ENGINEERING EDUCATION PROFESSIONAL DEVELOPMENT FOR TEACHERS IN THE DELTA GREELY SCHOOL DISTRICT

By

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Abstract

Over the last two decades engineering has become a new focus in many science curricula, in part due to the emphasis on STEM (science, technology, engineering, and math) education. Most teachers lack training or education in engineering and are not adequately prepared to implement effective engineering education. This research identifies the needs and constraints of one district, the Delta Greely School District (DGSD), in Delta Junction, AK (approximately 750 students district-wide). Surveys were distributed to fifty teachers and five administrators to gather information on attitudes and beliefs surrounding engineering education. Focus groups were conducted with teachers and administrators to better understand the needs of the teachers and the district as well as the perceived obstacles that currently limit engineering education in the classroom. The results were used to create recommendations for professional development to improve and increase engineering education in the district's K-5 classrooms. The final recommendations focus on a professional development plan and professional development delivery modes. Results of the study support two levels of professional development: one introductory level for teachers unfamiliar or not comfortable with engineering education and one for teachers who are comfortable with the subject and would like to improve their teaching. It was also determined that specific teaching resources (i.e., lesson plans and curricular material) should be part of professional development, and that professional development solution should be designed to complement the specific district-provided resources and curricula.

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Chapter 1 Introduction

1.1 Introduction

Qualified STEM professionals are needed in the United States to remain economically competitive in the global market and to meet modern demands in areas such as sustainable energy, effective healthcare, and technology advancement (Committee on Integrated STEM Education, 2014; DeJarnette, 2012; Epstein & Miller, 2011). The current shortage of graduates in science, technology, engineering, and mathematics (STEM) requires increasing students' interest in STEM careers and improving student proficiency in STEM-related content knowledge (Committee on Integrated STEM Education, 2014). In recent years, engineering education in K-12 schools has received substantial attention as an essential component of STEM education (National Research Council, 2013). Additional education of engineering principles as part of integrated STEM education may increase motivation and student engagement in K-12 schools (Yoon, Lucietto, Capobianco, Dyehouse, & Diefes-Dux, 2014).

Over the last two decades at least 22 states in the US have instituted engineering requirements for K-12 students and the recent release of the Next Generation Science Standards (NGSS) has made engineering a key component of science education for many districts and states (Douglas, Rynearson, Yoon, & Diefes-Dux, 2016). In Alaska, engineering education is especially important because of the problems and challenges unique to the state, especially those resulting from global change. Arctic coastal villages face a diverse set of geohazards ranging from sudden events such as flooding to longer-term changes such as decreasing sea ice and biodiversity loss. Systematic efforts and opportunities like integrating engineering education into the curriculum to engage and prepare Alaskan youth for STEM careers are essential. Many teachers are unfamiliar with engineering principles and how to integrate those into the current curriculum. Most STEM integration efforts use engineering and engineering design to promote the learning of science, mathematics, and technology content (Moore et al., 2014). There is an immediate need for effective teacher professional development in engineering education if true integrated STEM is to be implemented in classrooms. The current research on engineering education is limited however, especially when the scope is narrowed to rural schools, elementary education, and rural Alaskan schools. There is a need for research focusing on rural Alaskan schools and the teachers and administrators in those schools to provide all students with equal access to engineering education.

Engineering, as part of integrated STEM education, offers a rich learning experience for students to apply knowledge, explore ideas, practice problem solving and critical thinking, and develop social emotional skills, but many teachers have obstacles, real and perceived, that prevent them from exploring engineering education or implementing it in their classrooms (Margot & Kettler, 2019). Professional development has been identified by current research as an important tool to support teachers and administrators in integrating engineering education into the curriculum (Margot & Kettler, 2019). In order for professional development to be effective it needs to address not only content knowledge but also negative teacher perceptions of engineering education; "…[i]t is not the PD per se, but the experience of successful implementation that changes teachers' attitudes and beliefs" (Guskey, as cited in Al Salami, Makela, & de Miranda, 2017, p. 67). Teachers need a supportive environment to try something new like engineering education where they can see the potential for change and growth in student learning outcomes. Meaningful change often takes time and professional development must be designed so that it has a lasting effect because attitudes and practices do not change overnight. Duration needs to be considered when designing an effective professional development program (Archibald, Coggshall, Croft, & Goe, 2011; Darling-Hammond & Richardson, 2009; Yoon, Duncan, Lee, Scarloss, & Shapley, 2007).

1.2 Statement of Focus

The purpose of this study was to explore attitudes of K-12 teachers and administrators toward teaching engineering and to identify professional development modes for supporting teachers and administrators in planning and implementing integrated engineering education. The findings of the study will inform educational stakeholders regarding overcoming obstacles that currently limit the presence of engineering education in Alaska. The research took place in the rural Alaskan Delta Greely School District (DGSD). The conclusions recommend a plan for elementary engineering education professional development that meets the needs of the teachers and administrators within the Delta Greely School District.

1.3 Research Questions

The study addresses the following three research questions:

1. What are teachers' and administrators' current attitudes toward engineering in the classroom?

2. What prevents teachers from teaching engineering and administrators from supporting engineering education?
3. What professional development methods would motivate teachers to include engineering education in the classroom and suit the district's resources and needs?

1.4 Personal Rationale

As a math teacher my goal is to educate students in a way that prepares them for whatever path they choose to follow, whether that be engineering, the trades, business, or one of a plethora of other careers. More important than memorizing facts and learning high-level concepts in the traditional fields are the life skills that children should develop in school. Children need to learn critical thinking, problem solving, written and verbal communication, and social and emotional skills. Algebra is important, but these life skills are the lessons students need to walk away with to be successful regardless of the career path they choose. My goal as a teacher is to educate children for life, not to educate them for a diploma, and math is one context in which to develop these life skills. Engineering gives students an opportunity to use the skills and knowledge they've gained in a wide range of subjects to solve problems, think critically, communicate ideas and work with others. Engineering can reinforce the lessons learned in other subjects, it can help students to see connections between classroom material and the "real world", and it can present varied learning experiences to reach more students. Further, engineering can break the mold of a problem with one right answer, the black and white idea of right/wrong or pass/fail, and the idea that the teacher holds the knowledge and passes it on to the student.

Through engineering students can approach and solve the same problem in different ways and they can create new ideas and knowledge as they progress. Engineering can help children to become more than just receptacles for knowledge; they can be problem solvers, team members, leaders, and drivers of change.

As a new teacher I did not embrace engineering and I likely would not have for at least several years without assistance or an external motivator. When I started teaching there was an entire equipment package in my classroom to start up a robotics club that was ordered by the previous teacher but never used, and I never even opened the box. With everything else I was attempting to tackle as a new teacher the robotics project seemed too overwhelming and not high enough on the priority list to wade through by myself. I also did not have a strong support system in terms of content or curriculum. Now with the knowledge and experience I have since gained I see engineering education in a different, more valuable, and less overwhelming light. I left teaching when I was still a new teacher; it is important for me to consider that my perspectives on education, teaching, and STEM are all from that of a new teacher as opposed to a well-experienced or even mid-career teacher.

1.5 Theoretical Framework

The best practices for engineering education, which provide a foundation for the professional development approaches recommended through this research, are based in social constructivism (Chong, 2017; Frisque & Chattopadhyay, 2017; Kitto, 2010). Social constructivism is grounded in the view that "learning [does] not simply comprise the assimilation and accommodation of new knowledge by learners; it [is] the process by which learners [are] integrated into a knowledge community" (GSI Teaching and Resource

Center, 2018, para. 2). Social constructivism emphasizes group learning, teamwork, communication, learning as part of a knowledge community, and teacher as facilitator or guide to assist students in constructing knowledge from the world around them (GSI Teaching and Resource Center, 2018). Effective engineering education at the primary level involves teaching students how to think, not what to know. It is often collaborative, exploratory, and hands-on, and it involves interactions with teachers, other learners, and the community and world outside the classroom. The teacher is a facilitator and the student uses existing blocks of knowledge combined with guided exploration, experiences, and interactions to create new knowledge (Honey, 2018).

1.6 Definition of Terms

Delta Greely School District (DGSD) – The Delta Greely School District is a public-school district located in Delta Junction, Alaska. Figure 1 shows the location of DGSD highlighted in red relative to the rest of Alaska. DGSD is made up of an elementary school, grades K-5, with approximately 390 students and 22 teachers; a junior high school, grades 6-8, with approximately 154 students and 13 teachers; and a senior high school, grades 9-12, with approximately 202 students and 15 teachers. The district also has a homeschool program, with approximately 63 students and 1 teacher, and an alternative school, with approximately 29 students and 2 teachers (Alaska Department of Education and Early Development, n.d.b), (Delta Greely School District, n.d.).

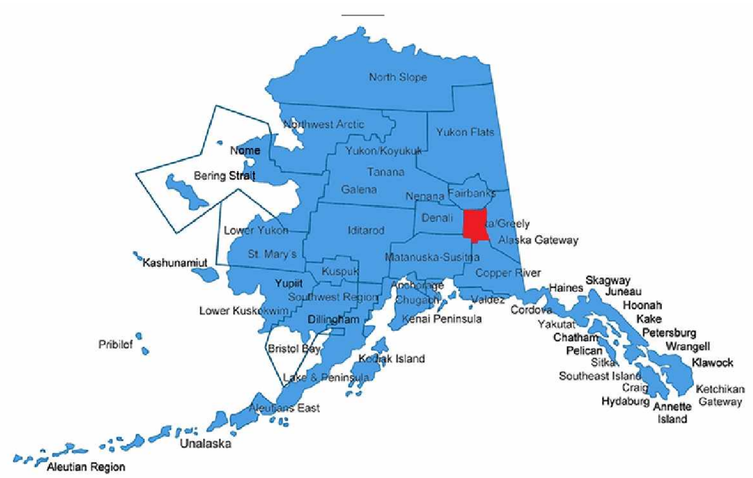

Figure 1. Map of Delta Greely School District (Alaska Department of Education and Early Development, n.d.a)

Elementary Education – For the scope of this research, elementary education is defined as K-5 education in conjunction with the organization of Delta Elementary School.

Engineering Education – Engineering education is the teaching and learning of engineering concepts, problem-solving skills, and habits of mind. According to the Committee on Integrated STEM Education (2014), “There is no formal agreement on what constitutes engineering knowledge and skills at the K-12 level, but there is growing recognition of the importance of the engineering design process and of concepts such as constraints, criteria, optimization, and trade-offs” (p. 19). Engineering education in this research generally includes lessons, projects, and activities that require students to practice the engineering design process or find and create solutions to real-world (or simulated real-world) problems within certain constraints.

High School Education – High school represents grades 9-12 in conjunction with the organization of Delta High School.

Junior High Education – Junior high school represents grades 6-8 in conjunction with the organization of Delta Junior High School.

Professional Development – Professional development means teacher education that is provided to teachers by the district or arranged and funded by the district. The content of the teacher professional development is based in theory but usually emphasizes practical skills that teachers can apply in the classroom. Some common delivery modes for teacher professional development are in-person workshops or classroom sessions, video-teleconference sessions with subject matter experts, and online courses (live or asynchronous).

Secondary Education – Secondary education represents grades 6-12, or Delta Junior High and Delta High School combined. This aligns with the composition of the secondary focus group.

Chapter 2 Literature Review

2.1 Current State of K-12 Engineering Education Literature

Margot and Kettler (2019) conducted a literature review of STEM integration and education. Of the 712 articles initially identified, only 25 met the criteria of being empirical studies focused on preK-12 STEM integration and education published in a scholarly journal in English in the last two decades. Of these 25 articles, the majority focused on middle and high school and only one focused specifically on rural schools. The research on elementary engineering education is already limited, and when the scope is narrowed to rural schools or rural Alaskan schools, the research is non-existent. Many efforts to improve education come from the Lower 48 and while the curriculum in Alaska is not especially unique at a high level, the teaching and learning environments can be drastically different, as can the challenges that rural Alaskan teachers and administrators face. Elementary engineering education is a relatively new area of study; there are organizations dedicating significant time and resources to research and development, but none have focused on small rural schools.

2.2 Engineering Education

Morgan et al. (2012) described engineering education as using well-planned lessons to connect students' classroom knowledge with the world around them. Effective integrated STEM activities allow students to apply math and science in meaningful ways, practice social emotional skills like teamwork and communication, and exercise creativity and problem-solving (Morgan et al., 2012; Thibaut et al., 2018). In the last two decades engineering has gained more traction and has been introduced in classrooms throughout the country as part of state and district science standards such as the Next Generation Science Standards (Douglas et al., 2016). In addition to the engineering being introduced because of new science standards and the curricular changes that those standards ultimately drive, engineering is also being introduced through informal or extracurricular activities such as robotics programs and makerspaces (Anwar, Bascou, Menekse, & Kardgar, 2019; Martin, 2015). Engineering education has also made its way into the technology education curriculum because of the interconnectedness and overlap between the two fields (Strimel & Grubbs, 2016).

In an interview-based study on the state of elementary engineering education in the UK, Clark and Andrews (2010) found three primary issues that currently limit the effectiveness of elementary engineering education: "pedagogic issues, exposure to engineering within the curriculum and children's interest" (Clark & Andrews, 2010, p. 588). The pedagogic issues that limit elementary engineering education stem from limited or no teacher training in engineering education and a resulting lack of teacher confidence, as well as curricular constraints (Clark & Andrews, 2010). Unfortunately, very few teachers have training in engineering education and they often view engineering as a new, unfamiliar, and sometimes scary subject instead of as a creative tool to synthesize and reinforce multiple curricular elements.

Further complicating the issue of professional development and pedagogy, there is limited reliable research on elementary engineering education (Margot & Kettler, 2019; Yoon et al., 2014). Some of this stems from a lack of consistent definition of engineering education (Committee on Integrated STEM Education, 2014; Moore et al., 2014; Thibaut et al., 2018). Measuring the effectiveness of engineering education at the elementary or secondary level, and relatedly measuring the effectiveness of teacher professional development on the topic, requires researchers to measure elementary and secondary student learning gains. While quantifying gains at any level is a significant challenge, there are a variety of additional obstacles when working with elementary students. These obstacles include "language barriers, reading/writing ability, experience with test taking…short attention spans… students' lack of familiarity with standardized tests [and] the construction of assessments that are developmentally appropriate for students" (Yoon et al., 2014, p. 381).

There have certainly been more engineering initiatives in the last few years than there have been in decades past, however most of these initiatives begin in high school when students' attitudes and opinions about engineering have already been developed. DeJarnette (2012) and Malone et al. (2018) discussed the effects of introducing integrated STEM in elementary grades on student preparedness to enter STEM degree programs later on in their education. DeJarnette (2012) discussed specific aspects of integrated STEM, such as hands-on inquiry-based learning, outreach programs that partner engineers and educators, and a focus on process skills, which can all benefit students at a young age. Students who are exposed to these types of opportunities are more likely to enroll in advanced math and science classes in high school and eventually in post-secondary STEM programs. Even for those students who do not go on to pursue STEM careers, integrated STEM education provides them with opportunities to learn and practice problem-solving, communication, and social-emotional skills.

Wilson-Lopez and Gregory (2015) took the benefits of STEM integration one step further and discuss the natural ties and concomitance between engineering and literacy, especially at the elementary level. The authors described a unit that revolved around a problem identified in a biography the students were reading. The students had to critically read the beginning of the biography to identify the problem and basic constraints, learn the history of post-war Germany to understand the context of the problem, and finally read an excerpt of a text on a science topic to better understand possible solutions. Students were participating in an engineering lesson that required them to use not just their critical reading skills but also their knowledge of science and history to successfully engineer a solution to their problem. Many elementary teachers view engineering as a separate discipline that takes time from the "important" (tested) subjects of ELA and math, but professional development and exposure could help teachers see engineering as a compliment to the core subjects and not as a distraction from the curriculum.

2.3 Engineering Education Professional Development for Pre-Service Teachers

Epstein and Miller (2011) discussed possible approaches for improving elementary STEM education at the initial teacher training and licensure stages. The authors discussed the lack of teacher preparation in STEM fields in most elementary teacher training programs in the US and drew attention to the lower standards in US teacher training programs than in those of countries with top-performing students. Most American elementary teacher training programs include only basic math and science, and most licensure requirements do not include standards for math or science performance at all. When new teachers complete pre-service training and enter the classroom, they often have a lack of understanding, and therefore a lack of confidence, in teaching engineering and other STEM fields. Institutional changes to teacher training programs and licensure requirements are beyond the scope of the research questions in this study, however understanding the root causes of the problem provides insight into the most effective ways to improve elementary engineering education.

2.4 Engineering Education Professional Development for In-Service Teachers

Lehman, Kim, and Harris (2014) conducted a study to analyze collaboration between educators and STEM university professors. The researchers created teams of three to four STEM professors and one sixth grade teacher who met periodically to develop engineering lessons. These lessons were ultimately distributed to a selection of elementary teachers for use in the classroom. The researchers discussed the creation of successful communities of practice among the professors and teachers, the effective collaboration and teamwork, and the benefits of having both levels represented in each group. Aside from the teamwork and leadership aspects, professors appreciated the teachers being available to help refocus the group on an appropriate grade level, and the teachers appreciated the professors being available for technical subject matter and ideas. Teachers who were not part of development but who taught the lessons had positive feedback that focused on the ease of use and comprehensiveness of the preplanned lessons and the ability to easily adapt the lessons to the curriculum and standards. Engineers often lack pedagogical skills and an understanding of grade level expectations, and elementary teachers often lack confidence and technical knowledge in engineering. Creating an ongoing partnership or mentorship program could take advantage of the strengths of both groups and lead to a productive relationship that benefits students. Such a partnership could be modified to meet the needs of the specific participants by varying factors such as length, group size, and level of involvement on both sides. An effective program would require an evaluation to determine available resources and identify the most effective ways to use those resources.

Nadelson et al. (2013) summarized a study that was conducted to evaluate the efficacy of a three-day STEM professional development workshop for elementary teachers. Like Epstein and Miller (2011), Nadelson et al. (2013) discussed the lack of math and science in teacher training programs; however, while Epstein and Miller (2011) focused on the need for overhauling pre-service teacher training, Nadelson et al. (2013) evaluated whether in-service teacher professional development is an effective solution. The researchers conducted a three-day professional development workshop for elementary teachers that contained lectures, discussions, hands-on activities, and independent assignments and then analyzed the impact on attitudes, confidence, and teacher efficacy (Nadelson et al., 2013). Feedback concerning the delivery and format of the workshop showed that there was room for improvement and in the future the researchers could refine the delivery to improve results, but overall the researchers concluded that:

> [The] institute content and instruction effectively increased participants' knowledge of STEM, which in turn influenced their confidence, efficacy, and attitudes toward engineering…[The] results provide justification for developing and providing concentrated short-term continuing education to teachers to increase their capacity to teach STEM concepts. (Nadelson et al., 2013, p. 166)

This research suggests yet another facet of professional development that could benefit students by increasing the prevalence of engineering in elementary classrooms. As with the other professional development approaches, there are a variety of delivery formats for short-term workshops. Additional analysis and evaluation would be necessary to design the most effective workshop for a given district or audience.

Ghalia, Carlson, Estrada, Huq, and Ramos (2016) described a professional development approach that combines a six-week summer intensive workshop for teachers with follow-up mentoring support throughout the school year. Surveys were conducted at the end of the program and teachers' self-reported learning gains and the impacts on their abilities as educators were extremely positive across the board. One important consideration when interpreting the survey results from this study is that teachers went through a significant application process where they were evaluated based on their professional backgrounds, interest in engineering, and finally their performance in an interview. This resulted in three cohorts of teachers with a pre-existing interest in engineering education and a motivation to introduce and follow through with engineering education in the classroom. One other consideration when looking at this professional development approach is the amount of resources it requires; teachers devoted six weeks during the summer in addition to time periodically throughout the school year, and program management dedicated more than six weeks of full-time staff in addition to the mentoring resources required throughout the school year. While this appears to be an extremely effective method of professional development, it does stand apart from many others in that it is a full professional development program as opposed to one piece of a district's overall professional development.

2.5 Elements of Effective Teacher Professional Development

Regardless of the delivery mode for professional development, several key qualities of effective professional development have been identified:

1. Alignment among school goals, state and district standards and assessments (including formative teacher evaluation), and professional learning activities
2. Focus on core content and modeling of teaching strategies for the content
3. Inclusion of opportunities for active learning of new teaching strategies
4. Provision of opportunities for collaboration among teachers
5. Inclusion of embedded follow-up and continuous feedback (Douglas et al., 2016, p. 312)

Effective professional development focuses on active teaching and student learning, observation, reflection, and assessment. Effective PD engages teachers in active learning of the material, models effective teaching strategies, and provides teachers with immediately useful information such as pedagogical strategies and content knowledge (Archibald et al., 2011; Darling-Hammond & Richardson, 2009; Porter, West, Kajfez, Malone, & Irving, 2019). Professional development should also be delivered as part of a coherent program or strategy, and not as a one-off workshop; there should be a connection between school goals, curriculum, standards, and professional development content (Darling-Hammond & Richardson, 2009). Yoon et al. (2007) found that the ideal duration for a professional development program is 6-12 months and consists of 30-100 hours of professional development.

There need to be opportunities for collaboration both during and outside of the professional development and teachers need ongoing support throughout the professional development program (Darling-Hammond & Richardson, 2009). Three key factors that affect the long-term implementation of engineering education beyond the professional development event(s) are the level of administrative support not only at the district level but also at the school level (principal), the level of peer support among teacher colleagues, and how well lessons align with district curriculum and standards (Douglas et al., 2016). These factors are as perceived by the teachers, not by an objective third-party scale, and they stem from "teachers' existing attitudes, beliefs, and knowledge" (Douglas et al., 2016, p. 312). Yasar, Baker, Robinson-Kurpius, Krause, and Roberts (2006) also stressed the importance of administrator support and buy-in and the ability to infuse engineering into the existing curriculum.

2.6 Obstacles to Engineering Education

There are several common obstacles that prevent teachers from teaching engineering in the classroom. One of the most common obstacles is teachers' lack of content knowledge and therefore teachers' lack of confidence in teaching engineering (Hsu, Purzer, & Cardella, 2011; Thibaut et al., 2018). Most teachers do not receive pre-service training on engineering education (Epstein & Miller, 2011) and many teachers cite a lack of in-service training on engineering education as an obstacle to teaching the subject (Clark & Andrews, 2010; Hsu et al., 2011). Related to teacher training and preparation, teachers have also reported that pedagogical challenges limit the presence of engineering education in the classroom (Porter et al., 2019). There are certain qualities unique to engineering education, such as accepting and persevering through failure, solving open-ended problems, and thinking creatively and independently, that can be difficult to teach.

Other common obstacles limiting the presence of engineering education in the classroom are lack of instructional and planning time and lack of resources (Sedberry, 2014). Instructional time is often limited because of the need to teach the core subjects, complete the curriculum, and teach to standardized tests (Porter et al., 2019). Planning time is often a challenge because teachers lack the time to create new engineering projects or to identify appropriate engineering lesson planning resources (Porter et al., 2019). Teachers also commonly report that a lack of resources limits engineering education in the classroom, specifically materials or the money to procure those materials (Porter et al., 2019; Sedberry, 2014).

Chapter 3 Research Methods

3.1 Research Design

This research uses a mixed methods sequential explanatory design consisting of quantitative and qualitative data collected through surveys and focus groups. Sequential explanatory research gathers quantitative data and then uses follow-on qualitative research to explain and interpret the quantitative findings (Creswell, 2014). This study explores complex questions with a small population where the results are not intended to be generalized. These attributes are best addressed through qualitative research, especially considering the limited body of existing research on engineering education professional development (Creswell, 2014). Development of the qualitative focus group instrument required a foundation of data specific to the Delta Greely School District if the results were to be useful and meaningful. Since there is currently no research on the teachers or administrators within DGSD, and effectively no research on engineering education in rural schools, it was necessary to gather baseline data of DGSD teachers and administrators through quantitative research methods (survey and archival data) prior to conducting focus group interviews. Themes from the existing literature on engineering education were tested for their applicability to DGSD using a quantitative survey and those results were then used to inform the development of focus group questions (Creswell, 2014). The survey data was expected to provide meaningful results, however the quantitative nature of the instrument could hide complexities and did not offer accurate interpretation of some of the human elements (Creswell, 2014). The follow up focus group questions provided the opportunity to further explore these elements and to create a more complete picture from the data set.

3.2 Participants

Participants for this research were all Delta Elementary School, Delta Junior High, and Delta High School teachers (N=50) and administrators (N=5) from the Delta Greely School District (DGSD). During the 2018-2019 school year the district employed 50 teachers and 3 principals in these 3 schools, as well as 2 district administrators (superintendent and assistant superintendent) (Alaska Department of Education and Early Development, n.d.b), (Delta Greely School District, n.d.). The homeschool program and alternative school were excluded from this study.

3.3 Surveys

The surveys gathered data on participants' attitudes toward engineering and engineering education, their confidence in their abilities to teach engineering, their interest in engineering education professional development, and their preferences for professional development. Survey data was analyzed and used to develop focus group questions. Data from the focus groups was analyzed along with survey data to address research questions and create recommendations for the district. Institutional Review Board (IRB) approval was received from the UAF IRB prior to collecting data (See Appendix A and Appendix B). District approval was also obtained from the Delta Greely School District Superintendent (see Appendix C).

There were two versions of the survey, one for teachers (see Appendix D) and one for administrators (see Appendix E). The teacher survey consisted of 38 Likert questions on a scale of 1-5, 11 open-ended questions, and 9 demographic questions. The administrator survey consisted of 41 Likert questions on a scale of 1-5, 6 open-ended questions, and 9 demographic questions.

3.3.1 Survey Development

The surveys were derived from two existing surveys: the "Teacher Efficacy and Attitudes Toward STEM Survey" (Friday Institute for Educational Innovation, 2012), produced by North Carolina State University, and a second survey designed at Arizona State University "to assess K-12 teachers' perceptions of engineers and familiarity with teaching design, engineering, and technology" (Yasar et al., 2006, p. 205). The relevant questions from these two surveys were combined and then revised to tailor them to the specific research questions in this study and to ensure they were appropriate specifically for the Delta-Greely School District. Questions were grouped into categories to ensure that all research questions were addressed, extraneous questions were removed, and additional questions were added where necessary to create adequate scales for each category. The survey questions were piloted on three individuals to increase validity and reliability. 35 of the questions were drawn from the two referenced surveys, which amounted to 60% of all questions on the teacher surveys and 63% of all questions on the administrator surveys. An attempt was made to keep the surveys as short as possible to maximize participation, especially considering the small population, while still providing insight into the research questions and key ideas.

The survey was designed to gauge attitudes toward engineering education, barriers to integrating engineering education, and interest in engineering education and professional development. To measure these areas several scales were developed. Scales are a set of related questions that measure a specific construct, such as familiarity with engineering education. See Table 1 for a list of scales and major ideas. Teacher and administrator questions are correlated in Table 1 (the teacher question and the related administrator question are located in the same row); where there is an entry in only one column (i.e., there is an entry in the administrator column but there is no corresponding entry in the same row in the teacher column), that idea did not apply to both groups.

Table 1

Survey Scales and Major Ideas

Teacher Surveys	Administrator Surveys
To understand how familiar teachers are with engineering professions	To understand how familiar administrators are with engineering professions
To understand how familiar teachers are with engineering education	To understand how familiar administrators are with engineering education
To understand whether teachers already incorporate engineering into the classroom	
To understand teachers' attitudes toward engineering	To understand administrators' attitudes toward engineering
To understand the importance of integrating engineering at different grade bands	To understand the importance of integrating engineering at different grade bands
To understand how teachers value certain elements of effective engineering education - teamwork, problem solving, and communication	To understand how administrators value certain elements of effective engineering education - teamwork, problem solving, and communication
	To understand how confident administrators are in teachers' ability to teach engineering
	To understand how confident administrators are in their teachers' ability to teach engineering compared to their teachers' ability to teach math and science
To understand how confident teachers are in their ability to teach engineering	To understand how confident administrators are in their ability to contribute to engineering education
To understand how confident teachers are in their ability to teach engineering compared to their ability to teach math and science	To understand how confident administrators are in their ability to contribute to engineering education compared to their ability to contribute to math and science education
To gauge teachers' interest in engineering education professional development overall	To gauge administrators' interest in engineering education professional development overall
To gauge teachers' interest in specific professional development delivery methods - in-service, VTC training, PD delivered as a college course, semester-long or year-long mentor program, collaboration with fellow teachers, other	To gauge administrators' interest in specific professional development delivery methods - in-service, VTC training, PD delivered as a college course, semester-long or year-long mentor program, collaboration with fellow teachers, other
To gauge teachers' awareness of existing engineering education professional development	
To understand barriers to integrating engineering in the classroom	To understand barriers to integrating engineering in the classroom
To understand freedom, ability, and frequency of integrating in the classroom	To understand freedom, ability, and frequency of integrating in the classroom
To gauge teachers' interest in specific engineering disciplines	

3.3.2 Survey Implementation

The method of dissemination was paper. The surveys were expected to take approximately 20 minutes to complete. Surveys were distributed during a district in-service and participants could return them at any time over the next week. The surveys were distributed to all teachers and administrators at a district in-service to maximize the participation rate.

3.3.3 Survey Participants

The survey was distributed to 50 teachers and 5 administrators at all grade levels. Participants were asked their grade level and school in the survey so that responses could be filtered and data analyzed by grade level. This allowed for a larger response rate where the K-12 perspective was desirable without losing the demographic-specific perspective where necessary. Ultimately 21 teachers responded, representing a 42% response rate for teachers. Three administrators responded, representing a 60% response rate for administrators as a whole. There was a 100% response rate for principals and a 0% response rate for district-level administrators. See Table 2 for a summary of sample sizes and response rates by demographic. The number of responses was considered adequate to continue with development of focus group questions, especially considering the small population.

Table 2

Survey Response Rates by Demographic

Demographic	Number of responses	Response Rate
Elementary Teachers (*N*=22)	8	36%
Junior High Teachers (*N*=13)	8*	62%
High School Teachers (*N*=15)	6*	40%
All Teachers (*N*=50)	21	42%
Administrators (*N*=5)	3	60%

Note. The combined junior high/high school teacher was counted in both the junior high and high school demographic groups when responses were broken out by demographic, which is why the number of participants in each group does not add up to the total number of participants

3.3.4 Survey Analysis

Surveys were analyzed in Excel using descriptive statistics. All Likert questions were analyzed using mean and standard deviation. There were not enough responses to measure internal consistency using Cronbach's alpha (Bujang, Omar, & Baharum, 2018). Likert questions were grouped by topic and were analyzed in demographic groups (elementary teachers, junior high teachers, high school teachers, and administrators) and as a whole. Likert responses were assigned numerical values and Microsoft Excel was used to aid in organizing and managing data. Open-ended questions were compiled and coded and themes were identified and reported. The data gathered from the surveys helped to identify areas of interest requiring further exploration or clarification and the original focus group questions were modified based on this data.

3.4 Focus Groups

The purpose of the focus groups was to gain additional insight into the nuances of teacher and administrator attitudes, perceptions, and needs, which are difficult to quantify or fully grasp from survey data. Focus group questions (see Appendix F) were based on the research questions and were finalized by survey results.

3.4.1 Focus Group Development

The first research question, what are teachers' and administrators' current attitudes toward engineering in the classroom, was addressed relatively well through the survey questions. More nuanced information on this subject was unlikely to be gained through a direct question (for example, "What are your attitudes toward engineering in the classroom?") so a specific question was not developed to address this point. Instead, more information would best be obtained from a thorough analysis of the responses to focus group questions on specific engineering education topics. For this reason, the focus group questions were developed primarily around the second two research questions ("What prevents teachers from teaching engineering and administrators from supporting engineering?" and "What professional development methods would motivate teachers to include engineering education in the classroom and suit the district's resources and needs?").

From survey data, elementary teachers are most comfortable with and open to engineering, and elementary teachers also currently teach more engineering than other grade bands. Interestingly though, teachers and administrators at all grade levels believe it is more important to integrate engineering into the 6-12 curriculum than to integrate engineering into the K-5 curriculum. To further explore this idea, one question was developed to learn more about participants' opinions on the place of engineering education in the K-12 spectrum. Two questions were developed surrounding professional development to understand both content and delivery modes. One question aims to better understand what specific areas of engineering education teachers are least comfortable with so that the areas of greatest concern can be addressed in any professional development recommendations. The other question explores professional development delivery. Elementary teachers were asked about the best delivery modes as well as a need for long-term support to assist in lasting change and administrators were asked about the needs and priorities of the district with respect to professional development. Participants were also asked what barriers exist to integrating more engineering and what could be done to assist teachers in integrating more engineering.

3.4.2 Focus Group Implementation

There were distinct differences between survey results for each grade band but especially between elementary and junior high teachers. It was important to acknowledge and further explore these differences and grouping these two demographics together for a focus group would have hidden those differences. The decision was also made to conduct a separate group with administrators, regardless of grade band, for two reasons. First, the needs, priorities, and resources of the district are often different than those of the teachers, yet they are equally as important when planning and implementing professional development. Second, administrators introduce a district-wide and K-12 perspective; while a teacher may be focused on her students today and this year, an administrator is in a better position to consider the district's long-term educational plans for students. Focus groups were designed to last no longer than one hour and ended up ranging from 20 to 60 minutes. The focus groups were semi-structured and the researcher moderated all three focus groups.

3.4.3 Focus Group Participants

All 50 teachers and 5 administrators were invited to participate in the focus groups. The target size for focus groups was 3-5 participants. Three focus groups were conducted: elementary teachers, junior high and high school teachers combined (secondary), and administrators. Multiple administrators volunteered to participate, however due to unexpected events only 1 administrator attended. Therefore, the administrator focus group became an interview. There were 2 teacher participants in the secondary focus group, both of whom taught at the junior high level. The elementary focus group was the largest, with 5 teachers participating from across the elementary grade band. Since there were no more than 5 volunteers for each focus group there was no need to screen participants based on certain qualities or traits and no volunteers were turned away.

3.4.4 Focus Group Analysis

Focus groups were recorded and transcribed verbatim by the researcher. Data was coded and analyzed through a combination of a priori codes and emergent themes using Microsoft Word and Microsoft Excel. A more detailed analysis was not warranted due to the small number of focus groups and participants. The results of the focus group analysis were used along with the survey data to create the professional development recommendations.

3.5 Confidentiality

To minimize the likelihood that individual respondents could be identified, all personal identifiers were removed and data was aggregated prior to analysis. Where a certain demographic had a sample size of 1, the data was not discussed down to that demographic level. For example, the sample sizes for K-5 administrators, 6-8 administrators, and 9-12 administrators were each n=1. For this reason, administrator data was not analyzed by grade level; instead it was analyzed for the demographic of "administrators" as a whole (n=3). Further, all specific identifiers used in quotes have been replaced with generic identifiers. For example, the quote "My first graders…" would be replaced with "My [grade level students] …"

3.6 Limitations

Despite the benefits, the current study and resulting conclusions have some limitations. The study was conducted in one specific Alaska school district (DGSD) and together with the small sample size the findings may not be generalizable. Additionally, focus group participants volunteered to participate and may not be a representative sample. Voluntary response bias may be present. The small sample size also affects the reliability of the survey results and leads to a higher variability. Further, the researcher moderated the focus group discussions. Great care was taken to analyze and interpret the data without bias, however researcher bias or unintentional influence of results could be present.

The qualitative nature of the focus groups leads to unique, individual results that cannot be generalized to other teachers. It is also worth noting that any one professional development approach may not support the personal learning styles of thirty or more teachers. An effort was made to develop a professional development model that employs varied components and techniques to better serve a diverse group of teachers with a variety of different learning styles.

Some research outcomes focus on elementary education and while there was a 36% survey response rate among elementary teachers that is still only eight respondents. Further, there were five participants in the elementary focus group, which is desirable, but all five of the participants had previously taken a professional development course through the University of Alaska Fairbanks entitled "Engineering Education in the K-8 Classroom", which was taught by the researcher.

Chapter 4 Results and Discussion

4.1 Overarching Themes

The major themes identified in analysis of the focus group data align with the research questions and the scales used in survey analysis. See Table 3 for a summary of focus group themes.

Table 3

Focus Group Themes and Received Responses

Theme	Received responses
Attitudes toward engineering education	• Many (but not all) teachers would be willing to try it • Engineering is engaging and associated with positive experiences • Engineering has strengths that science doesn't offer
Obstacles preventing or limiting engineering education	• Time • Materials, especially in a rural area • Obstacles in students' home lives • Space to build and store projects • Already too many curricular priorities, limited staff • Small school, logistics • Knowledge
Enablers for more engineering education	• Professional development • Engineering kits
Professional development delivery	• Professional development integrated with resources • Semester-long class • Presentation at district in-service
Professional development content	• Standards • Basic knowledge and pedagogy for some teachers • How to incorporate engineering into the existing curriculum • Interdisciplinary ideas • Lesson ideas
Opportunities for engineering education	• Junior high rotating electives • Integrating with or replacing engineering activities in current science curriculum • Extracurricular events like science fair • Clubs
Science grant, science curriculum	• Generally positive views toward science grant and new curriculum • More positive responses from administrators • Teachers found the grant requirements frustrating BUT the benefits were worth it • The new science curriculum must be considered in planning any professional development, engineering kits/materials, etc.

4.2 Teachers' and Administrators' Current Attitudes Toward Engineering Education

Overall, the attitudes of the participants toward engineering education are very positive and six of the seven teacher focus group participants already teach engineering in their classrooms. While there are many obstacles and challenges identified, 95% of teacher survey respondents and 67% of administrator survey respondents believe it is important for students to understand the use and impacts of engineering. 95% of teacher participants believe more engineering education would be beneficial to students and 81% expressed an interest in either introducing engineering in their classrooms or, for those who already teach engineering, improving their engineering education techniques and practices. Teacher focus group participants expressed enthusiasm toward engineering projects and lessons because of increased student engagement, opportunities for social emotional learning, and the critical thinking and outside-the-box aspects of engineering education. One elementary teacher said, "every time I do an engineering project they just love it and I think, 'why don't you do this more often, look how well they're working together.'" The elementary teachers also discussed how engaged their students are during engineering lessons as opposed to during science lessons. The new science curriculum relies heavily on completing a workbook and elementary students, especially those in the younger grades, are not used to taking notes or completing workbooks like those. A secondary teacher said, "I like the [engineering design] process because it's so open-ended, which is very different than a typical lab that you would do in a science class." None of the teachers downplayed the importance of science (on the contrary all felt that science is an important subject), but there was some discussion surrounding the educational benefits of the engineering design process that are not present in typical science projects and lessons.

One teacher focus group participant was more hesitant about taking the time to teach engineering education. She expressed not feeling comfortable with engineering or engineering education and stressed a lack of time and a focus on other priorities. This teacher works with special education students and does not have elective time or free time with her students. The conversation became more spirited when she and another teacher participant started discussing one particular student who is in the special education program and has exceled at several engineering or engineering-like lessons outside of his special education intensive time. The special education teacher appeared interested in the opportunities that engineering education can offer her students if done at the right level and in the right way but she felt that the best way for her students to have those experiences would be in their regular classrooms, as opposed to during the special education/intensive time where she works with them.

4.2.1 Importance of Engineering Education

In almost every survey category elementary teachers are more familiar with engineering and engineering education (average=3.4, SD=1.1) than junior high (average=2.0, SD=1.2) and high school (average=2.7, SD=1.4) teachers and administrators (average=2.0, SD=1.1). Elementary teachers are more open to engineering and engineering education than all other demographics, with 90% of elementary teachers already teaching engineering and only 30% of secondary teachers already teaching engineering. All demographics have overall positive attitudes toward engineering in the K-5 curriculum (average=3.8, SD=1.0), the 6-8 curriculum (average=4.2, SD=0.9), and the 9-12 curriculum (average=4.4, SD=0.8) and all demographics view engineering education as somewhat important to very important, depending on the grade bands in which engineering would be implemented. Specifically, teachers and administrators believe it is important that students understand the uses of engineering, the impacts of engineering, the relationship between science and engineering, and the engineering design process. Administrators agree that they are familiar with engineering professions, but they disagree when asked if they are familiar with engineering education. See Table 4 for a summary of responses concerning the importance of engineering in the classroom.

Table 4

The Importance of Engineering in the Classroom

Survey Scale	Elementary Teachers (*n* =8)		Junior High Teachers (*n* =8)		High School Teachers (*n* =6)		All Teachers (*n* =21)		Admins (*n* =3)	
	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
The importance of integrating engineering into the K-5 curriculum	3.9	1.0	3.5	1.1	4.0	1.1	3.8	1.0	4.3	0.6
The importance of integrating engineering into the 6-8 curriculum	4.5	0.5	3.8	1.2	4.3	0.8	4.2	0.9	4.3	0.6
The importance of integrating engineering into the 9-12 curriculum	4.8	0.5	4.1	1.0	4.2	0.8	4.4	0.8	4.7	0.6
Respondent familiarity with engineering professions	3.8	0.7	3.4	1.1	3.6	1.0	3.6	0.9	3.7	0.8
Respondent familiarity with engineering education	3.4	1.1	2.0	1.2	2.7	1.4	2.8	1.4	2.0	1.1
Respondent attitudes toward engineering	4.4	0.5	3.8	1.1	4.3	0.6	4.2	0.8	3.8	1.1

Note. Responses are on a scale of 1-5 where 1 is Not at all Important or Strongly Disagree and 5 is Extremely Important or Strongly Agree

4.2.2 Teacher and Administrator Confidence

When asked whether teachers are confident in their own abilities to teach engineering, their response as a group is generally neutral (average=2.9, SD=1.5). 52% of teachers report being more comfortable teaching engineering and 48% of teachers report being more uncomfortable teaching engineering. See Table 5 for a breakdown by grade band. Overall, administrators responded slightly positive (average=3.2, SD=0.9) regarding the statement that they are confident in their teachers' abilities to teach engineering. As a group, administrators are more confident in their teachers than the teachers are in themselves. Administrators are also more confident in their teachers' abilities to integrate engineering (average=3.2, SD=0.9) than they are in their own abilities to support engineering education (average=2.8, SD=1.0), but overall, they are generally neutral on both statements. 33% of administrators report being more comfortable in their ability to support engineering, 33% report being neutral, and 33% report being more uncomfortable in their ability to support engineering. See Table 5 for an overview of confidence in teachers' abilities and Table 6 for an overview of confidence in administrators' abilities. The administrator column in Table 5 represents administrators' confidence in teachers' abilities to teach engineering education, whereas Table 6 represents administrators' confidence in their own abilities to contribute to engineering education.

Additional questions on confidence were asked to compare teacher and administrator confidence in teaching engineering to teacher and administrator confidence in teaching math and science. Elementary and junior high school teachers are most comfortable with math (average=4.3 and SD=0.7, average=3.9 and SD=1.8, respectively) and high school teachers are most comfortable with science (average=4.3, SD=0.8).

Administrators are equally confident in their teachers' abilities to teach science (average=4.3, SD=0.6) and math (average=4.3, SD=0.6) and are neutral regarding their teachers' abilities to teach engineering (average=3.3, SD=0.6). In almost all content areas and all grade levels, administrators are again more confident in their teachers than the teachers are in themselves. Administrators are most confident in their own ability to contribute to effective math education (average=4.0, SD=0.0). All teachers and administrators are least confident in their own abilities to teach or contribute to effective engineering education. Due to the small sample sizes it is possible that results for junior high and high school teachers and administrators are skewed based on the content areas of those who responded. For example, several of the junior high teachers reported teaching math but none reported teaching science. This could explain why junior high teachers on average reported being more confident in their abilities to teach math than their abilities to teach science. See Table 5 and Table 6 for a breakdown of responses.

Table 5

Teacher and Administrator Confidence in Teachers' Ability to Teach Engineering

Survey Scale	Elementary Teachers (*n* =8)		Junior High Teachers (*n* =8)		High School Teachers (*n* =6)		All Teachers (*n* =21)		Admins (*n* =3)	
	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
Respondent confidence in teachers' ability to teach engineering	3.4	1.2	2.3	1.4	2.8	1.8	2.9	1.5	3.2	0.9
Respondent confidence in teachers' ability to teach **engineering** compared to math and science	3.6	1.1	2.8	1.3	3.3	1.5	3.3	1.0	3.3	0.6
Respondent confidence in teachers' ability to teach **science** compared to math and engineering	3.6	0.9	3.6	1.2	4.3	0.8	3.8	1.0	4.3	0.6
Respondent confidence in teachers' ability to teach **math** compared to science and engineering	4.3	0.7	3.9	1.8	3.7	1.8	3.9	1.4	4.3	0.6

Note. Responses are on a scale of 1-5 where 1 is Strongly Disagree and 5 is Strongly Agree

Table 6

Administrator Confidence in Administrators' Ability to Contribute to Engineering Education

Survey Scale	Administrators (*n* =3)	
	Avg	SD
Respondent confidence in own ability to contribute to engineering education	2.8	1.0
Respondent confidence in own ability to contribute to **engineering education** compared to math and science	3.0	1.0
Respondent confidence in own ability to contribute to **science education** compared to math and engineering	3.3	1.2
Respondent confidence in own ability to contribute to **math education** compared to science and engineering	4.0	0.0

Note. Responses are on a scale of 1-5 where 1 is Strongly Disagree and 5 is Strongly Agree

There is a correlation between how confident teachers are in teaching engineering and how often teachers integrate engineering. Causation cannot be derived from the data, but it does show that the teachers who are most confident in their abilities to teach engineering (elementary teachers) are also the teachers who integrate engineering most often. 90% of elementary teachers currently teach engineering in their classrooms, compared to only 30% of both junior high and high school teachers.

Teachers were asked in an open-ended question to list the types of engineering activities they currently teach. In elementary teachers' responses there was an emphasis on integrated STEM and the engineering design process. Elementary teachers' responses were primarily broad conceptual descriptions of engineering design activities and engineering activities integrated into the science curriculum, for example "basic engineering design process activities", "STEM activities within my science curriculum that I teach", and "simple problems/tasks for students to solve where they're given constraints and requirements." Junior high and high school teachers reported including engineering elements ranging from the "classic egg drop project" to AutoCAD and 3D printing. Responses from junior high and high school teachers were limited, however, and there were not enough responses from these grade bands to draw any conclusions on the types of engineering activities teachers prefer or emphasize.

4.2.3 Elements of Engineering Education

Respondents were asked about the priority they place on a variety of skills. These skills were listed randomly in the survey but were grouped during analysis into three main themes: teamwork, problem solving, and communication. These are three areas of focus in effective engineering education and the questions were asked to better understand how highly teachers value certain elements of effective engineering education. There were two motivations for this group of questions. First, some teachers might place an emphasis on these skills but not on engineering education because they do not realize that these skills are key aspects of engineering education. Second, these questions could facilitate more informed decisions regarding the types of engineering activities and lessons teachers might find beneficial. Teacher and administrator responses are summarized in Table 7. Teachers and administrators at all grade bands place the highest priority on problem solving skills (teacher average=4.3, SD=0.8; administrator average=4.2, SD=0.6) and a high priority on teamwork skills (teacher average=3.9, SD=1.0; administrator average=3.9, SD=0.9). Teachers and administrators place a medium-high priority on communication skills (teacher average=3.3, SD=1.1; administrator average=3.4, SD=1.1), depending on the grade band. Engineering education professional development or materials recommended in this report should clearly place an emphasis on problem solving skills. This will serve two purposes: first, it will raise teachers' interest and investment in engineering education, and second, it will help teachers achieve their educational goals for their students.

Table 7

The Importance of Certain Elements of Effective Engineering Education

Element	Elementary Teachers (*n* =8)		Junior High Teachers (*n* =8)		High School Teachers (*n* =6)		All Teachers (*n* =21)		Admins (*n* =3)	
	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
Teamwork	4.2	0.8	3.6	1.1	4.1	0.9	3.9	1.0	3.9	0.9
Problem solving	4.2	0.7	4.3	0.8	4.4	0.8	4.3	0.8	4.2	0.6
Communication	3.2	0.9	3.1	1.2	3.7	1.0	3.3	1.1	3.4	1.1

Note. Responses are on a scale of 1-5 where 1 is Not a Priority, 3 is Medium Priority, and 5 is Essential

4.2.4 Opportunities for Engineering Education

Several opportunities for more engineering education were identified by focus group participants. At the elementary and secondary levels, several teachers discussed the science fair. Students in this year's elementary science fair had the option to do an engineering project and teachers described the engineering projects as the best ones in terms of student interest, student engagement, and learning outcomes. Teachers at both levels explained that with traditional science fair experiments "you can just go to the web and…here's a science fair in a kit, and then it's 'how many volcanoes are we going to see this year?'" There are opportunities to incorporate more engineering into the science fair, and there are also opportunities to have a similar event separate from the science fair that would focus on engineering for those students who are interested.

Several focus group participants discussed the opportunity for engineering-type enrichment classes at the secondary level. The junior high offers 6-week enrichment classes on a variety of topics based on student and teacher interest. At first the participants did not believe there were any engineering classes currently offered, but after some thought a few participants identified different classes that do have elements of engineering education, even though they do not have "engineering" in the class title (i.e., 3D computer-aided design (CAD) printing). There could be more engineering enrichment classes if teachers have the interest, knowledge, and resources, and if students have a desire to participate. Additionally, secondary teachers and administrators identified the opportunity for teachers to work together on interdisciplinary projects or lessons. This collaboration would require some coordination and possibly training and resources, but the secondary teachers are generally open to working together and trying new things, and interdisciplinary teaching could be an opportunity to bring engineering into the classroom more heavily at the secondary level.

Another opportunity identified by a secondary teacher is the plethora of clubs and extracurricular activities that have an engineering focus. She identified programs like FIRST Robotics (currently at the elementary and junior high schools), Junior Engineering Technical Society (JETS, now part of the Technology Student Association), Project Lead the Way, and Odyssey of the Mind. The teacher participant did point out some of the resource and logistics challenges of clubs and after school programs, but she said

> These kinds of experiences that are worthwhile, of course they cost some money to have a program but it's all these things that could make a better, more well-rounded experience. To add in engineering would address a whole lot of these things because it's not just science and it's not just math. There's so much more that could come from that.

One other extracurricular suggested is "Science Saturdays", a weekend event open to the community where children and possibly their families could participate in short engineering activities. This event would require support from parents or guardians, but it would be an opportunity for those students and community members who are interested. If the activities are self-contained (completed in one day) then it would not require a long-term commitment from children or their families; instead they could attend as they are able to and interested.

4.3 Obstacles Limiting Engineering Education in the Classroom

Teachers report three primary barriers to integrating engineering education or integrating more engineering education in the classroom in both surveys and focus groups. These three barriers are time; training, knowledge, curricular support, and expertise; and money, materials, and equipment. See Figure 2 for a summary of obstacles identified in open-ended survey responses and their frequencies. See Figure 3 for a summary of obstacles identified in focus group discussions and their frequencies. Elementary teachers place a strong emphasis on time and materials, whereas junior high and high school teachers' responses are fairly evenly distributed. One high school teacher provided a response that did not fit into the categorization and was reported as "Other" in Figure 2. This response was "student preparedness, work ethic, attendance, and perseverance." Administrator responses to open-ended survey questions share common themes with teacher responses, however administrator responses are more overarching and are difficult to summarize because of the small sample size. Administrator responses when asked about the barriers to implementing effective engineering education in their schools were: "we are a small school with limited staff and resources", "supplies and space to create projects", and "space, materials, money, training, staffing."

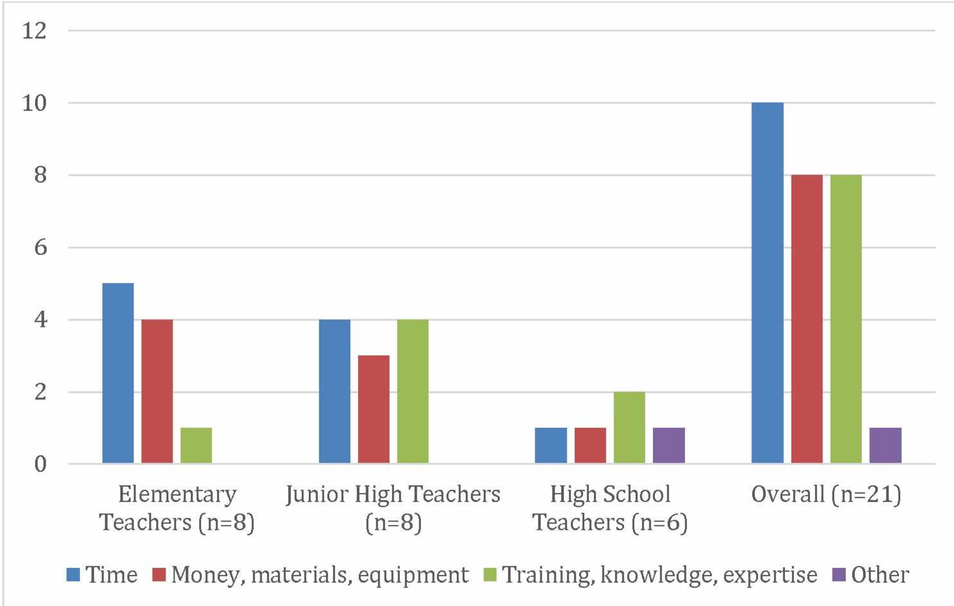

Figure 2. Obstacles and their Frequencies as Reported in Surveys

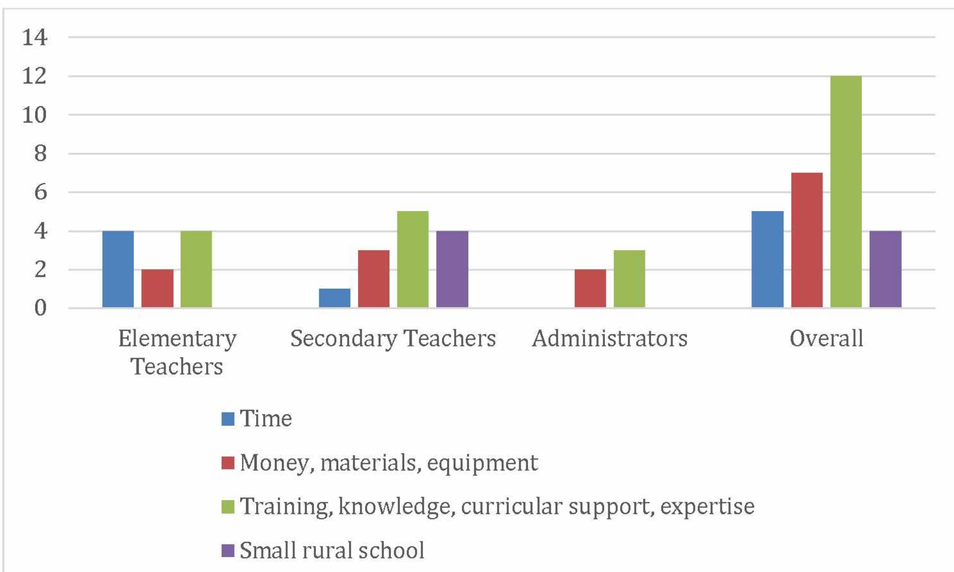

Figure 3. Obstacles and their Frequencies as Reported in Focus Groups

4.3.1 Time

Time was expected to be a significant obstacle preventing teachers from either exploring engineering education or incorporating more engineering education into their classrooms and that was found to be true in all focus groups. As expected, there are two facets to the challenge of time. First is that teachers who are unfamiliar with engineering education may be hesitant to learn more about it or try it in the classroom because they believe they do not have the time to jump in and learn about something new. Second is that teachers do not have the time to integrate engineering education into an already packed curriculum. One secondary participant said,

> I think we have people generally who are agreeable to trying new things. It's just harder to sell it for some people because they're like, well is this going to add anything to my day? Is this going to take 30 extra minutes, because I don't have 30 extra minutes.

The elementary focus group participants also discussed the issue of time, with one teacher noting that it is often easier for the younger grades to find time to incorporate things like engineering than it is for the older grades. The first participant said, "I think some of our colleagues, and I was too, get really worried about how much time it's going to take in the room plus how much prep time it's going to take." A second participant responded,

> And it really does take a lot of time. It really does, that you guys [teachers in higher grades] don't often have. We [teachers in lower grades] do, but you guys don't have so much time to play as we do.

4.3.2 Money, Materials, and Equipment

The second major obstacle identified by focus group participants is a lack of resources, which was also expected. Engineering generally requires more materials than other subjects – it does not need to be extremely resource-intensive, but it does often require more resources than the average, everyday core subject lesson. This obstacle overlaps with some of the challenges faced by a small rural school and is discussed in more detail with respect to small school challenges in the following paragraphs. From an administrative perspective, this is arguably one of the most tumultuous times in recent history with respect to funding for staffing, professional development, materials, etc. As the administrator stated,

> I have no budget at this moment. None. Zero. Because of the way the budget is with the State of Alaska…So it'd be, where do I get the supplies for anything like this or even the teaching materials for any of this stuff? I can't purchase that at the moment.

The elementary teacher participants discussed durable materials and resources as being available currently because of the science grant, but not consumable materials. They discussed their ability to acquire the big resources needed to enhance science education (which includes engineering) – items such as technology and curricular materials. On a smaller scale though, with consumable materials, they described a typical acquisition process. Elementary teachers do have access to a small closet with consumables, for example popsicle sticks, but for any materials not in the closet they purchase them out of their own pocket and then request reimbursement for qualified expenses.

One unexpected but heavily discussed obstacle is the logistical challenges faced by a small rural school. Teachers and administrators at all levels discussed obstacles that in some way stem from being a small school far from a major city. Delta Greely School District serves students from Delta Junction, Big Delta, Deltana, and Fort Greely (Alaska Division of Elections, 1984), which had a combined total population of approximately 4,339 people at the 2010 census (U.S. Census Bureau, 2012). With approximately 750 students in the district, or about 50 students per graduating class, one challenge secondary teachers identified is the limited number of courses they can offer. Because of the small student body and the corresponding small number of staff, DGSD is not able to offer twenty or thirty different electives each year; focusing on engineering may require shifting resources away from another elective or priority. Adding a new focus might also require a teacher to wear an additional "hat", as described by one focus group participant, and many teachers are already wearing multiple hats that relate to their content areas, grade levels, or teaching certifications.

Teachers discussed similar logistical challenges limiting the presence of engineering clubs and extracurricular activities, which are a common avenue for engineering exposure in many districts. Starting a new club would require a staff member to take on an additional duty, likely without compensation because it would be outside of the contract day, and would also require enough interest from a small student body. Further, there is no after school bus system so for students who live beyond walking distance, which is a significant portion since the district covers a relatively large geographical area, they may not be able to participate because of a lack of transportation. This obstacle extends especially to the high school. Currently there are very limited engineering opportunities at the high school and the challenges with staffing, resources, and student population are not facilitating more engineering opportunities there. It can be difficult to engage elementary and junior high students in engineering though when they have no way of pursuing their engineering interests past eighth grade. A lack of engineering opportunities to fill the gap between junior high and postsecondary does not encourage more engineering at the junior high level either.

Teachers at all levels stressed that obtaining resources is even more of an obstacle in a rural community like Delta Junction than it would be in other suburban or urban areas. There are two hardware stores, a grocery store, and several specialty shops (outdoor stores, souvenir shops, etc.) in Delta Junction, most of which are closed evenings, Sundays, and holidays, and there are no major stores in the surrounding communities. To obtain materials or supplies after 3pm on a Saturday, teachers discussed the need for their students (and those students' parents) to drive to the nearest major city, Fairbanks, AK, which is almost 100 miles away. This requires significant planning on the student's part, much more so than for a student who lives in a city. If a student has a project to work on over the weekend and he realizes on a Saturday afternoon that he is missing a component, he may not be able to get that in Delta Junction until the following Monday and driving all the way to Fairbanks can be a major affair. If the part he needs is not available in Delta Junction, which can often happen, then it would certainly require a trip to Fairbanks. The same challenges apply to teachers attempting to procure materials for their students; material runs often require a trip to Fairbanks which could mean planning the activity a month in advance or making a special trip to Fairbanks, depending on how often the teacher travels there.

Space is another challenge for a small school, which was raised in the secondary teacher focus group. Engineering projects often require space and sometimes even equipment, and the secondary teachers discussed the challenges of providing students with workspace. DGSD has limited facilities and the junior high school has already converted the teacher's lounge, one of the few "available" spaces, to a Maker's Lab for students. If a teacher wants to engage her students in some sort of building project, both workspace and storage space could be a challenge.

Finally, many students in the DGSD face the unique challenge of coming from an agricultural way of living. Secondary teachers raised the challenges faced by students who live on a farm or are part of some other family business. These students often must spend most of their home time helping on the farm or with the business. Engineering activities are often project-based and require time. Much of the work can either be done in the classroom or at home, and teachers may try to shift more of it to the home to help overcome the obstacle of time in the classroom. However, when students and their parents need to spend their home time working, those projects often do not get done. This not only affects the student's learning outcomes, but it can also distinguish certain students from their peers and draw unwanted attention.

4.3.3 Training, Knowledge, Curricular Support, and Expertise

A lack of confidence and content knowledge for both teachers and administrators was reported and discussed above and training needs are discussed in detail in the following section on professional development. In addition to a lack of confidence and content knowledge, stemming in part from a lack of training, teachers discussed a desire for engineering kits to support implementation of engineering education. Elementary teachers also heavily discussed the science curriculum and the ways it affects engineering education in elementary classrooms.

4.3.3.1 Engineering Kits

There was some discussion in all three focus groups concerning engineering kits for teachers. All elementary focus group participants agree that kits could be very useful if implemented in a way that works for DGSD teachers. Teachers discussed the need for the district to restock the consumables in any kits because "then we get into that same old, this is a consumable, it's gone and there's no more left, that whole thing." As an alternative to the district restocking consumables, one elementary teacher mentioned the possibility of using kits similar to the art kits available in Fairbanks. The teacher explained,

> [The art kits] have no materials in them. They just tell you everything you need to teach it and [contain] samples and stuff and you have to come up with the [materials], and you understand that's how it's going to be. You don't teach that unit unless you can get the construction paper or whatever, so it would either have to be that understanding of "this is available, make sure you can get the stuff" or "it's all here for you". It could go both ways.

In discussing supplies for kits, teachers connected back to the issue of being in a rural area. If there are materials required, those materials would need to be available in Delta. A lack of materials, further compounded by the inability to acquire materials locally and quickly, would deter most teachers from teaching a certain engineering lesson or activity. When asked whether the kits would need to be tied directly to the science curriculum, elementary teachers responded that it would not be a requirement. One teacher responded, "Not if it's interesting" and another said, "Just as long as it fits the standards and outcomes we're supposed to meet at each grade level." Teachers did agree that if the kit was long-term (for example, taught a few days a week for a month) then it would need to go along with the science curriculum. A secondary focus group participant who was not comfortable teaching engineering said that for "teachers like [her]" kits would be a good way to introduce the topic. In this context, she described giving teachers a kit with the curriculum and the materials along with instructions on where the kit should fit into the science curriculum. Teachers at both levels discussed the convenience of having practical, applicable lesson ideas supplied to them along with either the materials or a concise list of locally available materials.

4.3.3.2 Science Grant and Science Curriculum

In 2015 the Delta-Greely School District was awarded a five-year Department of Defense Education Activity (DoDEA) science grant. The 2018-2019 school year was the fourth of five years and the grant will end at the conclusion of the 2019-2020 school year. The goal of the grant is to increase the number of students who will pursue science careers after high school (Holoday, 2015) and the grant is intended to fund long-term changes and self-sustaining activities, meaning the gains and benefits created from the grant money will not cease at the end of the fifth year. This grant has had a major impact on science education throughout the district and was discussed in all three focus groups. The administrator participant expressed clear satisfaction with the positive outcomes of the grant so far. The teacher participants have mixed feelings on the grant but are generally satisfied with the end results. The following quote from one teacher participant illustrates these mixed feelings:

> Right now we have a science coach come into our classes and show us how to teach science even though we've all taught science for forever – it just wasn't in this very

structured textbook form…we had a tough time in the beginning but it's getting better now because we're just doing what we're supposed to do. So it's been a rough couple of years for science. We're like, 'ugh, science!', but then I'm like, 'but I'm already teaching it all the time!'

The elementary teachers, who have been the most heavily affected by the grant, expressed frustration with some of the grant requirements (for example a science coach and bi-weekly professional learning community (PLC) time focused on science) but at the same time they described the benefits as being worth the frustration. Now that the district is nearing the end of the grant the teachers are able to look back on the experience as a whole and they described how the technology and resources that have come from the grant, along with the focus on science, have been worth "putting up with" the requirements levied on them.

Along with the science grant came new curricula for both elementary and secondary. At the time of the focus group, the elementary teachers were in their first year of their new science curriculum and they discussed it in detail. Teachers described this new science curriculum as a significant time burden this year – not necessarily because it is a bad curriculum, but because with any new curriculum it takes time to learn the material and flow, and in this case to also learn the new Next Generation Science Standards (NGSS). One teacher participant said, "I personally am trying to get NGSS figured out, because it's totally changed everything for me." Each student has a write-in workbook and they follow along, filling in the blanks, as the teacher goes through the material. The workbook is connected throughout and the curriculum is meant to be completed in order, start to finish. There are short videos interspersed with the workbook material as well as experiments, projects, and activities. Since the curriculum is based on the NGSS there are significant engineering components. The elementary teachers are happy that there are engineering activities in the curriculum but are generally disappointed in the quality of the engineering activities. One teacher said, "that's kind of what bothers me about our curriculum, is we have engineering in it but sometimes it feels canned…there's just no fun to it because there's nothing real about it." They discussed the possibility of replacing the engineering activities in the curriculum with other engineering activities that are more pertinent to their students and more real-world. Another teacher responded, "Ya, I would do an engineering thing, but I wouldn't do [the activity in the curriculum], and I think that still checks the box. I really do."

4.4 Professional Development Content and Delivery

When asked to agree or disagree with the statement that they are interested in professional development about integrating engineering into the classroom or school, elementary teachers express the most agreement (average=4.4, SD=0.5), followed by high school teachers (average=4.2, SD=1.0). Administrators and junior high teachers are neutral (administrator average=3.7, SD=0.6; junior high teacher average=3.3, SD=1.5). Teachers and administrators were then asked to rank several different professional development delivery modes. The options provided were in-service (training organized by the district and provided to teachers during work hours, led by a subject matter expert who is physically present at the training), video teleconference (VTC) training (training organized by the district and provided to teachers during work hours, led by a subject matter expert who is not physically present at the training), professional development delivered as a college course (training delivered outside of work by an institution of higher learning), a semester-long or year-long mentor program (outside education or engineering subject matter experts work with teachers over an extended period of time), and collaboration with fellow teachers (teachers work together to create and share knowledge with limited outside involvement). Respondents were also given the option to rank “other” and describe this other option in a short-answer format, however due to the limited number of responses the “other” option was not considered in the analysis.

At the elementary and junior high levels in-service is the most preferred method followed by professional development delivered as a college course. Among high school teachers and administrators professional development delivered as a college course is the most preferred method. When all responses are aggregated in-service is the most desired method, followed closely by professional development delivered as a college course. There is little interest in any demographic for video teleconference training or a semester-long or year-long mentor program. Figure 4 shows the number of respondents in each demographic who selected a certain delivery mode as their first or second choice. Participants’ preferences for delivery modes are displayed in Table 8. Values in Table 8 represent the ranking, where 1 is the respondent’s first choice and 5 is the respondent’s last choice.

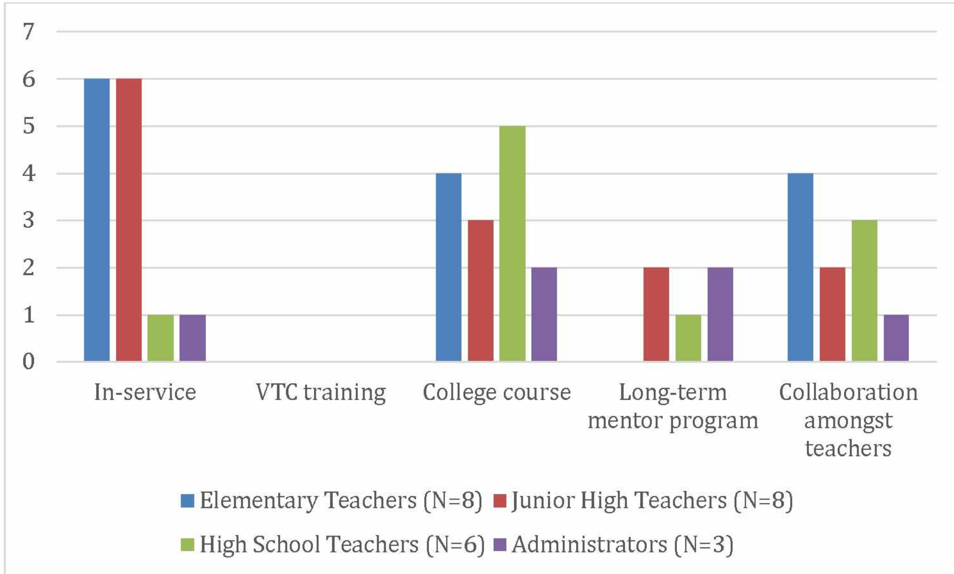

Figure 4. Number of Respondents Ranking Delivery Modes First or Second by Demographic

Table 8

Respondent Interest in Engineering Education Professional Development

Professional Development Delivery Mode	Elementary Teachers (*n*=8)	Junior High Teachers (*n*=8)	High School Teachers (*n*=6)	Administrators (*n*=3)	All Respondents (*n*=24)
In-service	1	1	3	1	1
Video teleconference (VTC) training	4	5	5	5	4
PD delivered as a college course	2	2	1	1	2
Semester-long or year-long mentor program	5	4	3	3	5
Collaboration with fellow teachers	3	3	2	3	3

Note. Responses are ranked from 1 to 5 where 1 is the first choice and 5 is the last choice

4.4.1 Professional Development Content

All focus group participants discussed the wide range of abilities and comfort levels of teachers with respect to engineering education. There are some teachers in the district who already teach engineering on a regular basis and others who would say they know nothing about engineering or engineering education. One teacher said she believes there are more teachers who are unfamiliar with or uncomfortable with engineering than there are teachers who are comfortable with the topic and no one disagreed with that statement. For those teachers who are not comfortable with engineering education, participants described a need for professional development that would touch on an introduction to engineering knowledge, the engineering design process, and engineering education techniques and pedagogy. The following exchange occurred in one of the teacher focus groups:

> Teacher one: "I don't know anything at all, so I'm one who needs lots [of training and assistance]. Find A, and then find B, and then put A and B together."
>
> Teacher two: "She needs the IKEA flat pack of engineering instruction."
>
> Teacher one: "I do! I would have no idea where to start."

Some of the teachers who are more comfortable with engineering education mentioned the potential benefits of professional development that would show unfamiliar teachers the strengths of engineering education. One teacher said, "I think the education just to show [teachers] how simple it is to incorporate engineering into our classes every single day [would be worthwhile]." They also discussed the benefits of showing other teachers how engaged students can be during engineering lessons to help spark their interest.

The elementary teachers who are already comfortable with engineering education described a need for applicable real-world prompts and ideas and the secondary teachers discussed the benefit of implementation techniques and ideas for interdisciplinary engineering (teachers of different subjects working together on different components of the same overall engineering lesson, project, or unit). When the elementary teachers were asked what would help them to incorporate more engineering into their classrooms, one teacher responded, "I really like prompts. It's hard to find, especially at my age group…problems to solve." All the teachers in that focus group agreed that real-world ideas and prompts would be extremely helpful and are lacking in the current science curriculum.

4.4.2 Professional Development Delivery

Two main delivery modes are the clear preferences among both teachers and administrators. They were discussed in no particular order during the focus groups but the first to be discussed in this report is the district in-service. Both teachers and administrators discussed the benefits of having someone present to the teachers at an in-service and this was discussed for teachers of all engineering comfort levels. The second delivery mode that teacher participants expressed interest in is a semester-long course. All the elementary focus group participants had taken an online engineering education course through the University of Alaska Fairbanks and they thought it was the most convenient and effective delivery mode for them. Some of the benefits of this mode they described are the ability to take what they learned one day and bring it into the classroom the next day (taking the course during the school year as opposed to the summer was an important element); keeping the information fresh by not just trying it once but trying it over the course of the semester (as opposed to having a one-day event); and the video elements of the course that showed actual elementary engineering lessons and walked teachers through the process.

One administrator made the point that professional development alone will not induce long-term change. A discussion on the interdependence between professional development and resources can be found later in this report, however it is worth noting at this point as well. When asked about the professional development approach that would most benefit his school, he responded, “Well it’d have to be two-pronged. I mean, you would have to have some PD for the teacher and then you would need to provide some materials or curricula that they could use.”

Chapter 5 Recommendations

5.1 Overview of Recommended Path Forward

Results of this study suggest that teachers and administrators within the Delta-Greely School District clearly support the presence of engineering in the classroom. Teachers identify several aspects of engineering education that support students' overall learning outcomes: the level of student engagement during engineering lessons, elements of the engineering design process that are not seen in the scientific method (especially critical and "outside-the-box" thinking), opportunities for social emotional learning, and the absence of workbooks and notetaking in engineering (as opposed to the current science curriculum). Survey and focus group results identify that teachers have varying confidence levels with engineering education though, with responses ranging from 1 (strongly disagree) to 5 (strongly agree) on a 1-5 Likert scale, and even those who are already comfortable teaching engineering identify areas where they could use assistance in improving their teaching of engineering, especially lesson planning and curricular support.

Data analysis identified different responses and needs between grade levels in the survey results, which was reinforced in the focus group discussions. For this reason, it is recommended that a professional development solution be focused on one specific grade band. Teachers' receptiveness toward engineering is one of the most important factors in determining the success of engineering education (Douglas et al., 2016) and while teachers at all levels express some interest in engineering education, elementary teachers are clearly more open to and interested in engineering education in the classroom. Further, elementary teachers are the most interested in engineering education professional development. Since teacher interest has a major impact on the success of professional development (Douglas et al., 2016), it would be beneficial to capitalize on teacher interest in the elementary school. Elementary teachers also have more time available during the day to focus on the social emotional skills and engineering habits of mind that can be developed through engineering education (DeJarnette, 2012; Van Meeteren, 2018). Engineering habits of mind "include systems thinking, creativity, optimism, collaboration, communication, and attention to ethical considerations" (Van Meeteren, 2018, p. 7), and these skills can be fostered at the elementary level through play, imagination, and natural exploration (Van Meeteren, 2018). Students would be best served by an introduction to engineering at the elementary level so that they have a strong grasp of basic problem-solving and engineering habits of mind. This would then serve as a solid foundation for higher-level engineering at the secondary and possibly post-secondary levels if students choose to pursue that path. Secondary students are beginning to develop a repertoire of knowledge that lends itself to more technical engineering problems, but they require the basic skills in order to tackle these problems. Further, the basic skills that can be taught and learned through elementary engineering are skills that will aid students in any field they choose to pursue, whether that be STEM, the trades, management, or a variety of other paths, and the earlier they can gain experience with those skills the more opportunity they will have for success.

Teachers and administrators strongly prefer professional development delivered as an in-service or as a college course, and very broadly speaking there are two levels of teachers represented in this study: those with experience teaching engineering, and those without. The recommendation is to have a two-pronged approach to teacher professional development that focuses primarily on elementary teachers but that is also available to secondary teachers where practicable and if district resources allow. The first prong is a district in-service that broadly covers engineering education, which could relatively easily be available to all teachers, and the second is a longer-term professional development plan that focuses on implementation that would be geared toward elementary. DGSD elementary teachers are likely to participate in this type of professional development program based on survey and focus group results.

All professional development should focus on overcoming the three primary obstacles identified by teachers and administrators: time; money, materials, and equipment; and training, knowledge, curricular support, and expertise. Any effective professional development addresses training, knowledge, and expertise. Curricular support and money, materials, and equipment will be addressed later as part of the implementation-focused professional development. To address the time concerns, professional development should focus on strategies to implement integrated engineering. Engineering is not another subject to be taught; it is a way of thinking and of solving problems, and a tool to help strengthen and complement education in other fields. Additionally, the professional development should focus on resources available to help decrease planning time. These strategies and implementation suggestions should cover a variety of subjects, not just the traditional math and science. Showing teachers how engineering can incorporate history, language arts, special education, and other areas can improve teacher buy-in and true integration. The special education teacher who discussed not having the time to work with her students on engineering was still excited at the prospect of her students being able to do engineering activities in their other classrooms, which presents one opportunity for collaboration. The special education teachers and aides could work with the core content teachers to develop accommodations that would allow all students to be able to participate in engineering lessons in their regular classrooms.

5.2 Recommendations for Introductory Engineering Education Professional Development

Initially there should be a district professional development (in-service) that broadly introduces engineering education and the value of supporting student engagement in learning STEM. Survey results show that this is the most desirable professional development delivery mode for elementary teachers. This could be done as part of another in-service or it could be an engineering-only in-service, depending on district priorities. The professional development should cater toward those teachers who responded that they are not familiar with engineering or engineering education by focusing on the following:

- What is engineering?
- What should engineering education look like (focusing on problem-solving, critical thinking, and social emotional skills)? Demonstrate a mini engineering lesson.
- How can engineering be integrated into the curriculum so it does not take too much class time?
- What are some basic strategies and resources that can minimize teacher planning time?

None of these questions need be explored in great depth and the purpose of this in-service should not be to prepare teachers to teach engineering. Instead, the purpose of the in-service should be to show teachers what engineering could and should look like; what makes an engineering lesson an effective educational tool; that there is a wide spectrum of topics and lessons that vary in length, complexity, and style; and that once a teacher gets over the initial hurdle of a new area, it does not require an engineering expert or a significant amount of planning time to plan for and integrate effective engineering education. This in-service would likely involve a lecture-style introduction to engineering, a partial or mini lesson demonstration where the teachers act as the students, and a discussion of basic implementation techniques and available planning resources participants might use in their classrooms. This in-service should stress active learning and model effective teaching strategies; address the alignment between engineering education and the current curriculum and standards; and provide opportunities for collaboration among participants (Archibald et al., 2011; Darling-Hammond & Richardson, 2009; Douglas et al., 2016; Porter et al., 2019). This can also serve as a level-setting opportunity where the district is able to set expectations for engineering education, especially since teachers throughout the district have a variety of different backgrounds and experience levels.

For teachers who are not comfortable with engineering, a presenter at a district in-service could help show them what engineering looks like in the classroom and create a picture of what engineering education really is. This session could show teachers two key points: first, that engineering is not as foreign as they might previously have thought and it might even be something they already teach to some degree even though they don't realize it; and second, it could increase teacher interest by showing them what effective engineering education looks like and what some of its strengths are. For teachers who are already comfortable with engineering, a presenter at a district in-service could share new ideas for both implementation and content/lesson ideas. Survey respondents who identified as being comfortable with engineering education still expressed an interest in engineering education professional development and in the focus groups these participants expressed an interest in curricular materials and content/lesson ideas.

Teachers responded in the surveys that it is most important to integrate engineering education into the 9-12 curriculum, then the 6-8 curriculum, and lastly the K-5 curriculum, but interestingly high school teachers reported being the least familiar with and least confident in teaching engineering. This learning opportunity should be made available to all elementary teachers because the overall professional development program should target elementary teachers first, but it could also be relatively easy to extend the opportunity to secondary teachers as well. Especially if there are secondary teachers who are already comfortable teaching engineering who would volunteer to present demo lessons, this in-service could be modified for secondary teachers with relatively few additional resources.

5.3 Recommendations for an Extended Implementation-Focused Professional Development

Teachers should not be required to participate in any engineering education professional development beyond a broad introduction, however for those who are interested there should be additional professional development available that focuses on implementation. Based on focus group data, the professional development content most desired by teachers who are already comfortable with engineering education is clearly "ideas". More specifically, teachers describe a need for applicable real-world prompts and lesson ideas at the elementary level and implementation techniques and ideas for interdisciplinary engineering at the secondary level. All teacher focus group participants agree that real-world engineering ideas and prompts are lacking in the current science curriculum.

When trying to induce long-term change, professional development and resources need to be considered together (Darling-Hammond & Richardson, 2009). Knowledge cannot be applied without the right tools, and tools are useless if not implemented correctly. There are cost-effective ways to teach engineering but those require more planning and research time, which teachers do not have. Instead of providing PD and then sending teachers off on their own, the district should invest the time and money in selecting appropriate resources and then tailor the professional development toward those resources. The district could either make complete stocked kits available to teachers (the district replenishes the consumables) or identify lessons that require minimal, inexpensive, and locally available consumables. The district would then provide the lesson plans, durable equipment, and a complete list of all required consumables to teachers (the teacher purchases the consumables). Whichever approach the district chooses, the expectations and requirements need to be clear to the teacher. This issue was discussed at length during the elementary focus group. If a lesson requires the teacher to purchase 100 feet of wire and 30 mini lightbulbs there should be a clear and concise list on the outside of the lesson package saying that is exactly what needs to be purchased. If the district restocks the consumables, they could be purchased in bulk and stored in a supply closet for teachers. In this case there should be a list on the outside of the kit informing the teacher that the wire and lightbulbs need to be obtained from the supply closet prior to beginning the lesson. If the teacher has to spend two hours digging through the lesson plans to identify the materials, hunt through the supply closet to see what's there, and then drive to the hardware store to find whatever is missing, she is likely to set the lesson down and go back to the clear-cut but less real-world science curriculum. Along the same lines, the lesson packages, however they are provided, should all follow the same general format. If a teacher has 30 minutes of planning time available that time should be spent thinking about how best to deliver the lesson as opposed to figuring out how the lesson plan is laid out.

Significant time should be spent identifying lessons that are real-world and connect with the students in some way (Moore et al., 2014). There should be a relatable purpose and impact. One elementary teacher described an engineering lesson in the science curriculum that required students to build a cylinder that could hold books on top of it. This type of lesson could be appropriate if it focuses on social-emotional skills or engineering habits of mind but as a content lesson it lacks meaning and purpose. Some of the best engineering ideas are the ones that occur naturally – one teacher shared a lesson she taught where her students had to solve the classroom problem of the whiteboard markers rolling off the teacher's desk – but those lessons require the right opportunity to present itself and they require more confidence and risk-taking on the teacher's part. Teachers should be encouraged to seize those opportunities when they can, but they should not be expected to. The lessons should fit well with the current science curriculum and should complement the other curricula as well. As discussed in the elementary focus group, there should be a variety of lesson lengths ranging anywhere from short 1-hour activities to 5+ hour mini-units that would be taught over a week or more. The lessons should incorporate math, science, and reading/writing, along with some history and electives scattered throughout. The lessons could be targeted toward grade bands instead of specific grades (i.e., K-2, 3-5) to make them more versatile and provide more options to teachers. Teachers would need to communicate so that students are not doing the same lessons every year (i.e., the 3rd, 4th, and 5th grade teachers each teach the same lesson every year), but an added benefit is this would provide an opportunity for students of different grades to work together – the 3rd and 5th grade teachers could pair their students to work together on a project.

One caution when gathering or creating lesson plans is that engineering at the elementary level does not need to be strictly planned. Creating a lesson plan does not necessarily mean putting together a minute-by-minute plan of an activity for students to follow. Some of the strengths of elementary engineering are the flexibility and freedom of exploration, and care should be taken not to plan the flexibility out of engineering (Van Meeteren, 2018). The specific content of these kits or lesson plans is beyond the scope of this report, however it is important that engineering education best practices are identified and considered when selecting or creating lesson plans. Moore et al. (2014) have published a "Framework for Implementing Quality K-12 Engineering Education", which can serve as a tool for evaluating the quality of elementary engineering lessons. Cunningham and Kelly (2017) provide a set of epistemic practices that can be used in creating or evaluating engineering education curriculum as well as the content of engineering education teacher professional development. Thibaut et al. (2018) offer a framework for instructional practices in secondary engineering education. There are many lesson kits commercially available and there are even more lesson plan ideas. The district does not need to create an entirely new package of lessons from scratch so long as the lessons are carefully reviewed before they are selected.

This package of engineering lessons and resources should focus on quality, not quantity. Delta Elementary School is not an engineering school and teachers will not be teaching engineering every day or even every week. Resources would be better utilized identifying or creating several strong lesson kits as opposed to a plethora of average ones. One lesson that meets all the critical criteria – easily acquirable materials, easy for the teacher to understand and navigate, applicable to the curriculum, is relatable to students, follows engineering education best practices – will be used more than 100 lessons that do not meet those criteria. Once the district has identified a package of engineering lessons and resources, then the professional development can be designed around those resources.

As mentioned earlier in this report, teacher participants expressed interest in a semester-long professional development course. All of the elementary focus group participants had already taken an online semester-long engineering education professional development course and believe this to be the most effective format for them because they had the opportunity to immediately apply what they were learning in the classroom, they were learning about and using engineering in the classroom over an extended period of time, and some of the specific learning components within the course were beneficial. This delivery mode does pose a logistical challenge for the district because there are not many online engineering education professional development courses available for teachers.

In the absence of such a course, a district-specific professional development plan should be developed that emphasizes the elements of an online course that elementary focus group participants and researchers have identified as most helpful. The most important elements are the content of the professional development, the long-term delivery during the school year (opportunities for implementation), opportunities for collaboration with fellow teachers, alignment with district curricula and standards, and administrative support (Douglas et al., 2016). According to Margot and Kettler (2019),

> The pedagogical strategies associated with STEM must be explicitly taught to teachers and modeled in order to improve fidelity of programming. Teachers have to become comfortable allowing their students to "take the wheel" and drive instruction. They have to learn how to play the role of facilitator of knowledge and how to encourage students to take academic risks. All of this can be practiced and reinforced in professional development before implementation in classrooms. The National Research Council (2013) recommends that districts develop a mechanism for focused professional development to be coordinated that aligns with instructional reforms and provides high-quality learning opportunities for teachers. The content knowledge and affective needs teachers have regarding STEM instruction must be attended to during in-service learning. (p. 14)

This could be even more effective than an online course because it could be tailored to the district's needs and district-provided resources. As an added incentive, the district could work with the University of Alaska Fairbanks and the Department of Education and Early Development to allow teachers to earn credits toward recertification.

If the district creates an implementation-focused professional development plan, it should relate specifically to the lessons offered by the district. This plan could be kicked off at a district in-service where teachers focus on what engineering education should look like at their grade level, what engineering habits of mind and the engineering design process are and how to use them, and some basic implementation strategies. Teachers could then meet for short sessions during planning time every two weeks and during professional development time monthly or bimonthly. During shorter sessions a district-provided lesson could be summarized and introduced, teachers could share ideas and reflect, or teachers could receive instruction on small focused topics such as engineering standards or engineering assessments. During longer sessions, professional development could focus on demonstrating engineering education or deeper explorations into specific ideas and techniques. Administrators should participate in at least some of the professional development sessions to show their support and to keep open communication between the teachers and the district. A sample professional development plan is included in this report (see Appendix G).

The biweekly engineering-focused planning time is similar to the biweekly professional learning community (PLC) time that arose from the science grant, which was not well-received by all teachers. During science PLC time teachers reported feeling like they had to spend their time talking about teaching science even though they already knew how to teach science – they felt that there was little value added from this planning time. The differences here would be that most teachers feel less comfortable with engineering than with science, this would be part of a voluntary program whereas the science program was mandatory, and there should be more opportunity for teacher input into the content of the engineering planning time. Teachers participating in this professional development should view themselves as and be treated as a learning community; teachers should be comfortable expressing new ideas, asking questions, taking risks, and reflecting on the strengths and weaknesses of themselves and others. Ideally, teachers would even be open to inviting other teachers into their classroom – this might be another teacher who has never taught engineering and wants to see what it looks like, or it might be another teacher comfortable with engineering who observes a lesson and provides constructive feedback.

This professional development plan should include professional development best practices identified by current research. It should be a regular, ongoing program that keeps the information fresh in teachers' minds and provides a range of skills and information related to engineering education. It should encourage implementation but allow teachers to try engineering education at a pace and level with which they are comfortable. It should interweave learning new skills, trying those skills in the classroom, and reflecting on planning and teaching experiences. It should provide teachers with a support system of their peers and should show teachers that they have the support of their administrators in their engineering endeavors (Archibald et al., 2011; Darling-Hammond & Richardson, 2009; Douglas et al., 2016; Porter et al., 2019). This professional development should also set teachers up for success because a negative experience with engineering education early on can be even more damaging than no experience with the subject (Rich, Jones, Belikov, Yoshikawa, & Perkins, 2017).

5.4 Summary

Teachers and administrators in the Delta Greely School District view engineering education as an important part of the K-12 curriculum, however most teachers lack confidence in teaching engineering and most administrators lack confidence in supporting engineering education. The biggest obstacles preventing more engineering in DGSD classrooms are time; training, knowledge, curricular support, and expertise; and money, materials, and equipment. Elementary and high school teachers are interested in professional development to better understand engineering education and elementary and secondary teachers are interested in resources to support implementation of engineering education.

DGSD's resources would be well-utilized by introducing all elementary teachers to engineering education and then focusing on those teachers who demonstrate interest. The district should develop a package of strong, real-world, relatable, and curriculum-connected elementary engineering lesson kits, and then provide interested teachers with professional development focused on those lessons. As Margot and Kettler (2019) write, "[c]urriculum is simply a blueprint, and STEM education requires a pedagogical shift to student-centered learning" (p. 3). The professional development should emphasize engineering content knowledge, implementation techniques for student-centered learning, engineering habits of mind, teacher collaboration, and the specific district-provided lessons. This professional development should occur over the course of a semester and foster a learning community of teachers and administrators who are interested in engineering education. Teachers should be encouraged to take risks, integrate different content areas, and try new engineering ideas, but they should feel safe to take these leaps at their own pace and in a supportive environment of fellow teachers and administrators who will help them learn from their experiences.

5.5 Suggestions for Future Research

Although this study provides an important step toward improving the implementation of integrated engineering education, the need for further research exists. Systematic examination of the effects of professional development and engineering education implementation on teachers' and students' learning outcomes is required. Moreover, looking at specific place-relevant elements of teacher professional development on these learning outcomes could provide information about the necessity of training and lead to a refinement of teacher training in Alaska. Finally, the influence of different factors (i.e., teachers' attitudes, school context) on the implementation of engineering education could be further examined. Insight into these factors could help to improve the implementation of engineering education and integrated STEM education and ultimately contribute to students' increased motivation for STEM careers.

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Appendix A

Institutional Review Board Approval

(907) 474-7800
(907) 474-5444 fax
uaf-irb@alaska.edu
www.uaf.edu/irb

UNIVERSITY OF ALASKA FAIRBANKS

Institutional Review Board

909 N Koyukuk Dr. Suite 212, P.O. Box 757270, Fairbanks, Alaska 99775-7270

November 26, 2018

To:	Ute Kaden, Ed.D. Principal Investigator
From:	University of Alaska Fairbanks IRB
Re:	[1344887-1] Engineering Education Professional Development for K-8 Teachers in the Delta Greely School District

Thank you for submitting the New Project referenced below. The submission was handled by Exempt Review. The Office of Research Integrity has determined that the proposed research qualifies for exemption from the requirements of 45 CFR 46. This exemption does not waive the researchers' responsibility to adhere to basic ethical principles for the responsible conduct of research and discipline specific professional standards.

Title:	Engineering Education Professional Development for K-8 Teachers in the Delta Greely School District
Received:	November 12, 2018
Exemption Category:	2
Effective Date:	November 26, 2018

This action is included on the December 5, 2018 IRB Agenda.

Prior to making substantive changes to the scope of research, research tools, or personnel involved on the project, please contact the Office of Research Integrity to determine whether or not additional review is required. Additional review is not required for small editorial changes to improve the clarity or readability of the research tools or other documents.

America's Arctic University

Appendix B

Institutional Review Board Amendment Approval

(907) 474-7800
(907) 474-5444 fax
uaf-irb@alaska.edu
www.uaf.edu/irb

Institutional Review Board
909 N Koyukuk Dr. Suite 212, P.O. Box 757270, Fairbanks, Alaska 99775-7270

February 27, 2019

To:	Ute Kaden, Ed.D. Principal Investigator
From:	University of Alaska Fairbanks IRB
Re:	[1344887-2] Engineering Education Professional Development for K-8 Teachers in the Delta Greely School District

Thank you for submitting the Amendment/Modification referenced below. The submission was handled by Exempt Review. The Office of Research Integrity has determined that the proposed research qualifies for exemption from the requirements of 45 CFR 46. This exemption does not waive the researchers' responsibility to adhere to basic ethical principles for the responsible conduct of research and discipline specific professional standards.

Title:	Engineering Education Professional Development for K-8 Teachers in the Delta Greely School District
Received:	February 26, 2019
Exemption Category:	2
Effective Date:	February 27, 2019

This action is included on the March 6, 2019 IRB Agenda.

Prior to making substantive changes to the scope of research, research tools, or personnel involved on the project, please contact the Office of Research Integrity to determine whether or not additional review is required. Additional review is not required for small editorial changes to improve the clarity or readability of the research tools or other documents.

Appendix C

Delta Greely School District Approval

UNIVERSITY of ALASKA Jennifer Dougherty <jcorrigan@alaska.edu>

Engineering education research in DGSD

Laural Jackson <ljackson@dgsd.us> Tue, Dec 4, 2018 at 9:04 AM
To: jcorrigan@alaska.edu

Greetings Jennifer

I conferred with the principals and they are fine with participating in your research. I cannot, of course, require anyone to participate, but you are welcome to request their assistance. Thanks for checking with me.

Laural Jackson, Superintendent
Delta/Greely School District
907-895-4657 ex 24

This message is considered confidential and should not be shared without explicit permission of the sender.

On Sat, Dec 1, 2018 at 1:43 PM Jennifer Dougherty <jcorrigan@alaska.edu> wrote:

> Superintendent Jackson,
>
> My name is Jennifer Dougherty. I'm a graduate student from Delta Junction in the UAF School of Education and I'd like to speak with you about conducting research in the Delta Greely School District this spring. The goal of my research is to gauge teachers' attitudes and beliefs surrounding engineering education and to identify effective types of engineering education professional development if there is interest and a need. I plan to conduct a survey of teachers and administrators and then follow up with focus groups or interviews, depending on participation. I've received IRB approval for the research and I'm working with my graduate advisory committee to refine the survey instrument. I would be happy to work with the district if there are related questions or topics you're interested in exploring. The results would be anonymous and all data and analysis would be provided to the district for you to use as you see fit (internal purposes, grant applications, etc). I look forward to speaking with you via email, phone, or in person and I'd be happy to answer any questions you have.
>
> Respectfully,
> Jennifer Dougherty
> [redacted]

Appendix D

Teacher Survey

Informed Consent Form

Engineering Education Professional Development for K-8 Teachers in the Delta Greely School District

IRB #1344887-1
Date Approved: November 26, 2018
Instrument: Survey

Description of the Study:
You are being asked to take part in a research study about engineering education professional development (PD). The goal of this study is to learn about ways to increase the presence of engineering in the classroom. You are being asked to take part in this study because you are a teacher or administrator working with K-8 students. Please read this form carefully. We encourage you to ask questions and discuss the study before making a decision on whether or not to participate.

If you decide to take part, you will be asked to complete a 15-minute survey. The survey will take place between January and February. The purpose of the survey is to learn more about attitudes toward engineering and PD.

Risks and Benefits of Being in the Study:
The risk to you if you take part in this study is the possibility of data being compromised. The survey will NOT collect any personally identifiable data such as your name or birthdate. However someone may be able to identify you by your demographics (ie. grade level and experience) if data is compromised. Data will be aggregated and survey results will be destroyed after analysis to mitigate this risk.

We do not guarantee that you will benefit from taking part in this study.

Compensation:
Unfortunately, we will not be able to pay you for your time and effort. Even though we will not be able to pay you, we want to thank you for participating.

Confidentiality:
Any information obtained about you from the research will be kept confidential. We will properly dispose paperwork and securely store all research records. Your name will not be used in reports, presentations, and publications.

Voluntary Nature of the Study:
Your decision to take part in the study is voluntary. You are free to choose whether or not to take part. If you decide to take part in the study you can stop at any time or change your mind and ask to be removed. Whether or not you choose to participate, will not affect your employment.

Contacts and Questions:
If you have questions, you may contact Dr. Ute Kaden, ukaden@alaska.edu, 907-750-3399, or Jennifer Dougherty, jcorrigan@alaska.edu.

The UAF Institutional Review Board (IRB) is a group that examines research projects involving people. This review is done to protect the rights and welfare of people involved the research. If you have questions or concerns about your rights as a research participant, you can contact the UAF Office of Research Integrity at 474-7800 (Fairbanks area) or 1-866-876-7800 (toll-free outside the Fairbanks area) or uaf-irb@alaska.edu.

Statement of Consent:
I understand the procedures described above. My questions have been answered to my satisfaction, and I agree to participate in this study. I am 18 years old or older. I have been provided a copy of this form.

____
Signature of Participant & Date

____
Signature of Person Obtaining Consent & Date

The Next Generation Science Standards define science and engineering in the K-12 context as follows:

- **"Science" is generally taken to mean the traditional natural sciences: physics, chemistry, biology, and (more recently) earth, space, and environmental sciences.**
- **"Engineering" in a very broad sense is any engagement in a systematic practice of design to achieve solutions to particular human problems.**

Please consider these definitions when responding to this survey.

Directions:

How important or not important is it...

		Not at all important	Somewhat important	Neutral	Moderately important	Extremely important
1	For students to understand the use of engineering.					
2	For students to understand the impacts of engineering.					
3	For students to understand the relationship between science and engineering.					
4	For students to understand the design process.					
5	To integrate engineering into the K-5 curriculum.					
6	To integrate engineering into the 6-8 curriculum.					
7	To integrate engineering into the 9-12 curriculum.					

Directions:

How much do you agree or disagree with the following statements? Please respond to these questions regarding your feelings about ***your own*** teaching.

		I do not teach engineering	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
8	I am confident that I can teach science effectively.						
9	I am confident that I can teach math effectively.						
10	I am confident that I can teach engineering effectively.						
11	I understand engineering concepts well enough to teach engineering effectively.						
12	I wonder if I have the necessary skills to teach engineering.						

Directions:

How much do you agree or disagree with the following statements? Please respond to these questions regarding your feelings about your own teaching.

	I do not teach engineering	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
13 When teaching engineering, I am confident enough to welcome student questions.						
14 I know what to do to increase student interest in engineering.						
15 I am continually improving my engineering teaching practice.						

Directions:

Please respond to the following open-ended questions.

16 I use engineering activities in the classroom. (Circle one)

YES NO

17 If you circled yes, please describe the activities or types of activities you teach:

____

____

18 I am aware of engineering education professional development that is currently available to me. (Circle one)

YES NO

19 If you circled yes but you chose not to participate in that professional development, please explain why:

____

____

20 Do you think your school would benefit from integrating more engineering? Why or why not?

____

____

____

____

21 What are the barriers to you integrating engineering in the classroom?

____

____

____

____

Directions:

How much do you agree or disagree with the following statement?

		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
22	I am interested in professional development about integrating engineering into my classroom.					

23 Rate the following delivery methods for engineering education professional development, where 1 is your first choice:

_____ In-service workshop
_____ Video teleconference (VTC) training
_____ Professional development delivered as a college course
_____ Semester-long or year-long mentor program with engineers and/or educators
_____ Collaboration with fellow teachers, e.g. resource sharing, group planning, and coteaching
_____ Other (please describe) ____
____

24 Rate the following engineering topics you are most interested in for your classroom, where 1 is your first choice. If you are not interested in a topic, leave it blank.

_____ The engineering design process
_____ Civil engineering (roads, buildings, bridges)
_____ Electrical and computer engineering (circuits, electronics, computers)
_____ Environmental engineering (public health, pollution, recycling)
_____ "Specialty" engineering (petroleum, mining, nuclear)
_____ Other (please describe) ____
____

How much do you agree or disagree with the following statements?

		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
25	I have the freedom to incorporate engineering into my curriculum.					
26	I regularly integrate different subjects in my classroom.					
27	My curriculum allows me to plan interdisciplinary lessons.					

Directions:

Consider the following skills that students may practice or use during instructional activities in the classroom. What priority would you give each skill when evaluating a lesson? You do not have to use every priority level in your responses and you can assign the same priority level to multiple skills.

		Not a priority	Low priority	Medium priority	High priority	Essential
28	Lead others to accomplish a goal.					
29	Think creatively to solve problems.					
30	Work together to accomplish a common goal.					
31	Communicate big-picture concepts and broad ideas.					
32	Include others' perspectives when making decisions.					
33	Manage their time wisely individually and in groups.					
34	Think critically to solve problems.					
35	Present their work formally to their peers.					
36	Solve problems with more than one right answer.					
37	Make changes when things do not go as planned.					
38	Apply existing knowledge to new problems and contexts.					
39	Communicate technical information.					
40	Write proposals and justifications explaining the strengths and benefits of an idea, approach, or concept.					
41	Respect the different ideas of their peers.					

Directions:

How much do you agree or disagree with the following statements?

		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
42	I know what an engineer does for a job.					
43	I know where to find information and resources for teaching students about engineering careers.					
44	I have specific engineering or engineering education training.					
45	I know the national science standards related to engineering or engineering design.					
46	I know what effective engineering education looks like at my grade level.					

47 Describe the role of an engineer.

____

____

48 How many engineers do you estimate work in the Delta/Greely community? ________

49 Are you involved with classroom or instructional activities with students?

☐ Yes ☐ No

50 School name:

☐ Delta Elementary ☐ Delta Junior High ☐ Delta High School ☐ Districtwide

☐ Gerstle River School ☐ Homeschool

51 Are you a licensed educator? If so, please list your area(s) of licensure:

☐ Yes ☐ No ______________________________

52 Please list the grade(s) that you teach or currently specialize in:

____

53 Please list all subjects that you teach (e.g. math, English, elementary generalist):

____

54 Please list any engineering classes that you teach:

____

55 Years of teaching experience:

____

56 Think about the current content that you teach or instruct. How many years have you taught this material?

____

57 Gender:

____

58 Do you have any other comments?

____

____

Appendix E

Administrator Survey

Informed Consent Form
Engineering Education Professional Development for K-8 Teachers in the Delta Greely School District

IRB #1344887-1
Date Approved: November 26, 2018
Instrument: Survey

Description of the Study:
You are being asked to take part in a research study about engineering education professional development (PD). The goal of this study is to learn about ways to increase the presence of engineering in the classroom. You are being asked to take part in this study because you are a teacher or administrator working with K-8 students. Please read this form carefully. We encourage you to ask questions and discuss the study before making a decision on whether or not to participate.

If you decide to take part, you will be asked to complete a 15-minute survey. The survey will take place between January and February. The purpose of the survey is to learn more about attitudes toward engineering and PD.

Risks and Benefits of Being in the Study:
The risk to you if you take part in this study is the possibility of data being compromised. The survey will NOT collect any personally identifiable data such as your name or birthdate. However someone may be able to identify you by your demographics (ie. grade level and experience) if data is compromised. Data will be aggregated and survey results will be destroyed after analysis to mitigate this risk.

We do not guarantee that you will benefit from taking part in this study.

Compensation:
Unfortunately, we will not be able to pay you for your time and effort. Even though we will not be able to pay you, we want to thank you for participating.

Confidentiality:
Any information obtained about you from the research will be kept confidential. We will properly dispose paperwork and securely store all research records. Your name will not be used in reports, presentations, and publications.

Voluntary Nature of the Study:
Your decision to take part in the study is voluntary. You are free to choose whether or not to take part. If you decide to take part in the study you can stop at any time or change your mind and ask to be removed. Whether or not you choose to participate, will not affect your employment.

Contacts and Questions:
If you have questions, you may contact Dr. Ute Kaden, ukaden@alaska.edu, 907-750-3399, or Jennifer Dougherty, jcorrigan@alaska.edu.

The UAF Institutional Review Board (IRB) is a group that examines research projects involving people. This review is done to protect the rights and welfare of people involved the research. If you have questions or concerns about your rights as a research participant, you can contact the UAF Office of Research Integrity at 474-7800 (Fairbanks area) or 1-866-876-7800 (toll-free outside the Fairbanks area) or uaf-irb@alaska.edu.

Statement of Consent:
I understand the procedures described above. My questions have been answered to my satisfaction, and I agree to participate in this study. I am 18 years old or older. I have been provided a copy of this form.

____
Signature of Participant & Date

____
Signature of Person Obtaining Consent & Date

The Next Generation Science Standards define science and engineering in the K-12 context as follows:

- **"Science" is generally taken to mean the traditional natural sciences: physics, chemistry, biology, and (more recently) earth, space, and environmental sciences.**
- **"Engineering" in a very broad sense is any engagement in a systematic practice of design to achieve solutions to particular human problems.**

Please consider these definitions when responding to this survey.

Directions:

How important or not important is it...

		Not at all important	Somewhat important	Neutral	Moderately important	Extremely important
1	For students to understand the use of engineering.					
2	For students to understand the impacts of engineering.					
3	For students to understand the relationship between science and engineering.					
4	For students to understand the design process.					
5	To integrate engineering into the K-5 curriculum.					
6	To integrate engineering into the 6-8 curriculum.					
7	To integrate engineering into the 9-12 curriculum.					

Directions:

How much do you agree or disagree with the following statements? Please respond to these questions regarding your feelings about the practice of the teachers ***in your school***.

		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
8	I am confident that teachers can teach science effectively.					
9	I am confident that teachers can teach math effectively.					
10	I am confident that teachers can teach engineering effectively.					
11	Teachers understand engineering concepts well enough to teach engineering effectively.					
12	I wonder if teachers have the necessary skills to teach engineering.					
13	Teachers are continually improving their engineering teaching practice.					

Directions:

How much do you agree or disagree with the following statements? Please respond to these questions regarding your feelings about your own practice.

		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
14	I am confident in my ability to contribute to effective science education.					
15	I am confident in my ability to contribute to effective math education.					
16	I am confident in my ability to contribute to effective engineering education.					
17	I wonder if I have the necessary skills to contribute to effective engineering education.					
18	I am continually improving my ability to contribute to effective engineering practice.					

Directions:

Please respond to the following open-ended questions.

19 What are the barriers to your school integrating engineering in the classroom?

____

____

____

____

20 Do you think your school would benefit from more integrated engineering? Why or why not?

____

____

____

____

Directions:

How much do you agree or disagree with the following statement?

		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
21	I am interested in professional development about integrating engineering into classrooms in my school.					

22 Rate the following delivery methods for engineering education professional development, where 1 is your first choice:

_____ In-service workshop

_____ Video teleconference (VTC) training

_____ Professional development delivered as a college course

_____ Semester-long or year-long mentor program with engineers and/or educators

_____ Collaboration with fellow teachers, e.g. resource sharing, group planning, and coteaching

_____ Other (please describe) ____

____

How much do you agree or disagree with the following statements?

		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
23	Teachers in my school have the freedom to incorporate engineering into the curriculum.					
24	Teachers in my school regularly integrate different subjects in their classrooms.					
25	The curriculum allows teachers to plan interdisciplinary lessons.					

Directions:

Consider the following skills that students may practice or use during instructional activities in the classroom. What priority would you give each skill when evaluating a lesson? You do not have to use every priority level in your responses and you can assign the same priority level to multiple skills.

		Not a priority	Low priority	Medium priority	High priority	Essential
26	Lead others to accomplish a goal.					
27	Think creatively to solve problems.					
28	Work together to accomplish a common goal.					
29	Communicate big-picture concepts and broad ideas.					
30	Include others' perspectives when making decisions.					
31	Manage their time wisely individually and in groups.					
32	Think critically to solve problems.					
33	Present their work formally to their peers.					
34	Solve problems with more than one right answer.					
35	Make changes when things do not go as planned.					
36	Apply existing knowledge to new problems and contexts.					
37	Communicate technical information.					
38	Write proposals and justifications explaining the strengths and benefits of an idea, approach, or concept.					
39	Respect the different ideas of their peers.					

Directions:

How much do you agree or disagree with the following statements?

		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
40	I know what an engineer does for a job.					
41	I know where to find information and resources for teaching students about engineering careers.					
42	I have specific engineering or engineering education training.					
43	I know the national science standards related to engineering or engineering design.					
44	I know what effective engineering education looks like at my grade level(s).					

45 Describe the role of an engineer.

____

____

46 How many engineers do you estimate work in the Delta/Greely community? _________

47 Are you involved with classroom or instructional activities with students?

☐ Yes ☐ No

48 School name:

☐ Delta Elementary ☐ Delta Junior High ☐ Delta High School ☐ Districtwide

☐ Gerstle River School ☐ Homeschool

49 Are you a licensed educator? If so, please list your area(s) of licensure:

☐ Yes ☐ No ______________________________

50 Please list the grade(s) that you work with in your current role:

____

51 Please list all subjects that you work with in your current role (e.g. math, English, elementary generalist):

____

52 Please list any engineering classes that you work with in your current role:

____

53 Years of experience:

____

54 Think about the current position that you hold. How many years have you been in this or a similar position?

____

55 Gender:

____

56 Do you have any other comments?

____

____

Appendix F

Focus Group Questions

Elementary questions

1. At what level (elementary, junior high, high school, or districtwide) do you think engineering education resources such as materials and/or professional development would best be utilized?
2. With what areas of engineering education are you most comfortable? Least comfortable?
    a. What topics would be the most beneficial in engineering education professional development?
3. Considering engineering education, what type of professional development, such as an in-service, would be most beneficial to you to integrate engineering or more engineering in your classroom?
    a. What kind of ongoing support do you think you might need to fully integrate engineering in your classroom?
4. What are the most significant barriers to you integrating engineering or more engineering in your classroom?
    a. What could the district do to eliminate this barrier in a perfect world?
        i. What about in the real world?
5. What do you think most teachers need in order to integrate more engineering in their classrooms?
    a. If teachers don't have suggestions – What about more professional development on planning and implementation strategies to better utilize

planning and instructional time? More money available for materials? Pre-stocked engineering kits available for teacher use?

Secondary questions

1. At what level (elementary, junior high, high school, or districtwide) do you think engineering education resources such as materials and/or professional development would best be utilized?
2. With what areas of engineering education are you most comfortable? Least comfortable?
    a. What topics would be the most beneficial in engineering education professional development?
3. What are the most significant barriers to you integrating more engineering in your classroom? What could the district do to eliminate this barrier in a perfect world? What about in the real world?
4. What do you think most teachers need in order to integrate more engineering in their classrooms?
    a. If teachers don't have suggestions – What about more professional development on planning and implementation strategies to better utilize planning and instructional time? More money available for materials? Pre-stocked engineering kits available for teacher use?

Administrator questions

1. At what level (elementary, junior high, high school, or districtwide) do you think engineering education resources such as materials and/or professional development would best be utilized?

2. With what areas of engineering education are teachers in your school most comfortable? Least comfortable?
    a. What topics would be the most beneficial in engineering education professional development?
3. What are the most significant barriers to teachers in your school integrating more engineering in their classrooms? What could the district do to eliminate this barrier in a perfect world? What about in the real world?
4. What do you think most teachers need in order to integrate more engineering in their classrooms?
    a. If administrators don't have suggestions – What about more professional development on planning and implementation strategies to better utilize planning and instructional time? More money available for materials? Pre-stocked engineering kits available for teacher use?
5. Do you (or does the district) have resources available that you would be willing to divert to engineering education professional development and engineering materials? Consider specifically district in-service, tuition for a college course, funds for teachers to purchase materials, and funds to supply teachers with pre-stocked engineering kits.

Appendix G

Sample Elementary Professional Development Plan

- Week one: Full-day in-service
  - Morning – Broad overview of engineering education for all teachers
    - What is engineering?
    - What should elementary engineering education look like (focusing on problem-solving, critical thinking, and social emotional skills)?
    - How can engineering be integrated so it does not take too much class time?
    - What are some basic strategies and resources that can minimize teacher planning time?
  - Afternoon – Implementation-focused in-service for interested teachers
    - Introduction to engineering habits of mind and the engineering design process
    - Implementation techniques
    - Overview of district-provided kits
- Weeks two, four, six, eight: 30- to 60-minute planning and professional development meetings for interested teachers
  - Provide an overview of two district-provided lessons and discuss implementation ideas OR
  - Demonstrate an abbreviated version of one district-provided lesson OR
  - Focus on an engineering core competency or topic (standards, assessments, asking questions, critical thinking, interdisciplinary planning) OR
  - Open discussion for teachers to share ideas, ask question, reflect, etc.
- Week ten: Full-day in-service

- Half or full day dedicated to engineering for interested teachers
    - Demonstrate abbreviated district-provided lessons, focusing on implementation techniques and idea sharing
    - Focused session on engineering background knowledge or engineering education pedagogy

- Weeks twelve, fourteen, sixteen, eighteen, twenty: 30- to 60-minute planning meeting for interested teachers
    - Provide an overview of two district-provided lessons and discuss implementation ideas OR
    - Demonstrate an abbreviated version of one district-provided lesson OR
    - Focus on an engineering core competency or topic (standards, assessments, asking questions, critical thinking, interdisciplinary planning) OR
    - Open discussion for teachers to share ideas, ask question, reflect, etc.