEACHER LESSON PLAN EVALUATION PROTOCOL

GEAR UP 2 Lesson Plan Evaluation Protocol (Completed by Researcher)

School: ______________________ Date: _________.
Teacher: ________________ Grade/Subject: __________.
Years of Teaching: _______. Evaluator: _________________.

Contextual Background

A brief description of the lesson and any other important details about the teacher or the class.

Ratings

How well has the teacher applied the Science and Engineering practices in this lesson? (practices specific to engineering are underlined)

(0 = Not present in lesson, 1 = negligible application, 2 = limited application, 3 = moderate application, 4 = substantial application)

1. Asking questions and <u>defining problems</u>	0 1 2 3 4
2. Developing and using models	0 1 2 3 4
3. Planning and carrying out investigations	0 1 2 3 4
4. Analyzing and interpreting data	0 1 2 3 4
5. Using mathematics and computational thinking	0 1 2 3 4
6. Constructing explanations and <u>designing solutions</u>	0 1 2 3 4
7. Engaging in argument from evidence	0 1 2 3 4
8. Obtaining, evaluating, and communicating information	0 1 2 3 4

Rationale for Ratings

A brief description of the reasons for the ratings above.

APPENDIX J

TEACHER LESSON PLAN WITH COMPLETED EVALUATION PROTOCOL

Science and Engineering Performance Lesson Plan	
Grade 9-12	**Title** **Gravity Fed Water System**
Topic – Environmental Engineering	
SEED Standards(s):	

Lesson Objective:

Students learn about water poverty and how water engineers can develop appropriate solutions to a problem that is plaguing nearly a sixth of the world's population.

After this activity, students should be able to:

- Define water poverty and relate the concept to global issues and the difficulty in providing sustainable solutions.
- Relate the general physics and fluid mechanic theory and principles that allow water to flow by gravity through pipe systems.
- Design and optimize a working gravity-fed water system based on constraints.

Student Science and Engineering Performance (5-E Model, GRC Model, etc.)

Day 1- Present the problem of water poverty in the world and have the students identify the main areas of concern related to the problem. (PowerPoint presentation)
Explain the possible constraints to consider when designing a system to solve the problem.

- Water Source Quality and Quantity: If the source water is not clean, it cannot be used. If the water quantity changes throughout the day and does not meet the community water demand, it will not work.
- Topography (how the surrounding land is shaped): The topography must allow for water to flow at all locations along the pipe through pressure differentials that result from water flowing from higher to lower elevations.
- System Demand: This is a function of the number of people using the system and the amount of water allocated to each person.
- Frictional Loss: Just like with a system that has moving parts, friction can occur in water systems as the water flows through the pipes and results in loss of pressure along the pipe, which can prevent flow altogether.
- Pipe Size and Length: Engineers design pipe size based on how much water is needed by the community and how much friction will occur through the pipes.

With the design, the goal is to have the highest flow (volume per time; that is, gallons per second), while having the greatest turbidity change.

Day 2- Engineering design process worksheet for a working model of gravity fed water system. Inform students that they can change the following parameters: tank elevations, tube diameters (sizes), and tube locations. Remind them how changing these parameters can affect the flow, where again, the goal of the activity is to have the water go from the top tank to the bottom tank the fastest, while changing the turbidity of the water as much as possible.

Day 3 and 4- After turning in their preliminary designs groups should swap designs and evaluate each other's designs and ask questions about their choices and hypothesis.

After evaluating each other's designs, each group should predict the outcome of their project using basic understanding of physics and fluid mechanics formulas.
Groups should start building their models using their final design.

They choose between different system parameters such as pipe sizes, elevation differentials between entry and exit pipes, pipe lengths and tube locations to find a design that provides the maximum flow and minimum water turbidity (cloudiness) at the point of use. In this activity, students play the role of water engineers by designing and building model gravity-fed water systems, learning the key elements necessary for viable projects that help improve the lives people in developing communities.

Each group of 6 students will need:

- access to water or, if necessary, a 5-gallon bucket filled with water
- safety glasses/goggles, one per student
- Gravity-Fed System Design Worksheet, one per student
- turbidity chart (to measure cloudiness), on the last slide of the presentation
- 2 calculators, for two students to check calculations
- 2 6-ft long 0.25" or 0.5" clear polymer tubing
- 1 3-ft long 0.5" clear polymer tubing to represent the tap
- 5 0.25-in and 5 0.5-in threaded hose barbs (thread on one end and barbed on the other), with o-ring that goes over the threaded section, along with a metal or plastic nut that threads on to the threaded section
- 3 clear 5-gallon tubs, holes drilled for the following;
- pipe adaptors for exit of spring catchment basin or dam (tub 1), entrance and exit for sedimentation tank (tub 2), entrance only for "community" tank (tub 3)
- 2 cups of dirt (sediment)
- 2 stopwatches to measure flow rate
- (5) 2' x 2' cardboard boxes, or larger cardboard boxes (to place tanks on)
- 1 clear plastic cup (end user) (note: this is the cup of water that students fill with tub 3 water to insinuate drinking)

To share with the entire class:

- 12 6-ft long 0.25" clear polymer tubing
- 12 6-ft long 0.5" clear polymer tubing

3 hoses connected to classroom taps to fill tub 1 (dam/catchment)

Day 5- Models should be tested with clean water first to make sure they work properly and there isn't any leakage in the system.
Once models have been tested and are working properly, 2 cups of dirt should be added to the first tub.
Each group should then record the time it takes for the water to get to the end of the system, and analyze the turbidity of the water at the end.
After collecting data from different trials, a data table should be built, analyzed and discussed by the group.

Science Essentials (Student Performance Expectations From Appendix C, D, E)	
Science and Engineering Practices 1- Asking questions and defining problems 2- Developing and using models 3- Planning and carrying out investigation 4- Analyzing and interpreting data 5- Using mathematics and computational thinking. 6- Constructing explanations and designing solutions 7- Engaging in argument from evidence 8- Obtaining, evaluating and communicating information	1- After learning about water poverty from the power point presentation, students should be able to ask questions and identify the problem to come up with a possible solution. 2, 3, 5- The engineering design process worksheet guides the students to design a working model of a gravity- fed water system based on mathematical calculations from physics and fluid mechanics formulas. 4, 6, 7, 8- After building the model, students should then collect data, analyze, and compare the results with different groups and different models. They should then engage in argument about the most efficient model based on their data.
Crosscutting Concepts	

1- Patterns 2- Cause and effect 3- Scale, proportion and quantity 4- System and system models	1- Observed patterns and consequences related to water poverty 2- Analyze the effects of water poverty 3- System Demand: This is a function of the number of people using the system and the amount of water allocated to each person. 4- Design a system model to solve the problem presented at the beginning of the process.
Disciplinary Core Ideas	

(B. Moulding, 2011)

GEAR UP 2 Lesson Plan Evaluation Protocol (Completed by Researcher)

School: ________________________ **Date:** **4/28/2020**

.

Teacher: **Teacher 4** **Grade/Subject** **9-12**

Environmental Engineering

Years of Teaching: ______________. **Evaluator:** _________________.

Contextual Background

This lesson plan introduces students to the global issue of water poverty and ask students to design and optimize a working gravity fed water based system. Additionally, it ask students to think about the physics and fluid mechanics principals that are involved in pipe systems.

Ratings

How well has the teacher applied the Science and Engineering Practices in this lesson? (practices specific to engineering are underlined)

(0 = Not present in lesson, 1 = negligible application, 2 = limited application, 3 = moderate application, 4 = significant application)

1.	Asking questions and defining problems	0	1	2	3	**4**
2.	Developing and using models	0	1	2	3	**4**
3.	Planning and carrying out investigations	0	1	2	3	**4**
4.	Analyzing and interpreting data	0	1	2	3	**4**
5.	Using mathematics and computational thinking	0	1	2	3	**4**
6.	Constructing explanations and designing solutions	0	1	2	3	**4**
7.	Engaging in argument from evidence	0	1	2	3	**4**
8.	Obtaining, evaluating, and communicating information	0	1	2	3	**4**

Rationale for Ratings

This is a complex project that spans multiple days and includes a good amount of material and equipment (and water) for students to use. While it may be challenging to implement, it includes all of the science and engineering practices which are explained in by the teacher as part of the lesson plan.

Students are first asked to engage in understanding water poverty and asked to define the problem (Practice 1). They are then asked to create a design or model of their system and predict the outcome using physics and fluid mechanics formulas (relating to Practice 2 and 5). Students are provided with materials and are able to construct their solutions (Practice 6). After constructing their designs students carry out an investigation of their system and analyze the results (Practice 3 and 4). This information is share with the class (Practice 7,8).

APPENDIX K

CURRICULUM VITAE

RYAN BARLOW, PH.D.

Phone: (801) 995-5395 | 1327 Vista Ridge Dr.
ryanfbarlow@gmail.com | Santaquin, UT 84655

SUMMARY OF QUALIFICATIONS

- Academically trained Engineering Educator with teaching experience in math and engineering at the college level to a diverse student population
- Passionate about providing the best education possible to students through research-based teaching practices
- Expertise in engineering/engineering education curriculum and course development for online and in-person courses, teacher and faculty development in engineering, and engineering student outreach

EDUCATION

PhD Utah State University, Engineering Education — August 2020
Dissertation: Transfer of Learning for K-12 STEM Teachers: From the GEAR UP Engineering Camp Professional Learning Experience to the Classroom — GPA: 3.94
Logan, UT
Committee: Dr. Kurt Becker (Major Professor), Dr. Oenardi Lawanto, Dr. Max Longhurst, Dr. Idalis Villanueva, Dr. Wade Goodridge

MA University of Maryland, Science Education — August 2016
College Park, MD

BS University of Utah, Mechanical Engineering — May 2012
Salt Lake City, UT

RESEARCH EXPERIENCE

zyBooks, a Wiley Brand, Campbell, CA — 2020 to Present
Engineering Content Author, Mechanical Engineering
- Develop content for online, interactive engineering textbooks
- Transition traditional print textbooks to the online, interactive zyBooks format
- Assist Engineering Professors with implementation of zyBooks
- Research the effect of zyBooks on student learning

Utah State University, Logan, UT — 2020 to Present
Postdoctoral Research Fellow, Department of Engineering Education
- Design and implement a hybrid professional learning experience in engineering education for high school science teachers

- Interact with and observe high school science teachers while they participate in authentic engineering experiences led by engineering professors
- Develop and implement new Statics problems related to Environmental and Biological Engineering. Study the effect of the new Statics problems on the self-efficacy and perceived value of Environmental and Biological Engineering students.

Dissertation, Utah State University, Logan, UT 2018 – 2020

Transfer of Learning for K-12 STEM Teachers:
From the GEAR UP Engineering Camp Professional
Learning Experience to the Classroom

Advisor: Dr. Kurt Becker

- Design and implement a professional learning experience in engineering education as a part of a student-focused engineering summer camp for seven participating high school STEM teachers
- Interact with and observe the teachers while they participated in authentic engineering experiences with their students, which were led by engineering professors and engineering graduate students
- Lead evening professional development workshops for the participating teachers, which focused on the Science with Engineering Education (SEEd) standards, the Science and Engineering Practices, and one model of the engineering design process
- Interview the participating teachers regarding their experience at the engineering camp and how they have been able to use what they learned at the camp in their own classrooms
- Observe the teachers while they enact a lesson plan created during the engineering camp professional learning experience that implements the Science and Engineering Practices which are described in the Utah SEEd Standards
- Analyze the data from the interviews, observations, and lesson plans to determine how well the teachers were able to transfer what they learned in the professional learning experience to their own classrooms
- Evaluate the effect of having professional development workshops combined with a student-focused engineering camp for an overall professional learning experience

Utah State University, Logan, UT 2016 to 2020
Graduate Research Assistant, **Department of Engineering Education**

- Develop an online Certificate of Engineering Education (CEEd) for present and future engineering educators
  - Create course objectives and course content for four online courses for the CEEd program (Principles of Engineering Teaching and Learning, Assessing Learning and Teaching in Engineering, Engineering Course Design, and E-Learning Course and Training Development in Engineering)
  - Develop assessments for the four online courses

    - Develop requirements for an engineering education portfolio that is part of the teaching internship portion of the CEEd program
- Collect and analyze qualitative data related to engineering design thinking and teacher professional learning
- Develop new Statics problems related to Environmental and Biological Engineering
- Assist in developing content for engineering student outreach program

University of Maryland, College Park, MD 2014
Graduate Research Assistant, Science Education
- Analyzed qualitative data related to science education

University of Maryland, College Park, MD 2013 to 2014
Graduate Research Assistant, Aerospace Engineering
- Wrote computer code and ran calculations related to wind turbines

RESEARCH INTERESTS

- Development of Online Engineering Textbooks; Transitioning Print Textbooks to Interactive Online Format; Engineering Faculty Development; Engineering Teacher Professional Learning for K-12 STEM teachers; Engineering K-12 Student Outreach Programs; Online Engineering Education; International Engineering Education; Engineering Assessment; Transfer of Learning; Creativity, Innovation, and Problem-Solving in Engineering Education

TEACHING EXPERIENCE

Utah State University, Logan, UT Aug 2018 to Dec 2018
Teaching Assistant, Department of Engineering Education
- Teaching assistant for Teaching, Learning, and Assessment in Engineering Education, a graduate course with 6 students, covering the following topics: active learning, teaching with technology, evaluation of teaching, creating effective assessments
- Course primarily taught using discussion with little to no lecture
- Developed quizzes and homework assignments
- Created all content for the course in Canvas

Prince George's Community College, Largo, MD Jul 2015 to May 2016
Adjunct Professor, Department of Developmental Mathematics
- Taught Arithmetic up through Introductory Algebra
- Assisted in developing new curriculum for the Arithmetic course when it was combined with the Pre-Algebra course

Prince George's Community College, Largo, MD Jan 2015 to May 2016
Academic Tutor, Department of Developmental Mathematics

- Helped students to learn Arithmetic up through Introductory Algebra

University of Maryland, College Park, MD Aug 2012 to May 2013
Teaching Assistant, Department of Aerospace Engineering

- Teaching assistant for Dynamics of Aerospace Systems and Aerospace Structures
- Led recitation sessions with lecture and example problems, graded homework, and helped develop exam problems

University of Texas, Austin, TX Aug 2004 to May 2005
Academic Tutor, University of Texas Learning Center

- Tutored students in math, physics, chemistry, and introductory Mechanical Engineering courses

TEACHING INTERESTS

- Engineering Courses: Design, Statics, Dynamics, Strengths, Materials Science and Engineering, Thermodynamics, Fluid Mechanics, Aerodynamics, and Heat Transfer
- Engineering Education Courses: Engineering Curriculum Development, Engineering Pedagogy, Engineering Assessment, Internationalizing Engineering Education, Engineering Education courses for any interested students

PUBLICATIONS

Journal Papers

Uziak, J., Barlow, R., Villanueva, I., Lawanto, O., & Becker, K. (2018). Development of a Graduate On-line Certificate Program in Engineering Education, *International Journal of Engineering Education, 34*(5), 1549-1561.

Journal Papers Submitted for Publication

Barlow, R.F., Longhurst, M.L., & Mahmoud, M., *Teacher Adaptation or Adoption of Activities from a Professional Learning Experience for K-12 Science Teachers Incorporated into a Student Focused Engineering Summer Camp.*

Journal Papers in Progress

Barlow, R.F., Lawanto, O., Villanueva, I., Longhurst, M.L., Goodridge, W., Becker, K.H., *Transfer of Learning of K-12 STEM Teachers from Professional Learning to the Classroom.*

Conference Papers

Barlow, R., Uziak, J., Villanueva, I., Lawanto, O., & Becker, K. H. (2017, June), *Work in Progress: Online Engineering Education Certificate Program.* Paper presented at 2017 ASEE Annual Conference & Exposition, Columbus, Ohio. https://peer.asee.org/29174

Barlow, R., Longhurst, M., & Becker, K. H. (2019, June), *Work in Progress: Integrating a Teacher Professional Learning Experience into the GEAR UP Engineering Camp*. Paper presented at 2019 ASEE Annual Conference & Exposition, Tampa, Florida.

Barlow, R., Longhurst, M., & Becker, K. H. (2020, June), *Embedding Teacher Professional Learning into the Student-Focused GEAR UP Engineering Summer Camp (Evaluation).* Paper presented at the 2020 ASEE Virtual Conference.

Conference Papers Submitted for Presentation

Barlow, R.F., Rios, O., & Haines, S. (2021, June), *Transitioning Mechanical Engineering Textbooks from Print to the Interactive Online zyBooks Format (Work in Progress).* Abstract accepted for presentation at the 2021 ASEE Annual Conference & Exposition, Long Beach, CA.

Sambamurthy, N., Barlow, R.F., Rios, O., Rajasekhar, Y., & Edgcomb, A. (2021, June), *High-Quality Text Descriptions of Visual Elements: Authoring and Pedagogical Philosophy.* Abstract accepted for presentation at the 2021 ASEE Annual Conference & Exposition, Long Beach, CA.

RELEVANT SKILLS

Academic Skills:
- Assessment creation and implementation
- Curriculum development
- Course development (online and face-to-face)
- Develop learning objectives
- Active learning experiences

Computer Skills:
- Programming: Matlab
- Applications: Word, Excel, Power Point, Solid Works, SPSS, MAXQDA

PROFESSIONAL AFFILIATIONS

American Society for Engineering Education, 2016-Present
American Society of Mechanical Engineers, 2005-Present

PROFESSIONAL SERVICE

Student Representative, Mechanical Engineering Curriculum Committee, University of Utah
Students Representative, Mechanical Engineering Enrollment Management Committee, University of Utah

COMMUNITY SERVICE

Full-Time Religious Service
Missionary, Ribeirao Preto, Brazil, January 2006 – January 2008

LANGUAGES

English: Native Language
Portuguese: Fluent (speaking, reading, writing, listening)
Spanish: Conversational (two years in Spanish-speaking country and 4 years of Spanish in school)

OTHER

Published Young Adult Fantasy Author (July 2015)
U.S. Citizen