Bridge Curriculum for Middle School STEM Classrooms

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WE, THE UNDERSIGNED MEMBERS OF THE GRADUATE FACULTY OF WESTERN OREGON UNIVERSITY HAVE EXAMINED THE ENCLOSED

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Candidate for the degree of : Master of Science in Education

and hereby certify that in our opinion it is worthy of acceptance as partial fulfillment of the requirements of this master's degree.

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Abstract

STEM education is becoming more and more prevalent and relevant. STEM education has grown out of the understanding that life is inherently cross-curricular and interdisciplinary in nature and that education should match. “It is no wonder that many secondary school students complain that school is irrelevant to the larger world. In the real world, we do not wake up in the morning and do social studies for 50 minutes. The adolescent begins to realize that in real life we encounter problems and situations, gather data from all of our resources, and generate solutions. The fragmented school day does not reflect this reality” (Hayes Jacobs, 1989, p. 1). We have known for decades, long before the term STEM was first used, that interdisciplinary education makes sense, as it better prepares students to face the problems that the postsecondary world will throw their way.

In essence, the engineering curriculum, and STEM curriculum overall need to prepare students to solve problems, and bridges pose a problem. Experts state:

> There are more than 617,000 bridges across the United States. Currently, 42% of all bridges are at least 50 years old, and 46,154, or 7.5% of the nation’s bridges, are considered structurally deficient, meaning they are in “poor” condition. Unfortunately, 178 million trips are taken across these structurally deficient bridges every day. (infrastructurereportcard.org, 2021, *Bridges*)

This information comes directly from the American Society of Civil Engineers, and this is one reason why it is important to educate students about bridges and the engineering conundrum they provide.

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I also would like to thank my other two committee members for being willing to be a part of this process with me. I know that you two lead very busy lives yourselves, and yet, you were willing to give up some of that very limited free time to help me. For that, I am very grateful.

Finally, I am thankful to my wife for all of her support. If not for her constant belief in my abilities I cannot guarantee that I would have been able to accomplish this task while also managing to balance all of the other aspects of my life. I could not have done this without her.

Chapter 1: Project Introduction

I am a graduate student at Western Oregon University. In addition to being a student, and due primarily to that fact, I am also currently employed as a STEM elective teacher by Salem-Keizer Public Schools. It is because of both of these things that I am here to present my project. The project that I am presenting on bridges is focused on how important bridges are from the perspectives of engineering, history, and culture. The reason why I have chosen bridges as my focus for this project is because of both the work I have been undergoing in pursuit of my master's degree in STEM education and my prior experience in achieving a bachelor's degree in social studies education. I believe that bridges are both an incredible engineering feat worthy of exploring, as well as an integral part of the story of mankind's growth and development.

This project is designed for the purpose of being used in my classroom as a STEM teacher. I am currently working as a STEM teacher under the math umbrella at a middle school in Salem Oregon, and in my position there I have been tasked with teaching a sixth-grade course dedicated to exploring engineering. I believe that a deep dive into the history and engineering of bridges would make for a great unit for my students.

This project will explore the history of bridges, and when implemented, it will assist students in understanding just how significant bridges are and have been, throughout the history of civilization. It also showcases the depth of engineering required to create such impressive structures as many modern-day bridges tend to be, while also showing them some amazing ancient bridges that have stood the test of time and even one ancient bridge that is continuously being rebuilt in the ancient tradition of the Incas.

In short, my intent is for this project to allow me to educate my middle school students about a phenomenal example of engineering dating back thousands of years. One that has

allowed man to overcome aspects of mighty mother nature herself, such as rivers, canyons, and mountain passes. I want to connect these two different worlds of their education, STEM, and social studies, and bring them together in a way that better helps them to understand the world that they live in.

This project is important to STEM education for several reasons. The first of which is that this project is designed to encourage my students to see the interconnectivity in the world. Too often in the field of education are our students exposed to individual ideas and subjects as being separate from other areas of learning. Math is in this corner, science operates over there, and social studies are in an entirely different realm. What I believe that this project, and STEM education in general, seeks to do is to demonstrate to students that the real world does not work that segmented and separate way. They will see and understand how the various aspects of STEM, social studies, and art are intrinsically connected in a real-world application.

I also believe that, as a society, we are constantly growing and expanding our technological advancements. Along with that is the natural need for more experts in various fields, predominantly the engineering fields and other such science and technology-based careers. The more that we see electric vehicles becoming the norm, the more that we will need both mechanical and electrical engineers to design and improve them. We are seeing massive growth in virtually everything data-oriented, and we will continue to need more data engineers to keep all of our information properly taken care of. I hope that this project will be able to be used in classrooms to help encourage students to recognize a potential interest and aptitude in engineering and to then pursue those careers.

There is a gap that I feel is often shown in science/STEM and social studies education, and that is that I have not often seen a focus put on bridges in secondary education. While it is

true that some Talented and Gifted students, or TAG, may remember a time in their elementary years when they were tasked with building bridges out of toothpicks or other similar craft supplies, while this is a great place to get kids interested in engineering, this is far from a deep understanding of what bridges are from an engineering, historical, and cultural viewpoint. That is the gap that I believe my project can begin to fill.

The big ideas of this project are from two different viewpoints: engineering, and historical/cultural relevance. What is engineering if not the field of utilizing the other branches of STEM to solve real-world problems? To put it simply, bridges solve many problems that would still be major inhibitors to daily life today had they not been invented in the first place.

> Bridges are a critical component of a nation's infrastructure, making it possible to ship raw materials and finished goods to factories, warehouses, suppliers, distributors, stores, and end-consumers. Bridges also facilitate travel so consumers can purchase goods and services in their communities and beyond. When a bridge closes, economic activity slows or grinds to a complete halt. (bridgemastersinc.com, 2018, *The positive economic impacts of Bridges*)

In this quote, the economic dependency that we have on bridges is made clear. Were they to all fail, our economy would likely suffer a similar fate; that is until we were able to repair said failed bridges. "There are more than 617,000 bridges across the United States. Currently, 42% of all bridges are at least 50 years old, and 46,154, or 7.5% of the nation's bridges, are considered structurally deficient, meaning they are in "poor" condition. Unfortunately, 178 million trips are taken across these structurally deficient bridges every day" (American Society of Civil Engineers, asce.org, 2022). Gone are the days of only being able to gain materials from nearby areas, as we are now able to easily access virtually anything we wish through the use of bridges.

However, according to this information from the American Society of Civil Engineers, there is always the growing threat of bridge failure. This is why I believe it is so important to help to educate the next generation of engineers.

From the historical and cultural perspective, I have two main avenues of thinking: the legacy perspective, and the more important humanitarian perspective. If someone were to ask you to think of a bridge, your first thought will likely be wondering why someone is asking you to think of a bridge. Then, your second thought will likely be either some grand spectacle of a bridge like the Golden Gate Bridge or a sentimental childhood memory of a bridge near your hometown. “This iconic value is likely to be a combination of multiple factors: a bridge’s size, its role in the collective and popular history of the locale, its architecture, and construction, or a combination of all of these. This means that some bridges, without these characteristics, have little iconic status to anyone, although this still does not deny their importance to some” (Warnaby & Medway, 2008, p. 516). While it is clear that the Golden Gate Bridge is more iconic than a smaller bridge that may be found crossing a small creek or ravine in any area, that does not diminish the importance of both bridges to their respective communities. I believe it to be important to recognize the versatility of importance that bridges hold for us. Not only are they the economic connectors that allow the travel of goods and services, but they are also the inspirational sights that people travel far and wide to see. They are important cultural landmarks worthy of awe, while also fulfilling the true purpose of engineering; which is solving real-world problems for the betterment of humanity.

On the other hand, while some bridges are certainly viewed as a lovely backdrop for a selfie while on vacation, they also are instrumental in the daily lives of those who live outside the sphere of comfortable convenience. From a humanitarian standpoint, these bridges are essential

in connecting people to their daily needs. “Almost 1 billion people around the world don't have safe access to critical resources like health care, education, or employment due to an impassable river. With a single innovation, we can impact households across multiple dimensions” (Bridges to Prosperity). Bridges to Prosperity is a non-profit organization that seeks to connect remote households and communities in Africa, and South America to essentials: education, health clinics, and markets which makes these bridges invaluable to these communities. It is easy to look at a bridge and take it for granted simply because of how many we are likely to see each day. It is not until we are shown how essential these bridges are to so many communities around the world that we can fully appreciate their value to our daily lives.

While it is important to be informative for knowledge's sake, this project also aligns with MSED goals through its use of advanced STEM and social studies content knowledge required in order to guide students toward the understanding of how bridges are built and repaired, as well as how they impact the culture, economy, and history of their surroundings. I am also demonstrating my ability to apply learning theories through a variety of contexts that are within the STEM and social studies fields of engineering, science, history, geography, culture, and so on. I also believe that my project demonstrates appropriate professional growth and dispositions that are expected within my field of education.

In addition to aligning with MSED goals, I have also connected my project to several educational standards:

- MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

- NCSS 6.4 Recognize historical and contemporary means of changing societies and promoting the common good.
- NCSS 6.14 Identify and describe how the physical and human characteristics of places and regions connect to human identities and cultures in the Western Hemisphere. (Geography)

Considering my position as an elective teacher who is specifically teaching this engineering elective to 6th-grade students, I did not feel the need to overburden this unit by focusing on too many standards. This project connects to the first standard through the exploration of different types of bridges seen throughout the world, how they were built, and the scientific reasons that dictated them. This also connects due to the geographical influences determining the size and type of bridge that would be most effective for the people there. Much of this same argument also connects to NCSS 6.14 as my students are discovering how these bridges impact the people who utilize them, which truly shows how people and geography affect each other. We are shaped by the environmental conditions of the places where we live. While we, in turn, shape our environments to better suit our needs. Due to our focus being worldwide, this would also connect to the similar 7th-grade standard that concerns the same human and geographical effects in the Eastern hemisphere, though I opted to omit that one as I am teaching this course to 6th-grade students. The standard NCSS 6.4 is connected to my project through the focus on the humanitarian and economic aspects of bridge building.

To better explain what my project will entail, I'll explain that my project is a unit for my 6th-grade course in exploring engineering. The unit is specifically on bridges and their impact on mankind. In this project we go through the history of bridges, learning about the first bridges built thousands of years ago; we will discuss the materials used, the building techniques used, as

well as the cultural importance to the ancient peoples who built them. My project also guides students through an understanding of the engineering feat of bridge building where we will explore some of the varieties of bridges and how they are more or less useful based on the needs of the bridge. Students are also allowed to utilize bridge-building software to try their hand at designing and building virtual bridges of their own using surprisingly realistic physics. This project also focuses on the economic and humanitarian benefits of bridges by exploring and comparing different communities both before and after bridge construction in crucial areas. In short, my project seeks to expose students to a general understanding and appreciation for bridges from the perspective of multiple contexts.

Chapter 2: Literature Review

Methodology

In conducting my research, it was my goal to see what existing bridge curriculum is out there, what reasons there are why bridges are important, and to see what experts believe is essential when designing an engineering curriculum. The bulk of my research took place in three locations. The first location was through the online Hamersly Library. This was a good choice as it would give me considerable access to various sources that are not only peer-reviewed but also usually locked behind a paywall. It never hurts to utilize the advantages that being in graduate school provides you. The second location I used when conducting my research was my old friend google scholar. Wherever I need to back up an argument during discussions with friends or family, I always do a quick Google scholar search. It is a great database filled with peer-reviewed sources and scholarly articles. It is also not uncommon to find great books through google scholar as well. The third resource I utilized was good old classic Google. While it is true that the vast majority of what you might find on Google is neither peer-reviewed nor scholarly, that does not automatically remove all merit from them. I like to find some sources that are easily approachable to students, whether through a more user-friendly interface, or more simplified language. I do make sure that the information I am seeing can be corroborated by more scholarly sources, if it is, then I have little issue in applying it to my work.

Literature Review Findings

Three major themes presented themselves during my research. The first major theme, and where I began my research, was to find resources about bridges for the middle school level. The second major theme I found among my resources, and one that I did purposely seek out, was the importance of bridges to education and society. While the third major theme that I found during the course of conducting my research was how to design an effective and equitable STEM curriculum.

Bridge Resources for Middle School Classrooms

When I began my search for any existing middle school bridge curriculum, I was sorely disappointed in the surprisingly small number of sources on this topic that I had the opportunity to analyze: therefore, I had to broaden my viewpoint and also focus on technical writing on bridges as well. The first source that I found on this topic was *Theory and Design of Bridges* written by Petros P. Xanthakos, and published in 1994. In reading through this source, I was presented with a dense, technical, 1,400-page explanation of the science behind bridges. The time when it was published, 1994, it was well up to date and relied on relevant and modern information. This is, as stated before, a very technical read that includes diagrams of bridge components, mathematical equations, and in-depth bridge engineering vocabulary. Considering the high level of content knowledge required to make use of this resource, I would not personally consider it to be a good resource for the designing of a middle school-level bridge curriculum. Now on to the connections between this source and others that I have found during this process. Unlike other sources concerning only bridges, this one is predominantly focused on the scientific and mathematical aspects of bridge design. Other sources that are also centered on bridges specifically are somewhat less focused on the math and are instead more about the story behind

the bridge, or the impact that the bridge has in its surrounding area. There is a strong similarity, however, between this source and a piece titled, *The Value of Old Bridges*. The similarity here is that in the introduction of Xanthakos' work, while briefly going over the history of bridge engineering, he highlights multiple historical bridges and similarly discusses them to what we see in *The Value of Old Bridges*. Other than that, the primary connection between this work and others is simply that of a purpose to educate.

The next work that falls into the category of either being curriculum, or resources for curriculum on bridges is *The Value of Old Bridges* written by Eric Delony and published in *APT Bulletin: The Journal of Preservation Technology* in 2004. This resource explores the cultural impact of bridges as well as the engineering feat that is bridges. Delony asks whether or not it is important to save old bridges, famous or otherwise, considering the connection to the past that they offer. The writer also highlights the fact that the required funding to replace the current, at the time, 159,000 structurally deficient bridges are not currently available. The remainder of the article consists of visuals and explanations of old bridges from various locales around the world. This heightens the argument for saving old bridges as it showcases them as historical sites or crucial setpieces of the story of their surroundings. Overall, this is a source that can be easily used as an argument for the importance of bridges, and also as a resource for information on a handful of individual bridges themselves. There are several important connections between this piece and others that I have found during my research for this project. For instance, the aforementioned connection to Xanthakos' *Theory and Design of Bridges*. Additionally, the overall theme of this resource would also connect to both the first and second of my major themes listed in the first paragraph of my literature review findings. They are the existing bridge curriculum for middle school classrooms and the importance of bridges to society. I would

consider this resource to be connected to the first as it has information that would easily find a home within the exploration of bridges for a middle school class, and it connects to the second theme as it is directly addressing the question of whether or not old bridges are important enough to society to be saved.

The third resource that I found to fit into this theme is *The Highways of the Incas*, written by Victor W. von Hagen and published by the *Archaeological Institute of America* in 1952. The first thing that could, and should be said of this resource, is that it is not able to be considered a recent work. Having been written seventy years ago, it is easy to assume that there are likely to be gaps in understanding that have since been filled. Much of this resource discusses the method and style of Incan roads and bridges across their entire empire. Only a small portion of this six-page article is devoted to the Incan rope bridges themselves, and that portion is significantly lacking in terms of details and specificity. Overall, I would not likely have this be a resource that makes an appearance in the curriculum due to its age, however, it does have use in terms of verifying the information in other newer sources. This resource connects to other resources I have found. Specifically, I would say that this connects to both of the previous resources through its visual and written description of the Inca rope bridge being similar to the descriptions of old bridges in *The Value of Old Bridges*. This resource, while outdated, is still a good tool to use when cross-referencing information about Inca roads and bridges. That being said, a cursory glance at YouTube is likely to leave you with better in-class resources for students.

The fourth resource in this theme is an article titled, *7 Types of Bridges That Every Engineer Should Know About.* This can be found on the Enerpac website. This does exactly what it states that it does, it explains aspects of the 7 main types of bridges. It does this through a picture of each type of bridge, as well as a list of advantages and disadvantages in the form of a

bullet-pointed list. What can be said about this resource is that it is not peer-reviewed, not to say that it is filled with incorrect information, but I point this out mainly to illustrate that it has a higher likelihood of being biased. That being said, due to the nature of this resource, in that it is delivering factual information about various types of bridges it is easy to see that any inherent bias is going to be minimal. This would be a good resource to have students explore in order to gain a better understanding of how the 7 main types of bridges are different. These resources share connections with several of my other collected resources. This shares a connection with Xanthakos' *Theory and Design of Bridges* in that it focuses on some of the technical aspects of bridges, albeit in a manner that is much more accessible to middle school students than the exceptionally technical writing of Xanthakos. Additionally, this resource also connects to, and gives context for, Delony's *The Value of Old Bridges*, as readers of both would then have a better understanding of why the different old bridges were used and what their strengths and weaknesses are. Another connection is to the major theme of the importance of bridges to society. I feel that seeing the connection between the appearance of bridges and the engineering design reasons for those aesthetics helps readers understand the importance of bridges and their designs.

The Importance of Bridges to Education and Society

One resource that goes a long way to explaining my reason for why I believe there is such a great need for a bridge curriculum at the middle school level is the American Society of Civil Engineers' *Report Card for America's Infrastructure*, specifically their section on bridges. This report card highlights many things pertaining to bridges, including the staggering number of bridges there are in the United States, as well as the uncomfortable number of them that are

currently considered to be structurally deficient. Additionally, there is also an emphasis on the preposterous amount of money it would take for the needed repairs on these bridges. This information is about as accurate and straight from the source as possible, and it is presented in multiple ways, including written explanations, graphs, and interactive graphics as well. Overall, this is a very good resource for use in the middle school bridge curriculum, as it clearly explains our current scenario which gives students a good opportunity to practice problem-solving. This resource connects quite heavily to any of my resources that deal with the issue of aging bridges and the concerns that accompany them. There is also a connection to any resource that references the issue of allocating the appropriate funds to repair the current, and future, structurally deficient bridges. The greatest of these connections is between this resource and the next resource concerning the economic impact of bridges.

In 2018 Bridge Masters Rentals, a construction company that specializes in bridge repairs and attachment installations wrote an article titled *The Positive Economic Impact of Bridges*. This article discusses this economic impact in terms of infrastructure, wages for workers responsible for bridge construction and maintenance, as well as the more direct impact of connecting goods and services to locations with the needs and means to acquire them. Additionally, the second half of the article showcases a specific set of bridges, specific in that they all are examples of bridges that have led directly to the economic benefit to the regions they are connecting. This resource's validity can easily be called into question as a quick glance at the Bridge Master's website will plainly state that they are in the business of bridge building and repair. Therefore, they are biased toward the building and repairing of bridges. On the other hand, they are fairly transparent about this bias as they highlight the economic benefit of those to conduct bridge repair, which of course includes themselves. Given their transparency, and the

accuracy of the information they are providing in this article, this is a solid source to utilize when discussing the economic impact of bridges. This resource connects to several resources that I have already spoken of due to their discussion of specific bridges including photos, descriptions, and locations. What is different is that this article is focused on economic impact specifically. It is, in fact, this economic viewpoint that connects the Bridge Master's article to the next resource, however, the next one seeks to spend money instead of making it.

In my research looking into why there is a need for there to be a middle school bridge curriculum, I found a charitable organization that seeks to build bridges where they are most needed. The organization is called Bridges to Prosperity, and they have a page on their website simply titled *Why Bridges?* They are a non-profit organization that deals with building suspended and suspension bridges in rural areas of Africa, South America, and Central America. This page highlights the number of people who are currently unable to have access to daily essential services such as healthcare, employment, etc. (Bridges to Prosperity). Now, there are multiple things that can be said about this group from a critical standpoint. This page is not a peer-reviewed source, nor do they provide citations for their claims. However, upon cross-referencing, the information presented on their site does seem to be substantiated by reputable sources, and beyond that, the work that they are seeking to do does indeed bring the people of these rural communities closer to their needs. This is a good resource to highlight the importance and impact that bridges have on their communities, and why it is important to learn about them at a young age so that we carry that understanding into our adult lives. Unfortunately, apart from some light references in the Bridge Master's article, this was one of the only sources I was able to find that was devoted entirely to the humanitarian usefulness of bridges, and why it is important for more bridges to be built to give resource access to rural communities.

While it is difficult to find an existing bridge curriculum for the middle school level, it is not difficult to find arguments for why such a curriculum should exist. One such example is *The Impact of a Middle School Engineering Course on Students' Academic Achievement and Non-Cognitive Skills*. This is a nineteen-page article found in the *International Journal of Education in Mathematics, Science, and Technology (IJEMST)*. This resource is a case study to see how middle school students are impacted by engineering courses. Not surprisingly, they find increased standardized test scores in math and science among those students who have taken two or more engineering courses. This resource is peer-reviewed, and clearly describes the curriculum's skills and practices used in the study, as well as the methods and sources of data. Due to the detail and thoroughness of this resource, as well as the content of the curriculum itself, it is a good resource to argue for why there should be a hands-on real-world engineering curriculum, like that of bridges. This resource connects quite heavily with many of the resources that fill out my third theme, that of effective and equitable STEM education. In addition, there is another of my sources that is also a case study with a focus on a hands-on middle school science-based curriculum.

Speaking of that other study with a focus on a hands-on science-based curriculum, it is called, *Productive Thinking in Middle School Science Students' Design Conversations in a Design-Based Engineering Challenge*. It was written by Maurina L. Aranda, Richard Lie, and S. Selcen Guzey, and published in the *International Journal of Technology and Design Education* in 2020. Much like the previously listed source, this study was designed to analyze science-based curricula. However, this particular study is based less on how those students go on to score in standardized tests and more focused on understanding the thought processes of those students who are currently engaging in design, which is a highly complex activity. The results of this

study are not surprising, students are able to think about designs and issues in a wide variety of ways while utilizing different cognitive processes. This supports the creation of a hands-on bridge curriculum for middle schools. This study is peer-reviewed, as well as being published in a reputable journal, and is backed by a significant number of sources. This is an excellent resource for curriculum planning, as it gives insight into some best practices based on empirical evidence. In addition to being connected to the previous resource, *Middle School Engineering Course on Students' Academic Achievement and Non-Cognitive Skills* , this study is also connected to my resources that fall into the theme of assisting in designing an effective and equitable STEM curriculum.

In 2012, an article was published in the *Journal of STEM Education* by two professors from Texas A&M International University. It is titled *Promoting Engineering Education Among High School and Middle School Students*, and it was written by Rohitha Goonatilake and Rafic A. Bachnak. Their goal for this study was to discover and promote an alternative to the, at that point, current secondary engineering curriculum in order to combat the decline in students pursuing engineering degrees. They did this by offering a one-week workshop to expose students to the field of engineering and to give them contextual knowledge about the careers within the field with the hope that this would demonstrate to them that engineering can be fun, interesting, and enjoyably challenging. In short, it was a success, students seemed to very much enjoy the workshop, they were thankful to the organizers for the opportunity, and some of them even stated that they would apply to take courses through the university that fall, with the majority expressing interest in doing so down the road. This is a strong source of information, their data set is clearly presented, labeled, and explained. It is peer-reviewed, and the study and article were both designed by experts in the STEM fields. This has some clear connections to the previous

two sources, as all three are articles written about studies focused on the implementation or effectiveness of engineering curricula. In addition, this also connects to my sources that focus on the design of effective and equitable STEM curriculum, as it was clear through the reading of this article that the vast majority of the students involved were engaged enough to express interest in college courses in engineering after just one week in a workshop.

Christine M. Cunningham, a professor of the practice of education and engineering at Penn State University, wrote and published a book titled, *Engineering in Elementary STEM Education* in 2018. There are many questions that this resource asks and seeks to answer, but they all revolve around engineering in the classroom. This resource discusses some of the reasons why they believe that engineering does not really exist at the elementary level, and points out how flawed they consider that line of thinking. Cunningham also discusses the inconsistency of in-depth science education that occurs in various classrooms. Each state, and therefore each science classroom, has a set of standards that they are required to teach to; however, not every state or district actually utilizes science standardized tests in order to verify the quality of the science education. Personally, I do not believe that standardized testing is the best methodology for testing due to its inherent inequities, I do understand that it is a tool that is readily available to use for the purpose of analyzing the effectiveness of the curriculum. While it is true that this resource is predominantly about the implementation of the engineering curriculum at the elementary level, there are still multiple references to the need for more engineering curricula at the secondary level as well. Overall, this resource is very well researched, supported by a significant amount of separate sources and studies, and seems to be able to be utilized to build the foundations of a solid argument for implementing more engineering curriculum at any educational level, despite its primary focus being on the

elementary level. Much of the themes present in this resource are also able to be found within my other sources that are concerned with curriculum design.

How to Design Effective and Equitable STEM Curriculum and Examples of Existing Curriculum.

Throughout my research on this topic, it became very clear that the most important resources to me would be ones that dealt with the design of an effective, equitable curriculum that could be applied to bridge curriculum designed for a middle school STEM/engineering classroom. Before the term STEM became common nomenclature in the educational world, the phrase, interdisciplinary studies, was the predecessor of what we now call STEM. In 1989, the *Association for Supervision and Curriculum Development* published a work titled, *Interdisciplinary Curriculum: Design and Implementation*. This seven-chapter piece discusses the need for a curriculum that is inherently cross-curricular, as well as detailed explanations of how one may go about constructing said curriculum. Essentially, what they are talking about is STEM, despite the fact that the term STEM had not been put into words at that point. One point that the authors make is to point out how different school is from the reality of life after school. School subjects are set up to be so segmented, math during this period, social studies during that period, etc... In reality, when we are confronted with a problem, we won't think about it in terms of math first, then the science second, we are usually presented with a multi-faceted problem that must be addressed as such. This suggests the need for a curriculum that is interdisciplinary by design. Overall, this resource is, despite its age, surprisingly relevant. The ideas that they are presenting are still mostly connected with what educators are currently talking about implementing. If anything, this source demonstrates just how slowly public education moves in

terms of curriculum updating. Definitely a useful resource, but I would make sure to back it up with more recent research as well. Very much connected with virtually every other source that I have on effective curriculum design in the sense that they are able to be used to support the argument for cohesive and interdisciplinary instruction.

In terms of a more recent curriculum design tool, not too long ago in 2020, Reina Fujii, Kevin W. McElhaney, and Nonye Alozie co-wrote a short yet detailed curriculum design tool titled, *Promoting Equity and Inclusion in STEM Curriculum Design*. There are two regular terms used in this short resource, ECD(evidence-centered design), and EI(Equity and Inclusion). In short, this is a step-by-step process for how to design a curriculum to be equitable and inclusive by breaking down all of the steps into a flowchart. Along with this flowchart is an expanded explanation of each step, including an introduction, design steps, and implications sections. Is it viable to use this when designing a curriculum? Absolutely, in fact, I would say that it seems to align with what universities are current;y teaching in terms of equitable education. This is especially true as the primary focus is to link design choices to evidence of student achievement in learning. This resource most connects to the few case studies listed in the previous section. This connection exists due to the fact that this resource requires there to be evidence, to be legitimate proof that the methodology that you are utilizing has actually led to student learning.

Closely linked to the idea of promoting equity is that of providing the best experience for ELL students to gain authentic academic language in English. In 2017, there was an article published in the *European Journal of Education Studies* titled, *Crucial Importance of Vocabulary in the Process of Second Language Learning: an Exploratory Study*, written by Birjees Fatima, and Inakhab Alam Khan. This seventeen-page paper utilizes a significant number of resources to highlight just how important it is to include vocabulary in the curriculum. From personal

experience, vocabulary has not often been anywhere near the forefront of importance in education. This same thought is echoed by the authors of this paper. This article also utilizes a wonderful graphic flowchart demonstrating what is currently known about the connections between academic language, vocabulary, and reading comprehension. They continue on to explain the types of vocabulary, and include another graphic showing the relationships between them. Overall, this is a solid source of information about how important vocabulary can be to the effectiveness of the curriculum. Due to the nature of this resource, being about best practices for equity in the classroom, it is quite connected to each of my other sources that focus on best practices in curriculum design.

The notion of hands-on learning being an effective method for students to truly learn from the experience is far from new. In 1999 a piece was published in the *International Journal of Engineering Education* titled, *Hands-on Engineering: Learning by Doing in the Integrated Teaching and Learning Program*, written by Lawrence Carleson and Jacquelyn F. Sullivan. If only to further the argument that hands-on learning is effective, this piece begins with a quote from Benjamin Franklin, "Tell me, and I forget. Teach me, and I may remember. Involve me, and I will learn." When we consider just how long ago Benjamin Franklin lived, it adds some context to how long educated individuals have valued hands-on experience in the educational setting. The resource is dedicated to detailing the Integrated Teaching and Learning Program, which was originally initiated in 1992 with the goal of reforming undergraduate engineering education. The authors explain various aspects of the program itself, including both methodological and physical aspects. This is not a source that I would personally find very useful when creating a curriculum for the middle school level. Essentially, this is an explanation of a collegiate program, its facilities, and the access to various physical resources that they provide to its students. The bulk

of this source does not really connect to much of my other research apart from the emphasis on hands-on experience. Due to this program being designed for college students, their access to funds for equipment will be significantly higher than what a middle school would be able to afford.

One very important thing to consider when designing a curriculum is to consider what manipulatives you will provide for your students. In terms of bridge curriculum, should the students be building with physical materials, or should you opt for a more digital approach utilizing virtual bridge-building technology? In 2007, the *Journal of Research in Science Teaching* published a work by David Klahr, Lara M. Triona, and Cameron Williams titled, *Hands on What? The Relative Effectiveness of Physical Versus Virtual Materials in an Engineering Design Project by Middle School Children*. This resource sought to compare physical and virtual manipulatives in order to determine which is more effective. In this scenario, the activity used to determine the effectiveness of each type of hands-on education was to design and build mousetrap race cars with the most effective being the one that went the farthest. They used a 2 x 2 x 2 factorial design utilizing different variables such as materials used (physical vs. virtual), constraints (fixed amount of time vs. fixed number of cars), and the test phase (pretest vs. posttest). The four groups, when all was said and done, scored very similarly on both the pretest and the posttest. The study found that while there were multiple differences in the students' results due to the variables, their learning was not one of them. In fact, they found that students' knowledge and confidence gains were not affected by the materials used. This resource is a good tool to demonstrate how effective both physical and virtual manipulatives can be in the classroom. It connects to other sources that highlight the importance of hands-on experiences, such as Carlson and Sullivan's *Hands-on Engineering: Learning by Doing in the Integrated*

Teaching and Learning Program. They both have different education levels in mind, but they are both promoting the use of hands-on inquiry-based learning.

One very important factor when designing a curriculum is choosing who is involved in the design process. In 2016 Merfat Ayesh Alsubaie wrote a short article titled, *Curriculum Development: Teacher Involvement in Curriculum Development*, which was published in the *Journal of Education and Practice*. In this article, the author discusses some of the important reasons why teachers should be involved, as well as some challenges that teachers may face depending on their situation. However, the reasons why teachers should be involved in the curriculum design process are fairly vague and could do with some more detailed descriptions of the advantages of their involvement. That being said, their arguments for some of the challenges that teachers may face when assisting in developing curriculum seem sound. It is stated that teachers do need to have the proper training and professional development in order to be qualified to assist in this process, and that is something that not all teachers have. In short, this is a peer-reviewed source that can be used, at the very least, as a conversation starter to work towards more teacher involvement in curriculum development. This connects to much of my work thus far, as I am indeed a teacher who is developing a curriculum.

The last three of my sources for this review are all examples of bridge-building activities, each one with a different methodology and focus, but all would find a good home in the middle school engineering curriculum. The first of these resources is Charles Beck's *Teaching Elements and Principles of Bridge Design: by Designing Model Bridges, Students Can Begin to Appreciate How Engineers Construct Elements that Produce Tremendous Force, Such as Arches and Cables*, published by the *International Technology Education Association* in 2005. Here, Beck promotes utilizing materials other than the standard fare, toothpicks, LEGOs, straws, etc...

Instead, he suggests supplying students with materials that will allow them to test their models in ways that real-world bridges are tested. He suggests styrofoam, wooden blocks, paper clips, and cotton pins. The idea presented is to use these materials to design and build suspension or arch bridges. The project involves some analysis of their bridges to determine their efficacy, as well as an extension activity utilizing extra research online, and a PBS series, to see the role of bridges in ancient society. This is a great activity, and it could be implemented at the middle school level quite easily. The biggest issue with this activity is that it is very material-heavy, and many of these materials are not good for the environment. I would not personally utilize any styrofoam materials, and I would seek to find a suitable replacement.

The next existing bridge-building activity comes from Australia. The activity in question is simply titled, *Building a Straw Bridge*, and was designed by the *Institution of Engineers, Australia*, often referred to by *Engineers Australia, in 2015*. This resource gives a brief description of how bridges are important as well as how they have evolved throughout history. There are examples of a few types of bridges including written descriptions along with some visual representations. The next, and final, two pages of this document are dedicated to the activity itself. This includes explanations of the overall structure of the project including descriptions of needed materials, student research, connecting the materials used to the comparative cost of construction materials, design, the testing stage, critiquing, and the assessment of student work. In addition, there is even a connection to standards, albeit Australian standards, but it would not be outside the realm of possibility to also connect them to the standards of any given area. Overall, this is a solid bridge-building activity, it is standards-based, from a peer-reviewed source, and seems to be designed in a way that encourages student participation. One weakness that it has is that it is based on the utilization of a significant number

of plastic drinking straws. This is not ideal due to the fact that these are single-use plastics that are not as eco-friendly as I would prefer. This connects to my sources on equitable instruction due to the formation of rotating team roles. This is also quite connected to the previous source, as well as the next one, due to all three being bridge construction activities.

The final resource for this literature review is a high school math teacher's take on a bridge-building project to aid students in utilizing their math skills in engineering. The resource is titled, *Geometry and Mathematics Through Bridge Building*, written by J. Joyner, and published by *The Journal of Mathematics and Science*, in 2000. This seven-page article describes the setting of, materials for, and implementation of a mathematics-based bridge-building activity for a group of middle school students during an extended day program. Joyner goes on to describe a hands-on, inquiry-based activity to encourage students to use their mathematics skills practically through engineering. The activity itself is broken down into three phases. The first phase is one of research, where students will create a one-page summary of their new knowledge of truss bridges. The second phase is one of designing a 2-dimensional truss bridge on graph paper, but one that fits certain criteria. The third phase is the construction phase, where students design and test a virtual bridge in digital bridge-building software. Overall, this activity does seem like a well-put-together task for students to complete. It is strong in that it absolutely connects STEM's M to its E as it heavily relies on student math skills in their engineering. It is not without its weaknesses however, this project is designed for a small group of students, Joyner mentions groups of eight to sixteen students specifically. This could be used in a more standard classroom setting, although it would require some adjustment. This is well connected to the previous two resources due to its nature as a hands-on bridge-building activity. Another resource that this connects heavily with is Klahr, Triona, and Williams' *Hands on What?*

The Relative Effectiveness of Physical Versus Virtual Materials in an Engineering Design Project by Middle School Children, due to the use of a virtual program for much of the construction and testing of the bridges. This is supported by their discovery that virtual and physical projects are accompanied by a similar level of learning.

Conclusions

This review highlights resources on bridges for middle school students, the importance of bridges to society, how to design an effective and equitable engineering curriculum, and the existing bridge curriculum for the middle school classroom. What can be said is that the bridge curriculum for the middle school level is certainly lacking. While it is true that some fantastic activities are already in existence, however, they are either somewhat simplified or a bit too narrow in scope to really educate students on the importance of bridges. Other sources here are able to be used to expand the existing curriculum into one that educates students about the different types of bridges, their uses, their importance, how to build them, and who is out there building them right now. Arguably the most important part of this review was to find resources for how to design this curriculum to give each and every student their best chance to both succeed and learn from it. The importance of proper vocabulary use to help ELL students gain practical academic language in English was highlighted. We also learned how both physical and virtual tools lead to roughly the same amount of overall learning among students. However, as this review has shown, a curriculum that promotes equity while also teaching about the multiple aspects of bridges that we have discussed simply has not existed yet.

Chapter 3: Methods

Classroom Context

I work for Salem-Keizer Public schools, a school district that extends through all of Salem and Keizer proper, both in Marion and Polk counties. Currently, the school district serves 40,155 students through its 65 schools making it the second largest school district in the state behind Portland Public Schools. Approximately 84% of the student population of Salem-Keizer Public Schools is considered to be economically disadvantaged. The English Language Learner population makes up about 18% of the district student population, while 17% of the total population is currently receiving Special Education services (Salem-Keizer Public Schools). The individual school where I teach is Carlos Houck Middle School, typically referred to simply as Houck. Houck Middle School serves neighborhoods in Southeast Salem and feeds into both North Salem High School, as well as South Salem High School. Based on data from the 2020-2021 school year, the school population is 1,043 students between 6th and 8th grade. The ethnic demographics at Houck are as such, 64% Hispanic, 25% White, 5%Native Hawaiian or other Pacific Islander, 3% Two or more races, 1% Black, 1% Asian, and <1% Native American, 1% Unspecified. Additionally, around 85% of all students at Houck are currently living under the poverty line (greatschools.org).

I was hired for the 2021-2022 school year as a full-time STEM elective teacher under the math umbrella. It was in this setting that I began the process of planning and testing this bridge-building curriculum. That being said, I am currently working for the same school as a 6th-grade social studies teacher. This project though is designed with my previous position in

mind. My elective class intended to guide students through engaging STEM curricula with a focus on building their mathematics skills. My course was a one-term, or twelve to thirteen-week course, that we titled *Math Workshop*, and given how it was scheduled the goal was that each and every student would have one term in my classroom during their 6th-grade year. During any given term, I would have approximately 150-165 students each day, with each class varying between 24 and 34 students.

In each of my classes, I would have anywhere from 7 to 23 English Language Learners at differing levels of English language acquisition. I would also have anywhere from 3 to 11 students receiving Special Education services. That is not including TAG students or those with 504 documentation, I had between 1 to 5 and 1 to 7 students with those forms of documentation respectively. To be clear, this is an approximation of the average across all five classes per each of the three terms. The intention behind my course was to be a project-based STEM elective with an extra focus on practicing mathematics skills. We explored the concept of engineering, and how the four STEM subjects are connected, worked on various projects, viewed the work of actual engineers, and discussed the engineering field as a career opportunity. Some of this work was directly led by me, but a fair bit was student-led with me acting more as a facilitator and guide. This was made possible due to the presence of Chromebooks for student use.

Purpose of this Project

We are currently living in a time of dramatic technological advancement, a time of interconnectivity, a time of practicality, and also a time of restructuring. Each of those advances requires, to varying extents, engineers. The intent of this project is, in short, to provide young students with the opportunity to step into the shoes of an engineer and understand the importance

of their work. When I thought of different project options to accomplish this goal, I decided to teach about something very important to our daily lives, the economy, and the general infrastructure of any region, bridges. Not only are bridges a marvelous feat of engineering, useful, and practical: but they are also something that most people take for granted. Perhaps they do not even notice when they cross over or under a bridge on their commute to work. It was not until I began this project that I started to realize just how frequently I use a bridge, and how often I have taken them for granted.

It is my belief that everyone would benefit from having better knowledge, understanding, and appreciation for bridges. Not only do I think that teaching kids about intricate and specific aspects of engineering will encourage some to pursue that particular career field down the line, but I also believe that those who choose not to traverse that career route would still benefit from having experienced that education. If nothing else, even if students do not feel inspired by the process, or do not consider the idea of becoming an engineer to be in their interests, they will still have had some real-world, hands-on, practical education on an aspect of their lives that they may have never really considered to be important. The purpose of STEM is to connect science, technology, engineering, and math together in a meaningful way, and I believe that bridges can do just that.

Design Process

I began the process of designing my curriculum by examining the amount of time that I would have to instruct it, as well as the end goal of what I would like to see from my students. Considering my situation, I knew that within a twelve-week course, and my other units to consider, I could only allocate a bit more than one week to this particular unit. I knew that I

could spend upwards of three to four weeks focusing purely on the topic of bridges. I had to take a cue from Larry David, and curb my enthusiasm if only just a little bit. For the end goal, as in the end product, I had envisioned that my students would work together in teams to design and construct a bridge for testing. This seemed an easy choice to make: however, I also decided that their bridges should be modeled after, and function like, an existing/previously existing bridge somewhere in the world.

Once I had those decisions made, it was time to figure out how to introduce them to bridges, their types, their purposes, and their importance, all in the first half of a week. So, I decided to do some research to find out why experts believe bridges to be so important. I came across multiple resources that strongly supported the importance of these engineering wonders, although, the resource that I felt best explained both the general importance of bridges and the scope of the problem that can occur if they are in disrepair was ASCE's 2021 Infrastructure Report Card, specifically, their section about bridges. Upon starting to read their report, I was floored immediately by the first few sentences, which stated:

> There are more than 617,000 bridges across the United States. Currently, 42% of all bridges are at least 50 years old, and 46,154, or 7.5% of the nation's bridges, are considered structurally deficient, meaning they are in "poor" condition. Unfortunately, 178 million trips are taken across these structurally deficient bridges every day. (infrastructurereportcard.org, 2021, *Bridges*)

This information had a profound impact on my perspective. It is difficult to understand the scope of the statistics that they provided here, but it is clear that bridges are integral and that they are also in need of care.

Next, I needed to determine which specific types of bridges I wanted to focus on. After some research into different types of bridges, their strengths and weaknesses, and their frequency of use, I found a good article detailing bridge types that everyone should be familiar with, and I agreed. The seven specific bridge styles are as follows: arch bridges, tied arch bridges, cable-stayed bridges, suspension bridges, cantilever bridges, truss bridges, and beam bridges. Additionally, because I cannot pass up the opportunity to make a dumb joke, I decided to add an extra eighth bridge, Jeff Bridges. With those decided, I found some good visual examples of these types of bridges for my slide shows, as well as a video that shows the same seven types of bridges. My thought process here was that my students were being exposed to the same information in a variety of ways. My hope was that this would allow for better understanding and retention of information, especially given how short the unit needed to be.

Project Structure

The first day in my five-day version of this bridge-building unit was focused on getting some relatively basic bridge information and terminology to my students. This was done through the use of a slideshow. I had dedicated one slide to each of the seven bridge types that we would be focusing on. Each of these slides had the name of the type of bridge, a picture of a typical example of that type, and some of the strengths and weaknesses that the type of bridge has. Some examples of strengths and weaknesses might be connected to its cost to produce, or perhaps the general physical strength and durability of that particular type of bridge. Other examples include achievable span length, rigidity, and materials used. Throughout this slideshow, students are taking focus notes about each type of bridge.

After the note-taking portion of the lesson, we moved on to a couple of short videos on bridges. The first of these videos was simply titled, *Types of Bridges*, it was published on YouTube by the channel, Engineering world on April 24th, 2021. This video very briefly shows these same seven types of bridges simplistically, but one that also shows the support systems fairly well, and it helps students to better conceptualize the types of bridges. The second, and final video, for that lesson, was titled, *Paper Bridge World Record - 1071 lbs*. This video was, as one might imagine, about the world record, as of February 2008, paper bridge that managed to have over one thousand pounds suspended from it before it eventually collapsed. I chose this video as it demonstrates the incredible strength of this engineering wonder. Which in turn also provides more visuals in my lesson, allowing for ELLs and SPED students to have more easy access. Then, to close out the day, I gave students a sort of verbal quiz where they would be able to use their notes to assist in answering. I would give them a handful of physical descriptions of areas that could use a bridge, it was their job as table groups to come up with one of the seven bridge types that would fit that location based on their strengths and weaknesses. During this process, I would have them write down the answers to the questions and turn them in before they leave. This marked the end of the first day of the project. This was just one day of my unit, given the time constraints that I had, it would be relatively easy to extend this out into two or three days if there is enough time to do so.

The second day of the project was focused less on the physicality of bridges and more on the humanitarian impact that bridges have. I started this lesson off with a seemingly simple question, “How do bridges help people?”. To answer this question, I had students think, and pair share, which began with about thirty seconds to one minute to ponder their individual answers, then another two minutes to share that answer with their neighbors and to hear their answers.

Finally, I would raise my hand to model good behavior and ask for volunteers to share their thoughts. Most answers were surface level, “people can go across rivers”, or, “they let people travel”. Then, it was my plan to take a step back, and allow students to look into how bridges help people. Students were to work in pairs to find a specific bridge out there in the real world, specifically one in a developing country, and to determine how many people, on average, cross that bridge each day, month, or year. This then turned into a classroom discussion about the different things that they would have to go without if that bridge was not there. The hope is that this will have provided my students with the perspective of, and empathy towards, those who are living in these situations.

Once we have finished our discussion, it is time to introduce the building portion of the unit. Each table group is tasked with designing and building a model bridge that is based on a real bridge. This bridge must also be an example of one of the seven main types of bridges that were discussed the previous day. Some groups, in my experience, were left looking like deer in headlights when given that level of freedom of choice, you could always opt to choose the bridge type for them, which would allow them to spend the time focusing on finding a specific bridge of that type. The information that I needed from each group prior to proceeding included: the bridge name, the bridge type, the location of the bridge, and when it was constructed. Once they had brought that information to me, we would discuss the materials they needed to build it. Some of the materials that I would provide include cardboard, string, rubber bands, paperclips, popsicle sticks, glue, and tape. Part of my lesson included allowing students to bring in materials from home if they preferred, given that they presented me with the materials and that I agreed. Before leaving on the second day, I had an exit ticket. It was simple, just one question. “How can a

bridge benefit a group of people?". This was a formative assessment that I implemented to make sure that students were able to articulate the positive impacts that bridges have on society.

The following three days were virtually the same, this was the project portion of the unit. Here, table groups would need to have written a list of materials they would need to construct their bridge. Once I had received the list, I would verify what they had planned for each of the materials, they defended their argument, and I provided them with the necessary materials. Then, those three days, or as long as anyone would like it to be, were spent keeping tabs on each group's project, asking questions that would require them to understand why they were doing what they were doing, and making sure that students were treating the classroom materials with respect. The goal was that, by the end of the week, each group would be done with their bridge, so that it would be ready for testing. It is no guarantee that each group, or class, would need all three days to complete their bridge. This is especially true in the case of some bridge designs. If any class was ready by the fifth day, we would have spent that day testing the bridges, otherwise, the testing would follow on the sixth day of the project.

Speaking of the sixth day of the project, we have arrived at the culmination of the previous week's work. This was the day when we show and break our bridges. I say show and break as the whole point of testing a bridge is to test it to failure. For this purpose, I had brought in about twenty dollars in pennies, all in one dollar rolls. The thought was to use these as the weights for strength testing of each table group's bridges. In designing this process, I had to decide how I wanted to go about testing their bridges. Most bridge tests that I came across in my research involved creating a hook or loop underneath the bridge to which some form of hanging weights would be added. While this does seem to be the most common process, I did not feel that this would be as realistic given the materials I had at my disposal for bridge building. Therefore,

I decided to test each bridge by seeing how much weight it could hold across its span, much in the same way that bridges carry weight in reality. So, the first thing we did was to meet up with another class who was working on the same project and run our gallery walk. Each group would need to explain what type of bridge they built, the name of the real bridge it was based on, where that bridge is in real life, and when that real bridge was constructed.

Once the gallery walk was over, it was time to walk back to my classroom to see which bridge was the strongest of them all. One by one, I would set a group's bridge up between two desks in my classroom. Once it was set up, I would add my rolls of pennies one at a time. Most of the bridges did not survive more than three to five dollars worth of pennies. This was due to the fact that most of the bridges were of the beam and suspension types, neither of which are listed among the strongest of bridges. In the end, there was one bridge that managed to survive all twenty dollars of pennies stacked along its span. Not surprisingly, this happened to be a model of a truss bridge, which happens to be the strongest style of bridge in real life. I then allowed students to take the remnants of their bridge projects home with them if the group could decide which team member got to do so.

Assessment

How did I assess this project? Overall, the assessment of each table group's project was based on a combination of project completion and effort given during the project. The simple fact is that not all students are going to be on an even playing field in any given activity. Some students will excel while other students struggle, and I believe that in an engineering elective course especially, it is important to take overall effort into account when grading a project. It did not matter whether we were working on building catapults, paper airplane launchers, or in this

case, bridges, young students should be graded heavily on effort and not just on the efficiency of their engineering projects. Luckily, each of my table groups in all of my classes managed to turn in a completed bridge, therefore, the only portion of the grade I really needed to think about was the effort given during the project. This was the portion that varied the most from person to person, even in the same group. Each individual would receive half credit just by having the bridge completed by their group, however, their effort score would be entirely based upon their individual effort given during the project.

Chapter 4: Final Product

Link to my lesson plans

Chapter 5: Reflection

I would like to think that I learned a great many things from my time working on this project. I realize now, as I look back, that I don't believe that I knew much more about bridges than my students did when I began to teach them. In my research, I learned about the seven main types of bridges, their advantages, and their disadvantages, and I learned just how precarious the state of bridges in the United States is, and just how drastically we are in need of the legislation, engineers, and funding required to solve the disrepair issue we are currently facing. I also learned that there is very little existing STEM education that has a focus on the topic of bridges. During my research, I found a handful of different bridge-building projects at various educational levels, however, the vast majority of them were focused on using a bridge merely as a means to teach a scientific principle and not to teach about the topic of bridges as a whole. This confirmed what I had believed to be true when I was researching various projects to instruct while I was designing my engineering course, that there is existing curriculum for most engineered structures, except for bridges.

In designing this project, I learned that there are very few engineering feats quite as difficult as bridges when you think about how they manage to support hundreds, if not thousands, of tons of weight in the air. That figure is often merely the weight of the bridge itself, not to mention the hundreds or thousands of vehicles or people that may be crossing said bridge at any given time. For instance, here is some information on one of the most famous bridges in the United State, the Golden Gate Bridge, "Original combined weight of Bridge, anchorages, and approaches is 894,500 tons." (goldengatebridge.org) Even though the Golden Gate Bridge is so massive, it could be undone When I thought about just how strong yet fragile bridges are, I could not help but think about them as something that everyone should learn about.

I also learned quite a bit through the process of teaching this to my students at the tail end of last year. I learned how much many students enjoy the idea of breaking down their projects while testing them. There is a certain amount of morbid joy when a bridge snaps under the pressure of several dollars in pennies. In addition to their glee at bridge failure, I also experienced the power of choice first-hand. I have always been told how empowering it can be to give students choice, but it was very different to see the impact to this extent. I have the opportunity to see their excitement as the teams began to decide upon the particular bridge to emulate with their models. It was also during the teaching of this project that I realized how useful it may be to specifically assign individual roles to group members, as this might avoid unnecessary in-fighting when students attempt to self-assign group roles.

This project made me think about teaching an engineering feat, and projects in general, in a more holistic way. What I mean by this is that I began to think about things from the perspective of teaching about not just the act of building a bridge, but understanding a bridge. I wanted students to know how bridges are designed and built of course, but I also wanted them to understand the history of bridges, and more importantly, the humanitarian benefits of bridges. I had to think about things differently than I usually would, as I had to put emphasis on how bridges affect the populations that utilize them. Considering how infrequently most people think about bridges at all, or how they themselves are impacted by bridges, it is even more infrequently that they think about how bridges affect other people.

This project also impacted me as a professional, as it was the first time that I was required to explain the process of my teaching to this great a depth since I completed my EdTPA in undergrad. In working through this process, I realized how much I have gained and retained throughout my time in grad school. Your first year teaching can be very difficult, I can only

imagine that it is made more so when that happens to coincide with the tail end of a global pandemic that caused students to spend the last year-and-a-half going to school remotely, as was the case for my first year. It was nice to go through the process of crafting detailed lessons and intricately explaining them, as I was reminded that this was something that I was still capable of accomplishing.

If I could do this project differently, the number one thing that I would do is lengthen the project. I truly believe that there are many things that can be understood through the study of bridges, and I believe that in crafting a, roughly, one week long unit, that I merely scratched the surface of the topic. Unfortunately, I was somewhat held back by the amount of time I had with each class of students, only about twelve weeks. Were I to have had an entire year, I could see this subject being stretched out easily into four to six weeks, if not even longer. That being said, I am convinced that some time spent on this project, even one week, is enough to have a positive impact on students, and I consider it to be a solid foundation for the topic.

Another thing that I would consider doing differently during the teaching portion of this project would be to better organize the student groups. This could be done in multiple ways that I had not considered at the time. Given that this was happening at the very end of the year, and how difficult the year had already been for students, I had decided to be nice and let them choose their own three-to-five person groups. I, at the time, thought that this would be a good way to give them the power of choice. However, I soon realized that this was not the method that I should have chosen if maintaining order was something that I would have liked to have had accomplished in my class. The sad reality is that most 6th grade students, when given the opportunity to choose their partners and groups, Are only going to choose their friends. Now,

this is not always a bad thing, as there are some friend groups that are able to work together and stay on task, however, this is not true of most groups especially at this age.

Throughout the process of designing, writing, implementing and rewriting this project, both the largest and most difficult portion has been the literature review. This surely does not come as a shock to anyone, but it is the reality. Considering how important the literature review is, it is equally important to include its findings in the final projects where applicable. In terms of what I used from my literature review for my finished product, I tried to use what I believed would be the best options to assist in helping my students to understand both the content itself and the importance of the content. I will break down how I believe that I have used my literature review by focusing on each of the three themes mentioned in that chapter.

The first theme was the existing curriculum and resources for teaching about bridges in a middle school setting. The main way that I used these resources was primarily as a means to build a baseline of knowledge and understanding for me. Previously, I had not been very familiar with bridges beyond the simplistic understanding of how physics works. Petros P. Xanthakos' *Theory and Design of Bridges* definitely provided the opportunity to study the form and function of bridges to an extent that is far beyond my skill set, but even so, it helped me to have a better understanding of the science involved. However effective Xanthakos' work was, the resource from this theme that I believe had the greatest impact on my perspective was *The Value of Old Bridges* written by Eric Delony. This resource really connected the engineering to the history and the impact that bridges can have on people, not necessarily in a humanitarian way here, but more of in an emotional connection. While these resources are useful to me in gaining some new perspective for myself, I also found a resource that was invaluable was actually found at enerpac.com. This resource was titled, *7 Types of Bridges That Every Engineer Should Know*

About, and this is what provided me with the inspiration and information for the first day of my unit. The images of bridge examples of each type, and more importantly, the strengths and weaknesses of each bridge type were exactly what I needed to help students, and to a certain extent myself, understand the differences in utility that each type of bridge possesses.

The second theme of my literature review was concerning how important bridges are to both education and society. This portion of my literature review is, in my opinion, enough evidence that bridges are not highly valued in this country. The most important resource in this theme was The American Society of Civil Engineers' *Report Card for America's Infrastructure*, which details just how poorly our bridge-related infrastructure really is. I used this resource heavily as inspiration for the justification of this project, as well as to provide my students with a few hard hitting quotes about the current state of our bridges. There were other resources in this theme that I used mainly for the purpose of my own inspiration and understanding, one such resource was, *Why Bridges* from an organization called Bridges to Prosperity. Their purpose is to build bridges in underprivileged communities in rural areas of Africa, South America, and Central America. This was an eye-opening resource that really encouraged me to include a humanitarian element in my project. I did end up using a quote or two from them as well, to give my students some perspective.

The third, and final, theme of my literature review was, about the process of designing an equitable STEM curriculum, and included examples of existing bridge curriculum. It was very easy to find information on how to craft and implement an effective STEM curriculum in the classroom, and while much of the information that I came across was familiar due to my studies throughout this program, I was still able to find it useful in helping me make decisions for this project. In addition, it is easy to find a considerable amount of STEM curriculum with a cursory

Google search. However, when you set your sights as narrowly as I did for this project, that is, to focus only on the bridge-building curriculum, there is a shockingly limited pool of resources to pull from. In fact, out of the wide variety of sources I found for my literature review, only I was only able to find three solid sources that were dedicated to the process of designing and building model bridges. I did find each of these three resources to be interesting, and I did gain some perspective from reading through them, however, I did not directly utilize anything from them in terms of materials or methods. There was an article by Merfat Ayesh Alsubaie titled, *Curriculum Development: Teacher Involvement in Curriculum Development* written in 2016 that focuses on, and encourages, the involvement of teachers in the curriculum development process. Considering the fact that I have chosen to create a curriculum for this professional project, it was nice to see a peer-reviewed article stating that, as a teacher, I should be involved in the process. It was a very validating experience to read this.

Ultimately, It is important, to understand how I might use this project, this thing that has devoured a significant amount of my time over the last seven months. Well, to put it simply, I am still figuring that part out. Currently, I am only in my second full year of teaching, and as it stands, I am not sure what the future will hold for me. If I am ever in a position where I am teaching some form of STEM again, then I will absolutely put this work into use, and I may, as I stated above, extend it past a one-week unit. However, despite the fact that my content area has changed since last year, the whole point of STEM is to be interdisciplinary in nature, and I believe that bridges are an important part of the story of mankind. Considering that, I do think that I could find a way to sneak this process into my current class, perhaps as some form of a capstone project where students can do something a little different than is standard in social studies. Beyond that, I am not sure; perhaps I may share this with other educators who may be

looking for a way to expand their STEM repertoire. Now at the end of all of this, I do believe that I have made something that I can be proud of. I did not think that I would feel particularly strongly about this project. I was told by those who are wiser than I am that I would, but I was not convinced until very recently. They were right, and I am grateful for the experience.

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