5-2025

"INTEGRATIVE" VS "INTEGRATION": STEM SKILLS AND CONCEPT DEVELOPMENT IN 6TH GRADE STUDENTS

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May 2024

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Abstract

As a whole, interest in Science, Technology, Engineering, and Mathematics (STEM) education in schools is on the rise at a national level, and it is widely recognized that the development of skills and concepts in science, technology, engineering, and math are not only beneficial to students, but are in fact necessities for future citizens of an increasingly global world (Kelley & Knowles, 2016.) Despite this increasing acceptance and awareness of the need for STEM literacy, there is a critical lack of guidelines on what STEM education actually entails and how to effectively integrate these concepts and skills into the educational system. Approaches span a broad range of ideas, from perspectives encouraging STEM integration to be more dynamic and led by students to other viewpoints emphasizing the more typical procedure of teacher-led learning. Situated in a metropolitan elementary school, this study examines a University-School District partnership through an undergraduate research experience which aims to determine how young students best learn and develop STEM knowledge and skills.

Keywords: STEM, education, integration, K-12, learning

1. Introduction

For many Americans, the acronym “STEM,” which stands for Science, Technology, Engineering, and Mathematics, is often associated with the part of a plant or stem cell research, but is actually becoming increasingly important in educational and political circles (NAE & NRC, 2014). In fact, STEM practices within the sphere of education are becoming more and more necessary as predictions of 7 million job openings until 2025 redirect curriculum attention towards a greater interdisciplinary focus (Caprile et al., 2015). Within this newfound national awareness lie many complicated perspectives amidst constraining educational requirements. Efforts to more fully integrate cross-disciplinary STEM practices are further made complex by the history of the K-12 curriculum; roots of today’s educational practices trace back “to the work of the Harvard Committee of Ten (NEA, 1894) which stressed learning in discrete subject areas.” (Honey et al., 2014) Although the depth provided by focusing exclusively on one discipline is important with regards to the specialized training and specific knowledge bases necessary for distinct careers, it hinders the development of interdisciplinary skills and connections. The Committee on Integrated STEM Education found that, “students do not always or naturally use their disciplinary knowledge in integrated contexts. Students will thus need support to elicit the relevant scientific or mathematical ideas in an engineering or technological design context, to connect those ideas productively, and to reorganize their own ideas in ways that come to reflect normative, scientific ideas and practices.” (NAE & NRC, 2014, pp. 5) Yet the ability to apply techniques and information from one practice into another is paramount in an increasingly global and STEM focused world. Examples include the use of technological tools in scientific experiments, the use of statistics to interpret data, the use of mathematical tools and reasoning to create models, and the use of scientific principles to design products and systems. Professionals also increasingly work with others in diverse and multidisciplinary teams (Honey et al., 2014). In spite of this expanding acceptance and awareness of the need for STEM programs to be integrated into school curricula, there is almost no agreed-upon definition of STEM education, let alone cohesive and extensive guidelines. Various suggestions have been proposed to address this critical gap, some of which will be explored more in the following section.

2. Background Literature

The current state of STEM education in the United States varies widely from district to district. In some cases, it is even left up to individual educators to create connections between subject areas in an effort to address the need for STEM education. Although programs designed to satisfy the demand for increased STEM activity in the K-12 grades are multiplying, these initiatives offer drawbacks as well as benefits. Several different perspectives and programs will be discussed here.

2.1 Programs Outside of School

Many STEM-focused K-12 solutions are based around after-school programs. These programs are often offered by a third party (i.e., not the school district itself, but an entity that works with the school district) directly at the school or at a location nearby. One such program located in Omaha, Nebraska, NE STEM 4U, focuses on training undergraduate students as mentors for K-8 students in their outreach program, where problem-solving sessions are held twice weekly during the school year in an informal setting. Objectives are geared towards both the undergraduate mentors, in improving research abilities and developing professional and educational skills, as well as the K-8 participating students, in improving critical thinking and problem solving skills and decreasing behavioral problems while guiding students towards greater STEM proficiency (Cutucache et al., 2016).

Proponents of this program argue that, “Given the short timeframe for addressing the STEM deficit, programs that engage youth in structured, high- quality after-school programming that excite youth about STEM areas through consistent, mentored activities while also training STEM undergraduates in career readiness skills have the best chance to make immediate impact as well as establish and maintain a competitive pipeline in STEM.” (Cutucache et al., 2016, pp. 2). These types of programs do benefit K-12 students in increasing their STEM literacy and in being able to solve multi-faceted problems rather than just learning the concepts associated with one discipline, among other benefits. However, these programs also have drawbacks, such as limits on participation due to transportation inaccessibility or a schedule already full of other after-school activities. They also required sustainable funding and strong university-school district-community agency collaborations.

2.2 Programs Inside of School

On the other hand, there are a variety of perspectives on how to best implement STEM practices within the classroom. A “during school” approach addresses transportation issues, but can still grapple with finding time and ways to implement STEM-based activities in an already stuffed school day. Many different frameworks have been proposed that attempt to address these difficulties. Bryan et al (2021) suggested a “STEM Roadmap,” where three forms of STEM integration are identified, including “(a) content integration where learning experiences have multiple STEM learning objectives; (b) integration of supporting content where one area is addressed (e.g., mathematics) in support of the learning objectives of the main content (e.g., science), and (c) context integration where the context from one discipline is used for the learning objectives from another.” (English, 2017) Kelley and Knowles (2016) designed a “pulley system” conceptual framework, which contains four distinct “pulleys”: (1) engineering design, (2) scientific inquiry, (3) technological literacy, and (4) mathematical thinking.Other models offer a simple STEM integration matrix, designed to assist educators in analyzing and categorizing the content of STEM activities that can be incorporated within a school curriculum (English, 2017).

Though these frameworks are useful, they each depend on a specific and different definition of "STEM integration." In fact, some researchers argue that even the phrasing "STEM integration" is different from "integrative STEM," where "integrative" suggests a learner-directed and dynamic process, as opposed to "integrated" which indicates a more static and typical teacher-led approach (Sanders, 2012; Wells, 2013).

With this controversy as background, the focus of this project is to investigate the differences between "integrative STEM" and "STEM integration," and to determine in which "during school" format students learn and develop best, if either. Situated in a metropolitan area elementary school, this study implements both approaches to STEM learning to teach and expose 6^{th} grade students to careers and concepts in STEM disciplines. This research specifically seeks to answer the question, "Do elementary-age students learn STEM skills and concepts more effectively through integrative STEM approaches or through STEM integration approaches?"

3. Methodology

3.1 Context

This study was performed in a Title I school within a metropolitan school district in Omaha Nebraska, in conjunction with a partnership with the University of Nebraska at Omaha. As an undergraduate STEM student, I, the lead researcher and a university honors student, collaborated with a local metropolitan school district to implement and study STEM education instructional content and methods through a STEM class for their 6th grade high ability learners. The STEM class met once per week on Wednesdays, during a time designated by the school administration for Excellence in Youth instruction, for approximately 50 minutes. The class met either in the library or the music and art room depending on the school schedule. Since the premise of this class was to encourage STEM interests specific to the class, students chose a STEM discipline or career that they were interested in individually or with a partner. For example, two students chose architecture together while another student chose biology individually, and a third student chose medicine. Two weeks were devoted to each career, where one week focused on the "STEM integration" method and the other week emphasized the "Integrative STEM" method. During the "STEM Integration" class, I taught the entire time exclusively as befitting a "teacher-directed" method of integrating STEM concepts and skills. Conversely, a student or a pair of students led the entire time during the other week's class time, focused on "Integrative STEM" methods. The typical structure included a slideshow presentation followed by an activity to engage the class in the material. Students chose their specific topics in the form of questions (e.g. within the architecture discipline, two students worked together to answer the question "How are houses built to be weather-resistant?") in advance and were usually given a week or two to prepare for their assigned class date. My presentation was within the same discipline, but answered a different question (e.g. "How do bridges work?"). Presenters were encouraged to lead the class however they would like, but each was required to include a presentation of their chosen concept and a related activity to engage the other students in their learning. Students were also allowed to choose if they wanted to teach their class the first week or the second week. One student opted out of presenting.

Every class session began with a pre-class survey and ended with a post-class survey, where students rated the applicability of several statements to themselves (Appendix A). These statements were designed to gauge several elements: how well the students felt that they liked a given STEM discipline (e.g. mathematics, chemistry, etc), how much they felt that they knew about that discipline in general as well as specific concepts from that subject area, how interested the students were in pursuing that discipline, and how they would rate a given particular STEM skill. These statements varied slightly depending on the unit that was being covered by the class. For instance, during the architecture unit, the statements were as follows:

"I like architecture."

"I know a lot about architecture."

"I want to be an architect."

"I know a lot about bridges and how they work/how houses are built to be weather-proof."

"I am good at focusing and working with a partner."

The fourth sentence varied based on if it was the student-led week or the teacher-led week, as it directly related to each specific topic.

The students were instructed to rate each sentence according to how well they felt it described them on a 1-10 scale, where 1 indicated "This doesn't sound like me at all!" and 10 indicated "This describes me perfectly!" Both the pre-class and post-class surveys were printed on the same side of the same page so that students could see their pre-class answers if they wanted to, but could not see their answers from the previous week (Appendix B).

The class was then conducted and included a presentation and an activity. Students who were presenting met with me typically once or twice before their presentation to ensure that content was appropriate and that the presenter(s) felt comfortable with their material. Within the architecture unit, two female students were partners and presented the first week. As previously mentioned, their question was "How are houses built to be weather-resistant?" The presentation included fifteen slides, where slides two through nine detailed how houses are built in general and then slides ten through thirteen demonstrated specific disaster prevention techniques. Slides fourteen and fifteen included activity instructions and references (Appendix C). Students developed their own activity or found instructions for an activity online. Their activity required the other students to build houses out of popsicle sticks, glue, and tape and then test the houses against simulated disasters, such as putting the popsicle house in the art room sink and running water over or around it to simulate flooding (Appendix D).

During the teacher-led week of the architecture unit, I focused on the question "How do bridges work?" My presentation included twelve slides, with slide two including a short introductory video, slides three through ten portraying various types of bridges and having participants form groups to determine what forces each bridge felt, and slides eleven through twelve including various facts about bridges and activity instructions (Appendix E). In like manner to the students, I developed my own activities or found activity ideas and instructions online from various resources. The activity that followed required students to form groups and build a bridge out of paper towel rolls, glue, and string, and then try to place a weight on their bridge to determine if it would hold up against various forces (Appendix F).

Table 1. Examples of Questions Explored in Various Units

Unit	Student-led Question	Teacher-led Question
Biology	"How does the human knee work?"	"How does the human ear work?"
Chemistry	"How do chemical reactions occur?"	"How does water work?"
Medicine	"How do eyes and the brain interpret optical illusions?"	"How does the brain recognize visual cues?"

Table 1 above records a few examples of other questions that were explored in other units. Note that this table is not inclusive of all questions from all units, but rather intended only to provide several examples.

Finally, after both weeks were completed, students were given another survey regarding which class they preferred and why, as well as which class they felt that they learned more and improved their skills more effectively (Appendix G). Responses required them to circle which class for each question and then provide an open-ended answer to why they circled that particular preference.

3.2 Participants

This STEM class was composed of eleven students: five girls (45.45%) and six boys (54.54%). Of these, five students (four boys and one girl) were previously in a pre-algebra group, which meant that these students were performing at a seventh grade level in mathematics and therefore ahead of their peers. The other six students were selected by their teachers based on their mid-year mathematics test scores, since these students would miss an hour of their typical math instruction once a week in order to come to this STEM class. All students were between eleven and twelve years of age and in one of two sixth grade classes at the same school.

3.3 Research Design

The research design for this study consisted of both qualitative and quantitative data sources. The qualitative data sources included observational data documentation and also open-ended participant responses to weekly questionnaires. The quantitative data included descriptive statistics and also inferential statistics including conducting a two-tailed t-test to determine if the intervention had a statistically significant impact on participants perceptions of their learning and enjoyment during the STEM lessons. Ultimately, I used an explanatory sequential, mixed methods analysis to review data from each source separately before examining and narrating all of the data in its entirety (Creswell, 2011; Creswell & Plano Clark, 2007).

4. Findings

Upon beginning this research project, the initial expectation was that students would prefer the student-led integrative STEM method by far. However, this was not always the case. In this section, several observational differences in teaching styles, quantitative results, and descriptive results will be described.

4.1 Observations

As a rather obvious note, the students did not have any prior teaching experience, nor did I expect them to. This section is devoted to observational differences in style between the teacher-led lessons and the student-led lessons in order to allow the reader to gain a feel for the class. The following table simply gives information about which student(s) led each unit and whether they chose to present the first or second week for their unit. "M" indicates a male student and "F" indicates a female student, with the numbers correlated to specific students, whose names will not be given for privacy reasons.

Table 2. Data Displaying Student Leader(s) and Preference of Presentation Week Per Unit

Unit	Student Leader(s)	Student-Led Week
Biology	M1	Second
Architecture	F1, F2	Second
Chemistry	M2, M3	First
Medicine	F3	First
Nuclear Physics	M4, M5	Same Day
Computer Programming	F4	Second

Almost all students read their entire slide presentation verbatim, with varying amounts of information given per slide during different presentations. For example, M1 had a very long slideshow with lots of text details and information on each slide, as well as some descriptive anatomical figures. He also provided a worksheet for the other students to fill out as they followed along. His activities included leading the group through several knee pain recovery exercises and playing a game of Jeopardy with information that they learned during the presentation.

During the architecture unit, F1 and F2 quickly went through their presentation, reading off the slides with very little text, but large images. Most of their allotted time was dedicated to their activity, which required students to build houses out of popsicle sticks and other materials, and they posted a timer on the board to keep students aware of remaining time given. These students walked around occasionally to check on how each group of students was progressing with their house, and asked other students for details on how they were disaster-proofing their house, as well as ideas on how to test the strength of the houses.

As a final example, M2 and M3 did not provide a worksheet as they went through their slides, with the bolder student encouraging the shyer student to read and participate in their presentation. These students performed an "elephant toothpaste" chemical reaction as an activity, and then began an eighteen minute science video, partway through which they decided that the group would rather perform the chemical reaction again.

On the other hand, I have spent several years as an educational assistant, and I have taught classes of varying topics and time lengths to a range of different age groups. I have additionally attended district training on how to teach and have some experience in this field, although I have not had undergraduate teacher training or education classes.

My slideshow presentations were 10 slides or less, and typically didn't have much text, unless the slide was describing a process or factual information. I infrequently read off slides, and tried to engage students in multiple activities during each lesson, such as videos, worksheets, games, or arts and crafts. Every class had some form of handout or worksheet to fill out, and students often worked in groups on different projects while I monitored. For example, during the nuclear physics unit, students used blank CDs and white paper to create different light reflections, and during the computer programming unit, students learned about modulus 26 and how to encode sentences using the Hill cipher.

4.2 Quantitative Data

As noted in Section 3.3, data was obtained through a self-assessed survey where students rated their own perceived skills and concept comprehension. The following tables display the rating each student recorded before and after each student-led and teacher-led class, as well as the difference between the before and after values. When no data is recorded, the student was absent for one or both weeks. The student highlighted in green was the student leader for that unit, and increases in ratings from pre-class to post-class are highlighted in orange.

Table 3. Statement 1 Data for the Biology Unit

Student	*"I like biology"*					
	Week 1 (Teacher-led)			Week 2 (Student-led)		
	Initial	Final	Difference	Initial	Final	Difference
F1	5	5	0	7	7	0
F2	7	8	+1	7	5	-2
F3	6	8	+2	8	9	+1
F4	8	8	0	8	8	0
F5	5	8	+3	5	6	+1
M1	8	10	+2	10	10	0
M2	6	8	+2	6	8	+2
M3	6	6	0	6	6	0
M4	3	2	-1	2	2	0
M5	2	2	0	1	1	0
M6	--	--	--	--	--	--
Mean	5.6	6.5		6	6.2	
S.D.	1.955	2.718		2.748	2.898	
two-tailed t-test	p-value		0.0542	p-value		0.555

For the teacher-led week of the Biology unit, the final perceptions of students' enjoyment of the subject area (M= 6.5, SD= 2.718) were greater than their initial perceptions (M= 5.6, SD= 1.955) based on statement 1. While there was an increase, the difference was not statistically significant ($p>.05$). Similarly, the final perceptions of students (M= 6, SD= 2.748) were greater than the initial perceptions of students' enjoyment of the subject area and content (M= 6.2, SD= 2.898) for the student-led week. While there was again an increase, the difference here also was not statistically significant (p>.05).

Table 4. Statement 1 Data and Leader for Each Unit in Order of Units

Unit	Week 1				Week 2			
	Led by	**Initial Mean**	**Final Mean**	**P-value of two-tailed t-test**	**Led by**	**Initial Mean**	**Final Mean**	**P-value of two-tailed t-test**
Biology	Teacher	5.6	6.5	0.054	Student	6	6.2	0.555
Architecture	Teacher	6.3	7	0.044	Student	6	6.2	0.508
Chemistry	Student	5.9	6.9	0.067	Teacher	5.2	5.8	0.025
Medicine	Student	5.3	4.5	0.641	Teacher	4.5	4.2	0.363
Nuclear Physics	Teacher	5.6	6.4	0.047	Student	5.9	6.5	0.180
Computer Programming	Teacher	6.6	6.6	0.341	Student	6.7	6.8	0.724

In Table 4, we highlight the statistically significant values in orange.

Table 5. Statement 2 Data for the Biology Unit

Student	*"I know a lot about biology"*					
	Week 1 (Teacher-led)			Week 2 (Student-led)		
	Initial	Final	Difference	Initial	Final	Difference
F1	1	2	+1	4	4	0
F2	3	5	+2	6	7	+1
F3	5	7	+2	5	7	+2
F4	5	7	+2	7	7	0
F5	3	5	+2	6	6	0
M1	5	8	+3	9	9	0
M2	4	6	+2	4	6	+2
M3	4	5	+1	6	7	+1
M4	3	4	+1	6	6	0
M5	3	3	0	4	5	+1
M6	--	--	--	--	--	--
Mean	3.6	5.2		5.7	6.4	
S.D.	1.264	1.873		1.567	1.349	
two-tailed t-test	p-value		0.0002	p-value		0.024

For the second statement in the biology unit, we found a significant increase ($p<.05$) for the student-led week, with a more significant increase during the teacher-led instruction week ($p<.05$). Within that teacher-led week, the final perceptions of students' knowledge of the content (M=5.2, SD= 1.873) were greater than their initial perceptions (M= 3.6, SD= 1.264). However, the final perceptions of students (M= 6.4, SD= 1.349) were still greater than the initial perceptions of students' knowledge of the content (M= 5.7, SD= 1.567) for the student-led week as well.

Table 6. Statement 2 Data and Leader for Each Unit in Order of Units

Unit	Week 1				Week 2			
	Led by	**Initial Mean**	**Final Mean**	**P-value of two-tailed t-test**	**Led by**	**Initial Mean**	**Final Mean**	**P-value of two-tailed t-test**
Biology	Teacher	3.6	5.2	0.0002	Student	5.7	6.4	0.02
Architecture	Teacher	4.8	6.0	0.008	Student	5.4	5.8	0.103
Chemistry	Student	5.0	5.8	0.042	Teacher	5.2	6.0	0.093
Medicine	Student	3.2	4.5	0.010	Teacher	3.5	3.7	0.363
Nuclear Physics	Teacher	3.6	5.1	0.216	Student	5.3	5.8	0.170
Computer Programming	Teacher	5.73	6.10	0.371	Student	5.36	5.82	0.138

Table 7. Statement 3 Data for the Biology Unit

Student	*"I want to be a biologist"*					
	Week 1 (Teacher-led)			Week 2 (Student-led)		
	Initial	Final	Difference	Initial	Final	Difference
F1	4	7	+3	8	6	-2
F2	3	3	0	3	5	+2
F3	4	6	+2	6	9	+3
F4	3	6	+3	6	6	0
F5	2	4	+2	2	3	+1
M1	7	9	+2	10	9	-1
M2	1	1	0	1	1	0
M3	4	4	0	2	2	0
M4	1	1	0	1	1	0
M5	1	1	0	1	1	0
M6	--	--	--	--	--	--
Mean	3.0	4.2		4.0	4.3	
S.D.	1.886	2.781		3.266	3.164	
two-tailed t-test	p-value		0.018	p-value		0.520

Using the data from statement 3, we note a statistically significant increase (p<0.5) in students' desire to work in that career from initial (M= 3.0, SD= 1.886) and final mean values (M= 4.2, SD= 2.781) during the teacher-led, integrational week. However, we do not see a statistically significant increase (p>0.05) in students' desire to work in a biology career during the student-led week, based on initial (M= 4.0, SD= 3.266) and final (M=4.3, SD=3.164) values given above. Based on a scale of 1-10, the SD within the week 2 student-led data likely impacted the ability to see a group difference as there was high variability in the outcomes (perceptions) of students on this content.

Table 8. Statement 3 Data and Leader for Each Unit

Unit	**Week 1**				**Week 2**			
	Led by	**Initial Mean**	**Final Mean**	**P-value of two-tailed t-test**	**Led by**	**Initial Mean**	**Final Mean**	**P-value of two-tailed t-test**
Biology	Teacher	3.0	4.2	0.018	Student	4.0	4.3	0.520
Architecture	Teacher	3.7	4.1	0.104	Student	3.5	3.5	1
Chemistry	Student	3.7	4.0	0.175	Teacher	3.4	3.8	0.076
Medicine	Student	4	4	1	Teacher	5	5	1
Nuclear Physics	Teacher	4.5	4.8	0.699	Student	4.5	4.6	0.598
Computer Programming	Teacher	4.3	4.9	0.046	Student	4.3	4.4	0.588

Table 9. Statement 4 Data for the Biology Unit

Student	*"I know a lot about the human ear/the human knee"*					
	Week 1 (Teacher-led)			Week 2 (Student-led)		
	Initial	Final	Difference	Initial	Final	Difference
F1	4	6	+2	0	4	+4
F2	6	8	+2	6	8	+2
F3	2	8	+6	3	8	+5
F4	4	7	+3	8	9	+1
F5	7	9	+2	6	7	+1
M1	1	10	+9	10	10	0
M2	5	7	+2	5	7	+2
M3	2	7	+5	3	8	+5
M4	1	4	+3	4	5	+1
M5	1	4	+3	3	3	0
M6	--	--	--	--	--	--
Mean	3.3	7.0		4.8	6.9	
S.D.	2.214	1.944		2.860	2.234	
two-tailed t-test	p-value		0.0006	p-value		0.007

For this unit, we can see that there was a statistically significant increase ($p<.05$) in students' understanding of the specific biological topic for both the teacher-led and student-led weeks. The final values (M= 7.0, SD= 1.944) rose rather drastically from the initial values (M=3.3, SD= 2.214) for the teacher-led week. The student-led week also showed a significant, though not quite as drastic increase from the initial values (M= 4.8, SD= 2.860) to the final values (M=6.9, SD= 2.234).

Table 10. Statement 4 Data and Leader for Each Unit

Unit	Week 1				Week 2			
	Led by	**Initial Mean**	**Final Mean**	**P-value of two-tailed t-test**	**Led by**	**Initial Mean**	**Final Mean**	**P-value of two-tailed t-test**
Biology	Teacher	3.3	7.0	0.0006	Student	4.8	6.9	0.007
Architecture	Teacher	4.9	6.9	0.0002	Student	4.5	6.5	0.158
Chemistry	Student	4.0	5.7	0.011	Teacher	4	6.3	0.084
Medicine	Student	5.3	6.2	0.042	Teacher	3.8	5.2	0.043
Nuclear Physics	Teacher	4.5	6.5	0.033	Student	5	6.5	0.111
Computer Programming	Teacher	1.6	4.3	0.0008	Student	5.2	5.6	0.053

Table 11. Statement 5 Data for the Biology Unit

Student	*"I am good at understanding and explaining how something works"*					
	Week 1 (Teacher-led)			Week 2 (Student-led)		
	Initial	Final	Difference	Initial	Final	Difference
F1	6	6	0	7	8	+1
F2	5	5	0	7	7	0
F3	6	7	+1	9	9	0
F4	10	10	0	10	10	0
F5	9	9	0	9	9	0
M1	9	10	+1	10	10	0
M2	5	5	0	5	5	0
M3	9	9	0	10	11*	+1
M4	7	8	+1	8	8	0
M5	8	8	0	8	8	0
M6	--	--	--	--	--	--
Mean	7.4	7.7		8.3	8.5	
S.D.	1.838	1.889		1.636	1.716	
two-tailed t-test	p-value		0.081	p-value		0.168

**This is a student error as ratings were intended to be out of ten.*

Finally, with respect to statement 5, the mean values only shift about 0.3 from the initial (M= 7.4, SD= 1.838) to the final value (M= 7.7, SD= 1.889) during the teacher-led week, but this shift is statistically significant ($p<.05$). During the student-led week, the mean values shift even less, about 0.2, from the initial value (M= 8.3, SD= 1.636) to the final value (M=8.5, SD= 1.716), but this is not a statistically significant shift ($p>.05$).

Table 12. Statement 5 Data and Leader for Each Unit

Unit	Week 1				Week 2			
	Led by	**Initial Mean**	**Final Mean**	**P-value of two-tailed t-test**	**Led by**	**Initial Mean**	**Final Mean**	**P-value of two-tailed t-test**
Biology	Teacher	7.4	7.7	0.081	Student	8.3	8.5	0.168
Architecture	Teacher	8	7.9	0.729	Student	7.3	7.4	0.591
Chemistry	Student	7.2	8.3	0.287	Teacher	6.2	7.2	0.111
Medicine	Student	6.5	7.5	0.175	Teacher	7.8	7.8	1
Nuclear Physics	Teacher	6.6	6.6	1	Student	6.5	6.4	0.351
Computer Programming	Teacher	7.7	7.7	1	Student	8.1	8.3	0.341

4.3 Descriptive Data

Results from the final survey descriptive feedback varied per unit, but did show a few general trends in responses (Appendix H).

For the first question ("Which week did you enjoy more?"), students who liked the student-led, integrative classes usually gave reasoning such as "It was more understandable from another student" or "I enjoyed the student-led activity more." On the other hand, students who preferred the teacher-led integrational style often cited reasons like "It was more organized" or "Mrs. Chain was a better teacher" or "It was more descriptive and informational." Much of this feedback related to a preference for the integrational week stemmed from components of teaching style or ability, while converse feedback connected to activities or concepts taught by the students. Across all of the units, students typically enjoyed the student-led, integrative week more: with the exception of the chemistry unit, at least 50% of the students picked the integrative class as the one they enjoyed more for each STEM career field module.

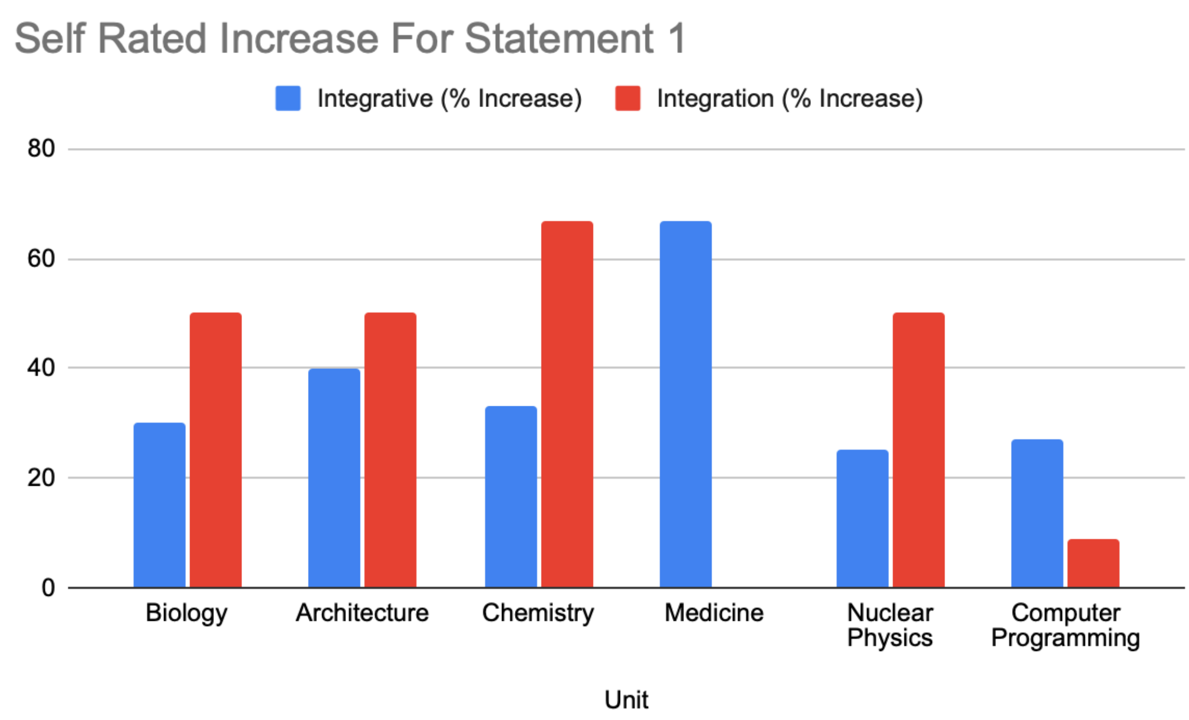
With respect to the second question ("Which week did you learn more about [STEM field]?"), responses flipped the other way, trending towards a preference for integrational teacher-led lessons. With the exception of the biology unit, 50% or more of students tended to choose this method over the student-led lessons, using rationales such as "It was an adult teaching us," "It was more direct," or "It was more descriptive/there was more information." Interestingly, these responses had to do with both content and teaching style/ability. In contrast, several of the students who said that they learned more during the student-led week were the ones who taught that class, and they cited that reason as the basis of their choice. The other students who answered that they learned more during the student-led, integrative week typically reported that they learned a lot about a specific concept that was taught by the student leader.

Finally, the last question asked the students about their STEM skills ("Which week did you get better at [STEM skill]?"). The skills considered included: understanding and explaining how something works, thinking creatively, focusing, and not getting discouraged. These results were somewhat mixed; for example, the skill of understanding and explaining how something works was measured twice, with the first time showing a self rated improvement for 25% of students for the teacher-led week and the second time reporting an improvement for 70% of students for the teacher-led week. However, the other three skills all showed an increase under the integrational class for 70% or more of students. Students quoted a variety of reasons for their choice, with overlapping logic towards both classes; for instance, some reported the activity or project as the driving factor in picking student-led, while others wrote down the same reason for picking the teacher-led class. Overall, many of the responses (whether for the integrational or integrative class) had the activity as their basis for explaining their choice. Possible reasons for these trends will be examined in the analysis.

5. Analysis

The following charts provide a clearer visual of comparative quantitative data, showing the percentage of students that reported any amount of increased applicability of the statements for the teacher-led, integrational week as compared to the student-led, integrative week. Note that the units are listed in order of progression, with "Biology" on the far left as the first module in January and "Computer Science" on the far right as the last module in May.

Chart 1. Self Rated Increase For Statement 1



For Statement 1 ("I like [STEM field]"), in every unit except medicine, a greater number of students reported an increase in how much they liked that field for the integrational week as compared to the integrative week.

Chart 2. Self Rated Increase For Statement 2

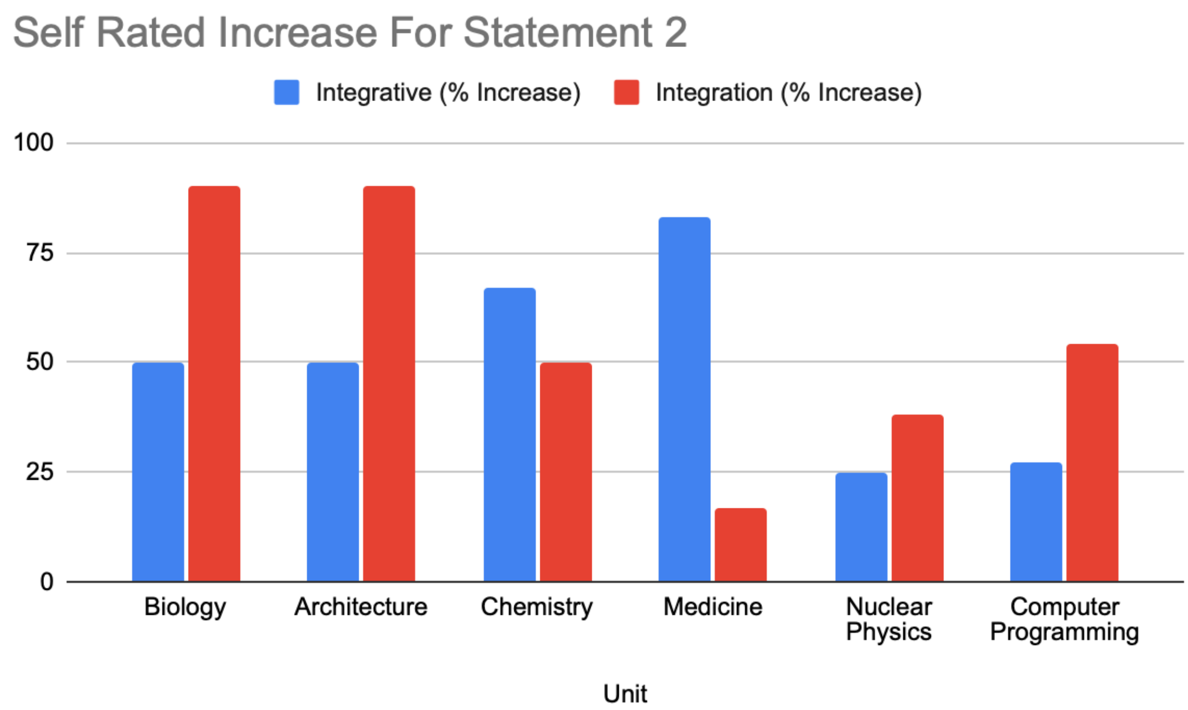
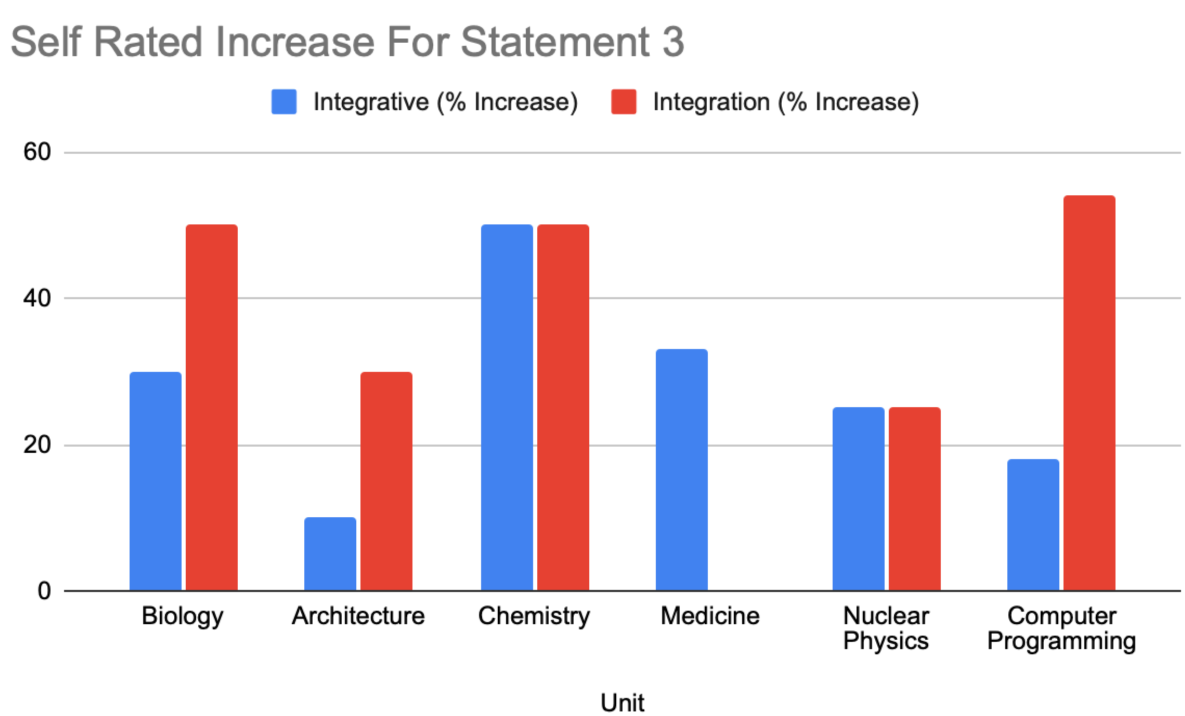
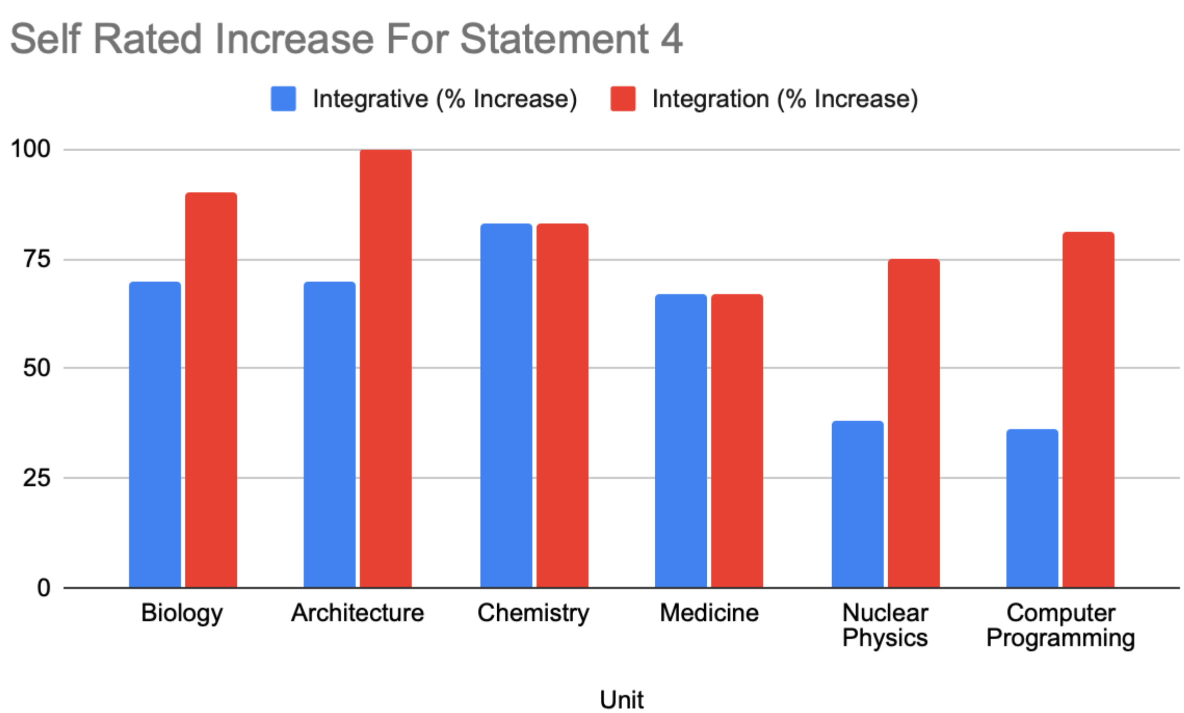


Chart 3. Self Rated Increase For Statement 3



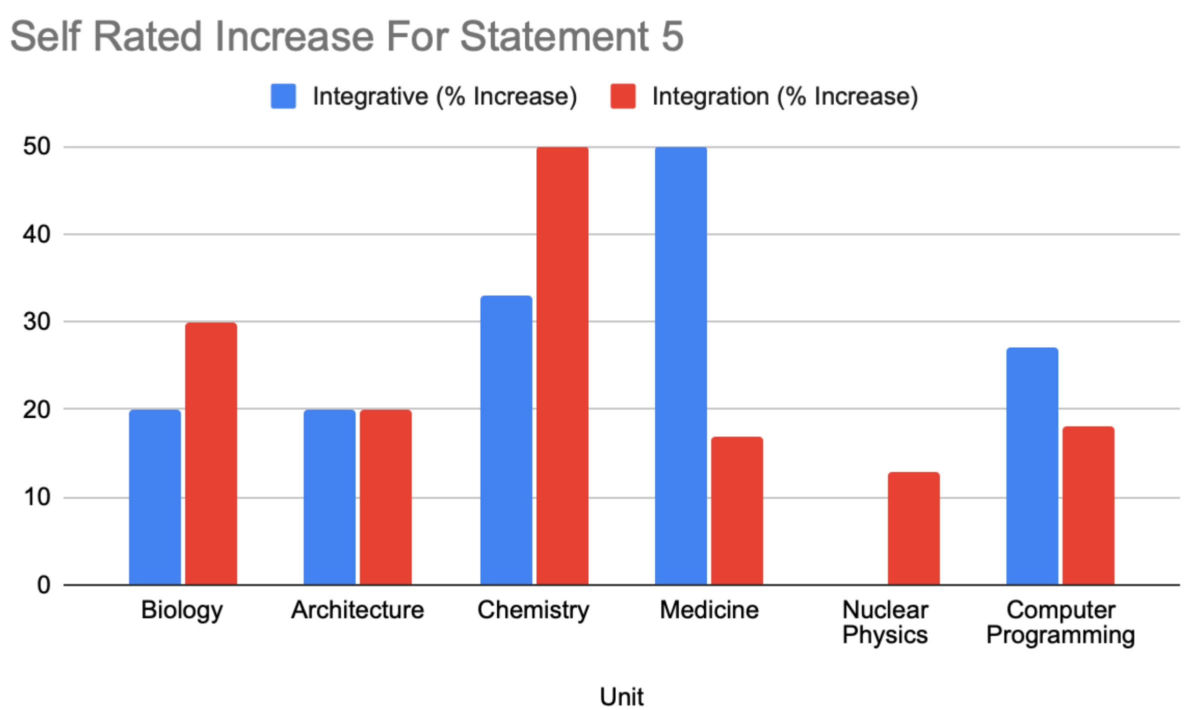
It seems that for Statement 2 ("I know a lot about [STEM field]"), the percentage of students who showed an increase with the student-led lesson initially was lower than that of the teacher-led lesson and trended upwards passing the teacher-led percentage of students who demonstrated an increase in applicability of Statement 2 up until the Nuclear Physics Unit. It may be important to point out that the Nuclear Physics unit is the only module of the six above which had both lessons given on the same day, and therefore a shorter time frame for both the integrative and integrational instruction time. For Statement 3 ("I want to be a [STEM career]"), no clear trends are readily visible.

Chart 4. Self Rated Increase For Statement 4



Statement 4 ("I know a lot about [specific STEM question]") generally seems to have little difference in percentage of students who reported an increase before and after class between the integrative lessons and the integrational lessons. The exceptions to this, of course, are the nuclear physics and architecture units, which have a difference of 37% and 30%, respectively.

Chart 5. Self Rated Increase For Statement 5



For Statement 5 ("I am good at [STEM skill]"), results again vary widely, with no clear trend shown.

Fom Chart 1, it appears that students tend to like a STEM field much more after an integrational lesson than after an integrative lesson. As mentioned in Section 3.4, one limitation of this study is that students with previous high scores in mathematics subject testing were chosen by their teachers for this class. These students obviously are accustomed to listening to and doing well under typical teacher instruction, which may contribute to a more comfortable feeling in an integrational lesson and have an impact on how much these students "like" the subject afterwards. While data showed that students liked the subject more after an integrational class, it is fascinating to note that the qualitative responses indicated that students liked the integrative class itself more in general. This seems somewhat contradictory, as one could assume that having a more positive or preferential class experience would increase their love of the subject taught in that class.

Given the lack of trend visible in Charts 3 and 5, it does not seem that the type of instruction, whether integrative or integrational, sufficiently impacts students' desire to work in that field of STEM or their perceived STEM proficiencies. This lack of correlation may be due to the fact that the lessons are limited, as only a rather superficial layer of each field can be explored and those particular aspects of the subject area may not strike the interest of the students. The lessons were also not geared towards the skills given in the questionnaire, but rather the statements related to skills were used as a way to assess if students felt they increased their STEM abilities as a general result of STEM lesson exposure with regards to the instruction methods.

The percentage of students who reported an increase in the applicability of the statement "I know a lot about [STEM field]" for the student-led integrative lessons was shown to be trending upwards until the second to last unit in the study, as shown in Chart 2. Initially, more students reported an increase in feeling like they knew a lot about the field during the teacher-led lessons, but this transitioned into a greater portion of students reporting an increase during the student-led lessons later on. This is somewhat surprising, since the qualitative feedback for question 2 indicated that students felt that they learned more under the integrational style of teaching consistently throughout modules after the biology unit. In fact, during the medical unit, 100% of students surveyed chose the teacher-led week in response to the qualitative question “Which week did you learn more about medicine?” while the quantitative responses after the class indicated that students had learned more (i.e., they felt they knew more after the lesson than before) during the integrative lesson - approximately 83% of students reported an increase after the student-led week versus only about 17% of students reported an increase in their knowledge after the teacher-led week. There is obviously some distinction between how and how much students learn versus how and how much they think they learn; here, the students thought they learned more during the integrational STEM lessons but in actuality appeared to learn more during the integrative STEM lessons according to their responses. This may have to do with how students are conditioned to learn as taught in schools, and these 6th grade students have clearly absorbed that method.

Finally, Chart 4 suggests that there is little difference between reported learning about very specific STEM topics as taught through either the integrational teacher-led method or the integrative student-led method. Interestingly however, in the descriptive statistics performed previously on statement 4 there is a significant increase in students’ understanding of the specific topics for every unit under the integrational method, while there is only a significant increase for two units (Biology and Medicine) under the integrative method. While the percentage of students who reported an increase doesn't seem to vary much between either method as shown in Chart 4, this increase is actually quite significant based on Table 10.

5.1 Limitations

Over the course of this research study, several adjustments were necessary in order to comply with school calendars and student needs, among other things. Initially, each unit was composed of two weeks where the student-led class and the teacher-led class were on completely separate days, and each had a full 50 minute class period in which to explore and share their topic. Due to absences, state examinations, and other unforeseen events within the school calendar, several units were confined to one week total in order to allow all students to present on a topic. This greatly affected the time allotted to each presenter as now the "Integrative STEM" and the "STEM Integration" classes were confined to approximately 20-25 minutes each. Obviously, this caused some difficulty in completing a pre-class survey, presentation, activity, and post-class survey and then repeating the process within the allotted time. Additionally, some classes were unexpectedly cut short due to last minute changes in scheduling.

Typically, the STEM class was conducted in either the art room or the library based on the rotating schedule of room availability. This was interrupted several times as rooms had been overbooked for other activities (such as author visits, etc.), which caused minor issues with presentations that required a whiteboard or activities that needed more space than was available, as it had previously been planned to take place in a room with a larger available area or greater resources.

Several small modifications to the language of the survey also became necessary to help students answer the questions accurately or keep track of which method (student-led or teacher-led) was the primary focus of each survey. Most units also had several students absent so most data is not out of eleven students, but rather six or ten, etc. Since this study required students to miss mathematics instruction time once per week, only students with sufficiently high test scores were permitted to attend by their teachers. This introduced an inherent bias, as participants could not be randomly selected and therefore all members of the study were sufficiently prone towards academic and mathematical achievement prior to beginning the research.

Other complexities arose when planning for the activity portion of the class, such as having the necessary materials in order to complete the project. For example, during the architecture unit, in order to build the bridges, paper towel rolls or toilet paper rolls were required. Given that this was not a material that the school had on hand, I needed to ask other teachers for donations several weeks in advance.

Although these limitations unfortunately placed some restrictions on the depth and extent of the data collected, several interesting findings still resulted from this research study, as noted in the previous section.

6. Summary

With predictions of the need for a greater STEM workforce, public schools in the United States have begun to implement more STEM-based instruction. Yet with no cohesive overarching and systematic way to do so, the integration of STEM practices is left up to districts and educators. With a myriad of different opinions and definitions offered by researchers and educators alike, creating clear guidelines in neither a simple nor easy task. One suggestion offered by educational researchers Sanders and Wells has been to stress integrative, student-led methods over static, integrational, teacher-led learning styles. This study used both an integrational and integrative approach to STEM education within a sixth grade class.

Students had the opportunity to experience both a teacher-led integrational class style and a student-led integrative class style and describe their preferences for either class through a self reported survey. This survey measured the learning and growth of STEM skills and concepts in these students by means of a quantitative rating of several statements as well as descriptive feedback. Students were able to teach a STEM subject of their choice and participate in activities and content related to these subject areas.

This study sought to answer the question: "Do elementary-age students learn STEM skills and concepts more effectively through integrative STEM approaches or through STEM integration approaches?" Data obtained during this study implied that students liked the STEM field more after an integrational lesson, but liked the integrative lessons themselves more. Additionally, students thought that they learned more during an integrational method-based class, but showed more learning from the corresponding integrative method-based class. No trends were found between perceived STEM skill absorption or desire to work in a given STEM field and a particular method of the two. Future work should modify this study in order to determine which method actually impacts students' abilities to learn STEM skills.

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Appendices

Appendix A: Sample Pre-class and Post-class Survey

Doctor: Mrs. Chain's Lesson

Beginning of class
Rate each sentence on how true it is for you:
(1 means "this doesn't sound like me at all!" and 10 means "this describes me perfectly!")

I like medicine. ___________

I know a lot about medicine. ___________

I want to be a doctor. ___________

I know a lot about visual cues & my brain. ___________

I am good at not getting discouraged. ___________

End of class
Rate each sentence on how true it is for you:
(1 means "this doesn't sound like me at all!" and 10 means "this describes me perfectly!")

I like medicine. ___________

I know a lot about medicine. ___________

I want to be a doctor. ___________

I know a lot about visual cues & my brain. ___________

I am good at not getting discouraged. ___________

Appendix B: Sample Filled Out Pre-class and Post-class Survey

Beginning of class

Rate each sentence on how true it is for you:

(1 means “this doesn’t sound like me at all!” and 10 means “this describes me perfectly!”)

I like medicine. 7

I know a lot about medicine. 6

I want to be a doctor. 8

I know a lot about visual cues & my brain. 7

I am good at not getting discouraged. 6

End of class

Rate each sentence on how true it is for you:

(1 means “this doesn’t sound like me at all!” and 10 means “this describes me perfectly!”)

I like medicine. 7

I know a lot about medicine. 7

I want to be a doctor. 8

I know a lot about visual cues & my brain. 8

I am good at not getting discouraged. 6

Appendix C: Sample of Student-led Slides

Floods

- Many homes feature waterproof walls (concrete or masonry) to resist floods
- Some homes are built on stilts or hills to prevent floods

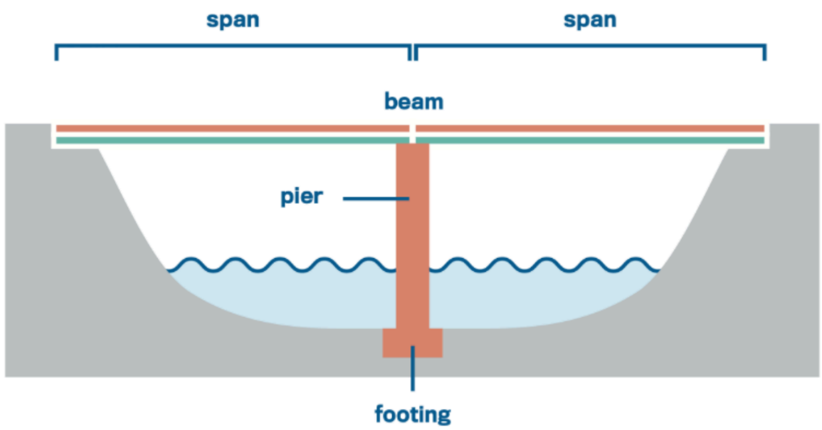
Tornadoes

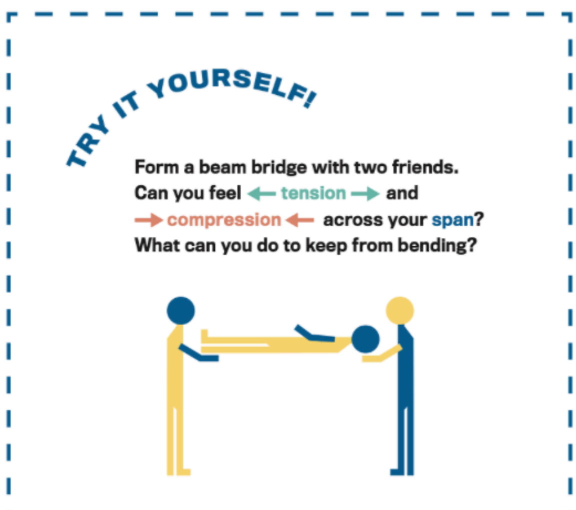
- Some houses are built to resist tornadoes, some just have a basement and some just having nothing to protect against tornadoes
- Tornado proof houses may be built with insulated concrete forms (ICF)
- Some houses have a tornado shelter room for tornadoes instead of just basements

Appendix D: Sample of Student-led Activity

Appendix E: Sample of Teacher-led Slides

Beam Bridge





Appendix F: Sample of Teacher-led Activity

Appendix G: Sample Final Survey

Week 2

Answer the following questions:

Which week did you enjoy more?

Week 1 (Mrs. Chain taught)   Week 2 (student-led)

Why?

Which week did I learn more about architecture?

Week 1 (Mrs. Chain taught)   Week 2 (student-led)

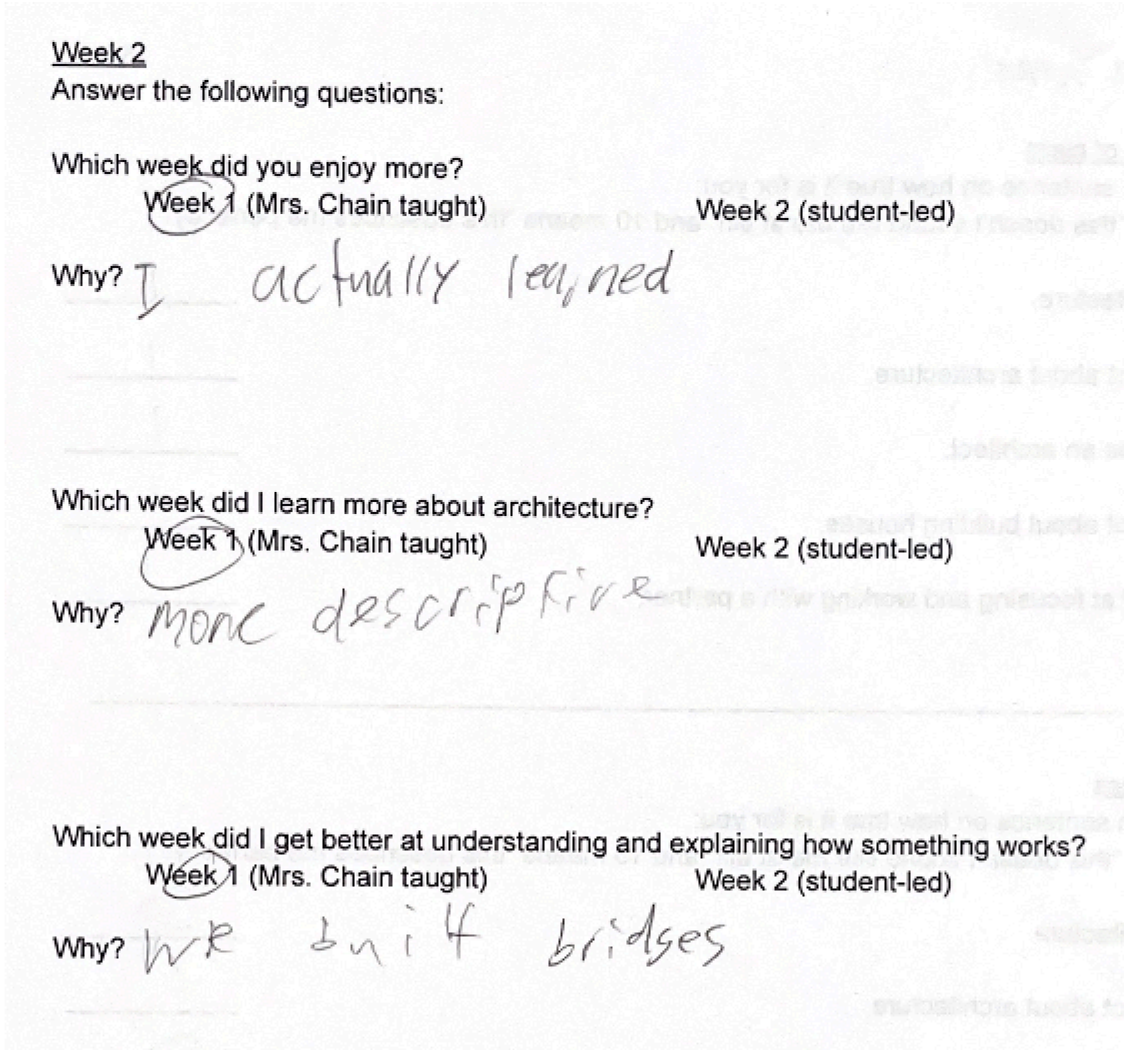
Why?

Which week did I get better at understanding and explaining how something works?

Week 1 (Mrs. Chain taught)   Week 2 (student-led)

Why?

Appendix H: Sample Final Survey Filled Out



Week 2

Answer the following questions:

Which week did you enjoy more?

Week 1 (Mrs. Chain taught) Week 2 (student-led)

Why? I actually learned

Which week did I learn more about architecture?

Week 1 (Mrs. Chain taught) Week 2 (student-led)

Why? more descriptive

Which week did I get better at understanding and explaining how something works?

Week 1 (Mrs. Chain taught) Week 2 (student-led)

Why? we built bridges

Acknowledgements

This research has been supported by Dr. Kelly Gomez Johnson and many thanks are extended to her for her brilliant insights and mentorship as well as her generous donation of time. Additionally, the flexibility and support offered by Dr. Lynn Spady & the Westside District Team (including Matt Kock & Emily Cutchall) is acknowledged and deeply appreciated.

This research study project proposal was reviewed by the UNMC IRB ORA and it has been determined that this project **does not constitute human subject research** as defined at 45CFR46.102. Therefore, it is not subject to the federal regulations, and **does not require IRB review**.