THE IMPACT OF ART ON STUDENTS' ATTITUDES AND LEARNING IN SCIENCE

by

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ABSTRACT

The purpose of this study is to explore how incorporating art into a science unit impacts students' attitudes towards science and their learning gains. There are currently only a handful of research papers that focus on incorporating STEAM (Science, Technology, Engineering, Art, and Math) into science classrooms, but not much research on using art in the science classroom to create transformative experiences. In this study paper engineering was used as the medium of art for the intervention group. Paper engineering for this research project is defined as the process of challenging students to create pop-up scenes that are three dimensional, create an effect to convey a message, and can be neatly folded away when done. Three out of four sections of chemistry classes were provided with an intervention of paper engineering (n=36) and the fourth section received traditional teaching as the control (n=16). All four sections took the Science Attitude Survey and a Pre-Content Assessment before starting a unit on atomic and nuclear theory. Throughout the unit the researcher reflected on the lessons being taught by filling out the Reflective Teaching Survey. After completing the intervention unit, all students took the Science Attitude Survey, Post-Content Assessment, and an Open-Ended Survey. Through quantitative and qualitative data analysis strategies, students from the intervention group demonstrated an increase in positive attitude towards science and a small learning gain. In conclusion, paper engineering is an effective STEAM strategy.

CHAPTER ONE

INTRODUCTION AND BACKGROUND

Context of the Study

In my second year of teaching, I enrolled myself into a professional development (PD) course called "Pop, Pull, Slide, Spin! Making Paper Engineered Pop-Ups to Spark Curiosity, Challenge Minds, and Assess Content Knowledge." I was eager to learn new strategies to engage my students and because the course aligned with my passion for the arts. The course focused on using the variety of pop-up folds that can be made, how they could be used to demonstrate student learning, and helping teachers find opportunities for art to be incorporated in the science classroom. After taking the PD course and experiencing success with using art to compliment and teach science content, I felt like there were endless ways that art could be incorporated into the science curriculum.

During my time in the course, the instructor referenced very few scholarly articles that demonstrated the impact and benefits of incorporating art into the sciences. I also found that my peers who had also signed up for the PD course were in the same boat as me; we encountered a lot of anecdotal evidence on the impact of incorporating art into education, but there was no official research that supported our experiences. After conducting some research on the topic, I found that there has been a push to incorporate art into the acronym for science, technology, engineering, and math (STEM) to create the acronym STEAM. The field of STEAM is somewhat new and is still in the development stages, where research is still being done on the benefits, practicality, and impact on students' learning. Therefore, the goal of my action research project is to contribute to the growing field of STEAM and, hopefully, demonstrate the impact that art can have on student learning in science.

I currently teach chemistry and biology to sophomores and first years respectively at Matthew C. Perry High School (MCPHS) in Iwakuni, Japan. MCPHS is one of the 45 schools that are in the Department of Defense Education Activity (DoDEA) district (DoDEA, 2021). Specifically, in the Pacific East division of the district, MCPHS is one of six high schools that serves a variety of United States Armed Forces families (DoDEA, 2022). MCPHS is home to roughly 220 students and reflects the diverse community of parents or guardians in the different branches of the U.S. Armed Forces and Department of Defense (DoD) civilian workers (Military Installations, 2022). According to the DoDEA, the racial demographics of the complex are broken down to the following: 43% White, 24% Hispanic, 12% Multicultural, 11% Black/African American, 7% Asian, 2% Hawaiian/Pacific Islander, and 1% AM Indian/AM Native (2021). The unique diversity in student identities described through the demographics shown above are reflected in the four sections of chemistry and one section of biology that I teach.

Focus Question

My focus question was, How does integrating art into a science unit impact students' learning and success in science?

My sub-questions include the following:

1. What impact does an art integrated science unit have on students' attitudes toward science?
2. Will students report an increase in their perceived learning and have a larger gain in their learning after an arts integrated science unit?

CHAPTER TWO

CONCEPTUAL FRAMEWORK

Introduction

Within the past millennia, science and art have been portrayed as divergent fields that have nothing to do with each other. Ozkan and Topsakal (2019) noted that the field of science represents objectivity, logic, and rationality, while the field of art can be boiled down to an aesthetic that represents emotion and creativity. However, historically science and art have coexisted naturally and not at odds. Leonardo Da Vinci is a prime example of the artist-scientist archetype; as he is known as the artist who painted the Mona Lisa, and as a scientist that contributed many significant inventions to society, such as the parachute, the diving suit, and a flying machine. Starud and Baines (2019) mention that other notable people who meet the artist-scientist archetype are Benjamin Franklin, Charles Darwin, Nikola Tesla, and Albert Einstein.

In the last two decades there has been a push and investment in Science, Technology, Engineering, and Mathematics (STEM) programs at every level of education. More recently, in the past five or so years, there have been whispers of the new acronym: STEAM, which includes art along with the other elements of STEM. The field of STEAM is in a unique position because the field is still relatively new and there is limited research and data on the effects of STEAM on student learning. In my conversations with colleagues, I’ve found that both teachers and researchers are supportive of the inclusion of art in STEM.

Many of the science programs that integrate art into their curriculum tend to use art as a tool to teach science rather than a truly interdisciplinary experience. Trott et al. (2020) criticizes that the incorporation of art into STEM has only been used at the surface level in science education, typically seen as drawing or coloring. After reviewing their two case studies on integrating photography to create transfer of information into tangible action in the community, Trott et al. reflect that being "transformative requires 'a shift or a switch to a new way of being and seeing'" (p. 1078). Ozkan and Topsakal (2019) expands on the transformative nature of integrating art into education by stating that artistic questioning allows educators to teach in more than one way, which allows students to create multiple nerve paths. The increase in neural pathways that are created when forming and reforming connections through new ways of seeing and understanding means that there is an increase in the likelihood that students will remember the information and experience of the lesson or unit. Thus, there is an undiscovered and underrated potential in embracing art as more than just a tool to teach science in science education.

Constructivist Roots

At the heart of STEAM are constructivist roots. The field of STEAM calls on the constructivist theories of Dewey, Vygotsky, and Piaget, where learning experiences, social learning, and student disequilibrium are valued and essential for student learning (Straud & Baines, 2019). One study that investigated the impacts of STEAM via creative dance found the lesson to align with the constructivist theories above. Valls et al. (2019) conducted a qualitative study on the integration of creative dance curriculum into the science classroom of elementary students. In the study, teachers instructed students from kindergarten to fifth grade on science content and creative dance. After learning about a given topic in science, the students would spend time alone and in small groups exploring what movements could represent the concepts that they had just learned. Valls et al. coded interviews with the teachers over the five years and found that the teachers reported that students were taking ownership of their learning, naturally asking deeper questions to help build their understanding due to a disequilibrium, and that they were working with their peers to construct a visual representation of the content they were learning. These themes align well with the constructivist theories and demonstrate one of the many possible ways that STEAM can be implemented.

A Transdisciplinary Approach

With the field of STEAM being so new and there being few studies completed on the impacts of STEAM, there is no framework established as the go-to method. However, out of the research that has been completed, the transdisciplinary approach seems to be the most common approach used by educators (Steele & Asheworth, 2019). Trott et al. (2020) defines the transdisciplinary approach as centering around the problem instead of the discipline to acquire knowledge. Wall et al. (2012) and Clark et al. (2020) demonstrated the benefits of this approach through their own qualitative research focused on the problems of climate change.

In their qualitative study, Wall et al. created a program called Cape Farewell that allows artists to create work based on scientific data. The work from artists were collected and put into an exhibit that allowed the community to interact and visualize the effects of climate change. As a result, Wall et al. (2012) found that the "hybrid of art and science generates interest in coral reefs and the challenges they are facing" (p. 152). Similarly, in their own qualitative study, Clark et al. (2020) found the benefit of the integration between art and science via a transdisciplinary approach. Six artists were paired with six scientists were tasked to create and define a mission statement for their initiative and individual project on exploring conservation issues in local Californian ecosystems. After completing the research and products, Clark et al. interviewed participants and found that the transdisciplinary approach took a lot more time and effort than they anticipated but found the overall holistic experience to be extremely valuable. One participant was quoted saying that

> Scientists pursue knowledge and artists pursue beauty. And sometimes a lot of art won't have substance to it, and sometimes science won't be so beautiful. And I think when those two disciplines collaborate together then it can create more of a clear message. Beauty that has meaning. Data, or maybe important research, is communicated in a more personal way (p. 826).

These studies show the transdisciplinary approach may be a valuable approach for learners because it allows students to build stronger connections between the content they have learned, but it may come at the cost of time.

Perceptions of Teachers on STEAM

With STEAM in the early developmental stages of its existence, the research on the topic has appropriately been focused on the benefits that come from the practice and how feasible it is for teachers to implement. Park et al. (2016) conducted a survey of teachers from elementary to high school in Korea and found that middle and high school teachers had negative perceptions when compared to the opinions of elementary school teachers. The survey also found that the largest concern from teachers regarding STEAM implementation were the added workload in grading and planning STEAM related content. Hero et al. (2019) did a similar qualitative study but with teachers from the United States, where they surveyed teachers' perceptions on the challenges of STEAM implementation. Their research found that teachers were concerned about not being able to stick to a pacing guide due to the longer nature of a transdisciplinary approach to STEAM and that they too were experiencing issues related to the amount of time it took to plan out the content. Together, these studies show that teachers generally see the benefits of integrating art into a STEM curriculum, but teachers find that there are drawbacks, like time, that are not necessarily within their control.

Perceptions of Students on STEAM

The limited research that has been conducted has indicated all the positive impacts that STEAM has on students. Bush et al. (2020) noted in their study on elementary students' perceptions of STEAM that there are very few studies that focus on student reported affect, such as attitudes, engagement, and satisfaction. Alongside Bush et al. (2020), Togou et al. (2020), and Swanson and Ostersmith (2021) have started to lay the groundwork for research on students affect toward the integration of art into STEM and science. In their research, Togou et al. looked to see what the impact that digital fabrication labs (fab labs) would have on students' attitudes toward learning STEAM. Thirty-nine students between sixth and seventh grade participated in units that involved designing materials that could be made via a 3D printer and took the Learner Motivation and Affective State questionnaires before and after the intervention. Togou et al. found that after students engaged with the fab labs there was a statistically significant increase in student engagement and a decrease in student boredom. These results are encouraging and demonstrates that the incorporation of art can have a positive effect. However, the sample size was relatively small and not all schools can afford to acquire and integrate a 3D printer into their science classes, so there is still space for research on how other interventions impact student affects towards STEAM and science.

Similarly, Swanson and Ostersmith (2021) found that simultaneously teaching science and art to first-year college students resulted in deeper learning for all students. First-year college students participated in both an introductory science and dance class where their learning was evaluated through journal reflections, scientific poster presentations, and dance performances. After analyzing the data collected, three themes emerged on the impact that the integrated course had on students. The three themes found were: (a) students were forced to engage with the content mentally and physically, (b) students with little to no experience in the content were forced to struggle in activities, and (c) students were tasked to discover and create. Swanson and Ostersmith noted that "learning dance provided a less academically threatening place to struggle and fail," which was the case for students who came to the class with a background in science or art (p. 4). Whether the student was struggling with the science or dance aspect, having a safe place to be in an educational disequilibrium provides the optimal zone of proximal development that Vygotsky attributed to quality learning. A student was quoted saying that "the dancing reinforced my understanding of the topics taught in the lecture. The dancing helped me visualize the process on a deeper level than just drawing diagrams off the whiteboard" (Swanson & Ostersmith, 2021, p. 5). Although limited to the population of higher education, Swanson and Ostersmith's research combined with Bush et al. (2020) and Toguo et al.'s (2020) findings demonstrate the immense potential for art to have a positive impact on students' attitudes towards science. However, those studies have had small sample sizes and used grade levels and students that were conveniently available, making the demographic of the research inconsistent. Therefore, there is huge potential for more research to be done on students' affect towards the incorporation of art into STEM.

Conclusion

Overall, we have only laid the first few brush strokes of what is possible with STEAM implementation. Although there have been documented benefits through the integration of art into STEM, such as increased creative thinking and collaboration skills, there is still a lot of research to be done (Herro et al., 2017; Ozkan & Topsakal, 2019). Turka et al. (2017) noted that "knowledge and experience are deeply intertwined in learning," which explains why there are many benefits to integrating art into science (p. 1405). STEAM presents students with unique learning experiences that allows them to transfer their scientific knowledge into something more creative which allows for deeper learning to take place. However, the field is still young, which means that teachers may have heard about STEAM but have not been taught how to meaningfully incorporate art into their science curriculum. Teachers who have tried integration reported a significant increase in the amount of time and money needed to plan meaningful lessons, which is something that not all teachers or schools can take on. While the perceptions of teachers on STEAM have been researched frequently, the research on student perceptions on STEAM has not. Therefore, there is a large opportunity for more research to be done on student perceptions on STEAM, along with the impacts STEAM has on student learning in the science classroom.

CHAPTER THREE

METHODOLOGY

Demographics

The purpose of this study was to evaluate how incorporating art into a science unit impacted students' attitudes towards science and their success in science, with the definition of success being the amount of knowledge gained. The two questions at the center of this research are "What impact does an art integrated science unit have on students' attitudes toward science?" and "Will students' report and demonstrate a larger gain in their learning after an arts integrated science unit?" The study used a mixed methods research design and data collection method to gather both qualitative and quantitative data to analyze and answer both focus questions.

This action research was conducted in the spring semester of the 2022-23 school year at Matthew C. Perry High School (MCPHS), which serves roughly 220 students in the Pacific East region of the Pacific district of DoDEA (Military Installations, 2022). As one of the two science teachers at the school, I am responsible for four sections of tenth grade chemistry and one section of ninth grade biology where the class size ranges from 15 to 22 students. The diversity in the five class sections that I teach reflect the demographics of DoDEA schools at large, which are broken down to be the following: 43% White, 24% Hispanic. 12% Multicultural, 11% Black/African American, 7% Asian, 2% Hawaiian/Pacific Islander, and 1% AM Indian/AM Native (DoDEA, 2021).

For this research, the chemistry class periods were chosen due to the number of sections that I teach. Three class sections were chosen for intervention, period B1 (n=10), period A1 (n=15), and period A2 (n=9). Periods B1, A1, and A2 were chosen due to being the inclusion class period (A2) and their similarity in ability and performance (B1 and A1). The inclusion class period was chosen to present the learning opportunity that would potentially help students who may benefit from an alternative style of teaching. The other class period, A3 (*n*=16) did not receive the intervention and was treated as the control. The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for work with human subjects was maintained (Appendix A).

Treatment

To test how incorporating art into a science unit impacts students' attitudes towards science and their learning gains, the student groups received different treatments. The group of three class periods (B1, A1, and A2), or the intervention group, went through a cycle of learning new paper engineering techniques, practicing those techniques, learning new content, and then applying the paper engineering techniques with the learned content. While the other class period (A3), the control group, received the same type of instruction and assessments that they had been receiving all year.

The intervention group started the intervention unit by completing the Science Attitude Survey (SAS) (Appendix B) and the Pre-Content Assessment (Appendix C). The intervention group then learned the different concepts of art, such as the different elements of art and principles of design. Students in the intervention group spent two weeks learning a paper engineering technique, practicing that technique, and then applying it to the content being taught. For example, student learned how to create the box fold one class, had homework to practice the skill, then next class they took notes and had homework that applied the box fold to summarize the content. That sequence of activities was used for learning about the triangle and v-folds, and movement folds. At the end of the unit students in the intervention group completed the SAS, the

Post-Content Assessment, and the Open-Ended Survey (OES) (Appendix D). Following a similar timeline, the control group completed the SAS and Pre-Content Assessment before starting the unit and then received normal instruction with similar activities that have been used in the past. Then at the end of the unit the control group also completed the SAS, OES, and Post-Content Assessment.

Data Collection and Analysis Strategies

The study used a mixed methods design and data collection methods to gather both qualitative and quantitative data to analyze and answer both focus questions. On the qualitative side of the mixed methods approach, this research follows a longitudinal case study format, while the quantitative research design used was quasi-experimental. The longitudinal case study design allowed the data to be collected within the context of the focus questions (Farquhar, 2018) and be compared to each other (Menard, 2022). The quantitative quasi-experimental research design is commonly used in the social sciences because it provides the researcher the ability to implement their research in the context of their field without having to randomize units to treatments (Stevenson, 2020). The data collection methods that were used in this mixed methods approach were a pre- and post-instruction Likert survey, an open-ended response survey, a pre- and post-content assessment, and reflective teaching.

Table 1. Data Triangulation Matrix.

Data Collection Instruments	Focus Questions	
	What impact does an arts integrated science unit have on students' attitudes towards science?	Will students report an increase in their perceived learning and have a larger gain in their learning after an arts integrated science unit?
Science Attitude Survey	X	
Open-Ended Survey	X	X
Pre- and Post-Content Assessment		X
Reflective Teaching Journal	X	X

Data Collection Methods

Science Attitude Survey. To collect data on students' attitudes towards science and answer the first focus question, students completed the Science Attitude Survey (SAS) twice during the intervention unit, once before the unit and the second time at the end of the intervention unit. The SAS was a Likert survey that collected qualitative data based on a series of nineteen individual ordinal scale items and had a six response Likert-Scale to choose from. Likert scales are widely used in educational research to measure attitudes and opinions on different topics (Jamieson, 2008). It is standard practice that Likert items have five response choices (two negative, one neutral, and two positive). However, the neutral option was eliminated to make sure the students are not defaulting to a neutral answer and being forced to choose from either end of the spectrum. (Gracyalny, 2017). The six Likert-Scale responses that students could choose from were strongly disagree, disagree, mildly disagree, mildly agree, agree, and strongly disagree.

Open-Ended Survey. To supplement the data collected from the SAS and to collect data on how much students think they've learned, students completed an Open-Ended Survey (OES) twice throughout the research, once before and after the intervention unit. The open-ended questions encouraged students to respond to questions through their perspective and in their own words (Lewis-Beck et al., 2004). Therefore, the open-ended questions encouraged students to share their experience with the intervention in their own words compared to the pre-determined options provided with in the SAS.

Pre- and Post-Content Assessment. Targeting the second focus question, "Will students' report and demonstrate a larger gain in their learning after an arts integrated science unit," students completed a Pre- and Post-Content Assessment twice throughout the research, once for the non-intervention unit and again for the intervention unit. The Pre- and Post-Content Assessment was a combination of multiple-choice and short-answer assessment, with a total of eighteen multiple choice questions and two short answer questions. The pretest-posttest instrument design is commonly used in educational research because it allows teachers to evaluate their own practice and effectively measure educational interventions (Shek & Zhu, 2018). The Pre- and Post-Content Assessment aligns with the two focus questions because it allowed me to quantitatively measure students' growth and run statistical analyses to look for any significant changes between the two.

Reflective Teaching Journal. The final data collection method used to answer both focus questions of this action research project was the Reflective Teaching Journal (RTJ), which was completed daily by the researcher throughout both the non-intervention unit and the intervention unit (Appendix E). Teacher journals can provide the practitioner-researcher the opportunity to reflect on not only their observations but also the feelings and interpretations associated with those observations (Mertler, 2019). The questions that were asked were like the questions that students were asked in the OES to allow for comparison. Therefore, the goal of the RTJ was to add more dimension to the data through a different perspective on any impact the intervention may have had.

Analysis Strategies

Following the mixed methods research design, the data that was collected were analyzed through qualitative and quantitative strategies. Qualitative data collected from the SAS was analyzed through descriptive and inferential statistics because the intervals between response choices (*strongly disagree, disagree, mildly disagree, mildly agree, agree, and strongly disagree*) cannot be assumed to be equal (Jamieson, 2008). Thus, mode and frequency were used to better understand and visualize any trends. More specifically, the mode provided insight on which responses were chosen the most for each statement on the SAS, while frequency gave insight to the distribution of responses. The data was also analyzed using a Chi-Square analysis that

To continue building color and detail, thematic analysis was used to analyze the qualitative data collected from the OES and RTJ. Thematic analysis is a process that "involves initially breaking data down – sometimes called 'drilling down' or 'fragmenting' – into the many different significant parts" to identify major themes from the responses (Silver & Lewins, 2014, p. 206). Once themes were identified from both data sources, the responses were sorted into the different themes based on the criteria identified. Data tables were created that listed the themes that were identified and the number of responses that fit those themes to emphasize the frequency of those themes. Furthermore, the themes identified from the OES and RTJ were compared to the data collected from the SAS to create a more wholistic picture of what happened.

On the quantitative side of the data collection and analysis, the Pre- and Post-Content assessment data were analyzed for trends and significant differences using a two tailed independent t-test and normalized gains. The independent t-test was used to determine whether there was a significant difference between students' average performance between the pre- and post-content assessment for both treatment and non-treatment groups (Belhekar, 2016). While normalized gains gave further insight on how much measurable learning took place due to the intervention unit. According to Hake (1998), a normalized gains of less than 0.3 percent is considered low, gains of 0.3 to 0.7 percent is considered a medium gain, and a normalized gains larger than 0.7 is considered high.

CHAPTER FOUR

DATA ANALYSIS

Results

Student Artwork

Students in the intervention followed a cycle of class periods where students learned a new folding technique, practiced the technique creatively for homework, took notes on the content for the unit, and then applied the folding technique to summarize their notes. An example of that cycle can be seen in the progression of figures 1 – 3. The three major paper folding techniques that students learned were the box fold, the triangle fold, v-folds, opposing levers, and spirals. Students demonstrated a wide variety of skills and creative applications of these folds both creatively and in their ability to summarize content notes.

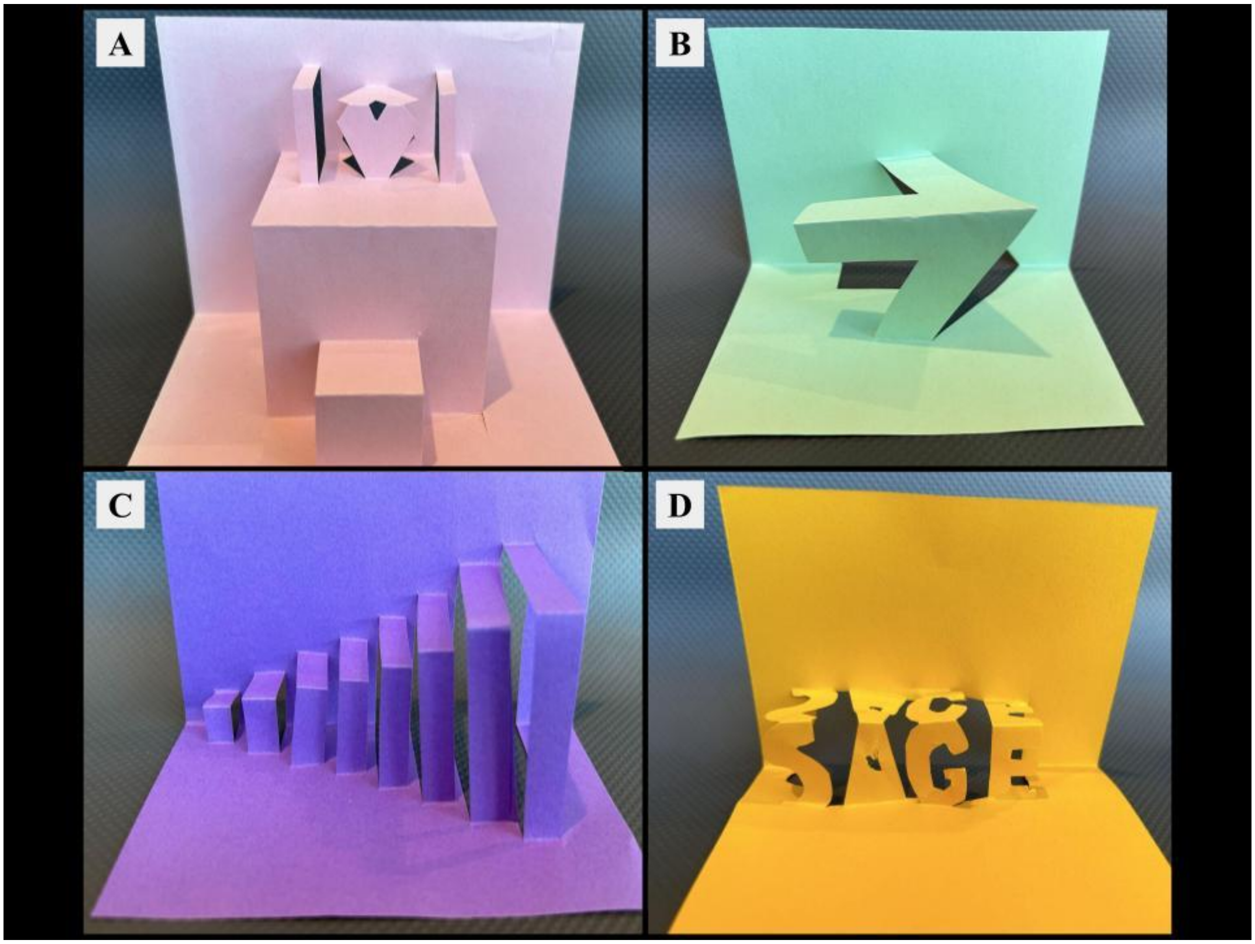

Figure 1. Student experiments after learning the box fold. A) Experiment with stacked boxes and different shapes. B) Experiment with shape and size of the box-fold. C) Experiment with pattern and movement with the box fold. D) Experiment with the shape and negative space of the box fold.

Figure 2. Student homework applying the box fold based on what they learned from their experiments. A) City scape that uses different textures and sizes of box folds. B) Café window that uses negative space in a basic box fold. C) Underwater scene that uses different shapes to create a box fold and utilization of a box fold as a support for images. D) Gundam that uses different shapes, negative space, and layering of different box folds to create the desired effect. E) Angry Birds scene that uses that box folds to create depths in the scene. F) New York City skyline that uses size to create depth of in the scene.

Figure 3. Student homework applying their knowledge of the box fold to the content learned. A) Caption reads “The particles called “atoms are small and indestructible even Yoshi can’t eat them all”. B) Comparison of the father and founder of modern chemistry. C) Notes about the history of the atom. D) Comparison of Dalton and Aristotle’s theories about the atom. E) Comparison of Democritus, Leucippus, and Aristotle’s theories about the atom.

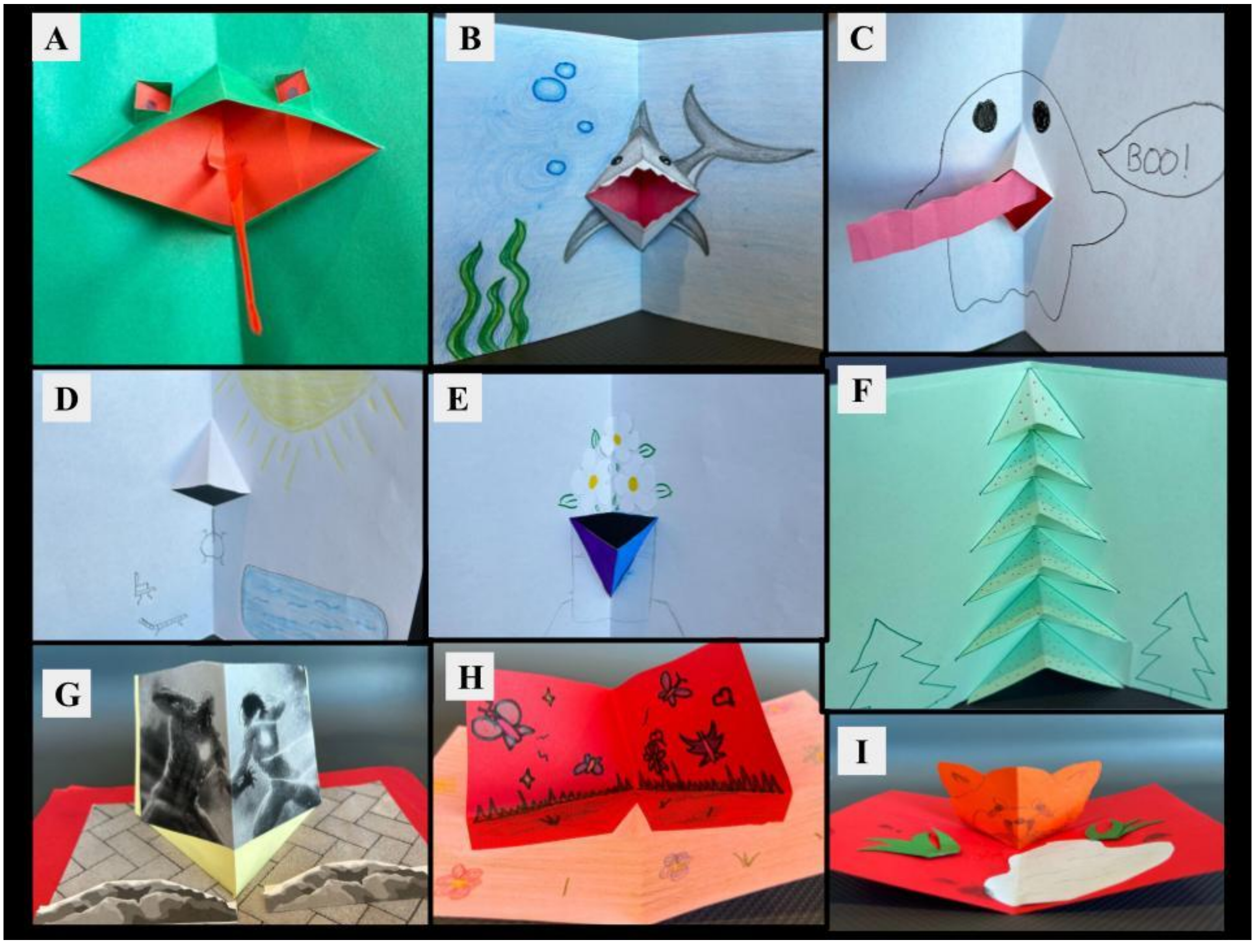

Figure 4. Student homework applying the triangle fold and different v-folds. A) A frog sticking its tongue out. B) A shark opening its mouth. C) A ghost sticking its tongue out saying “BOO!)”. D) Beach scene using the triangle fold as a sun shading umbrella. E) Triangle fold used as a vase for flowers. F) A large tree that is made up of multiple triangle folds stacked on top of each other. G) Attack on Titan scene from the anime using the acute angle v-fold. H) Summer scene using the obtuse angle v-fold. I) A red panda out in the wild that makes use of the right-angle v-fold.

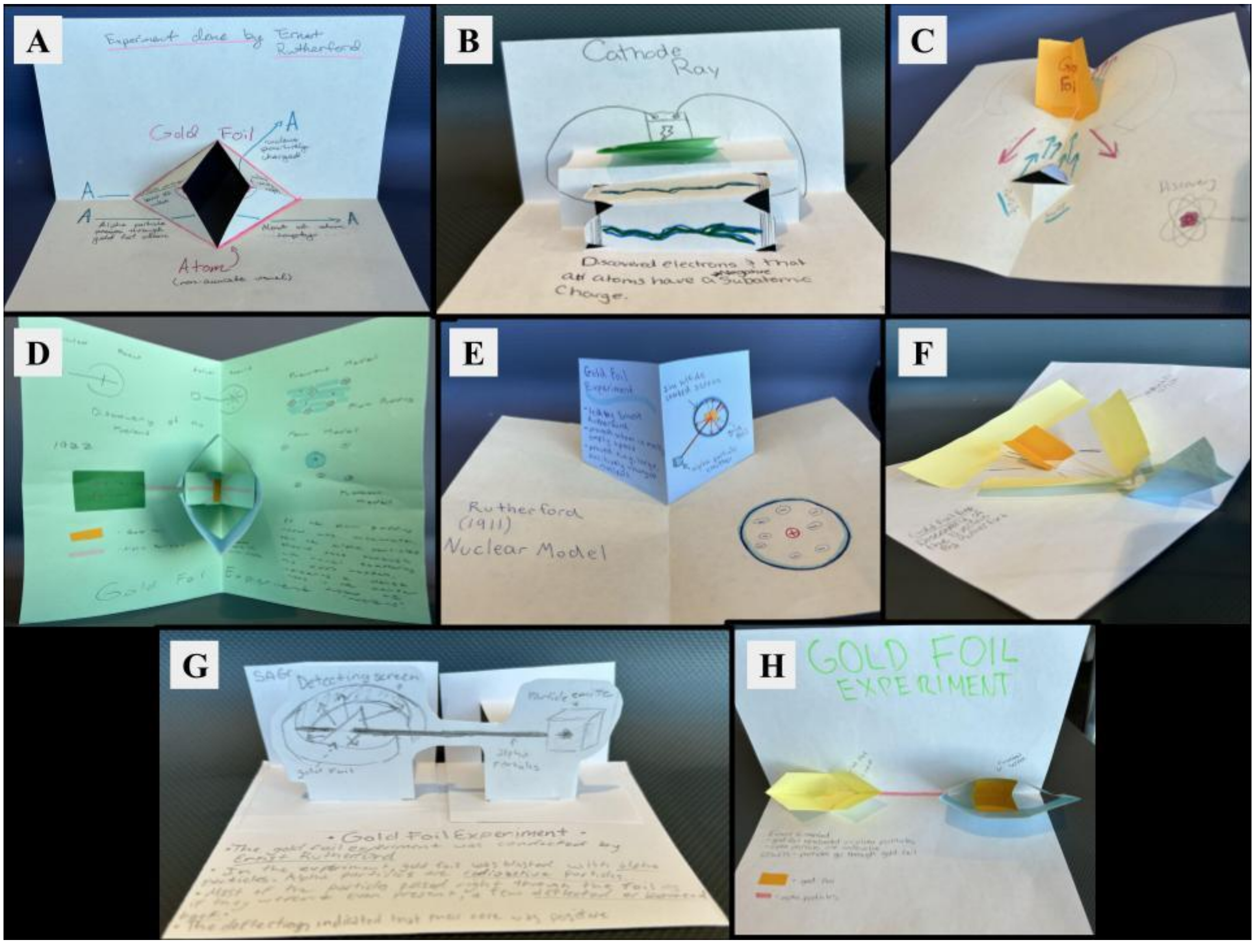

Figure 5. Student homework applying the box, triangle, and different v-folds to demonstrate and explain the content learned.

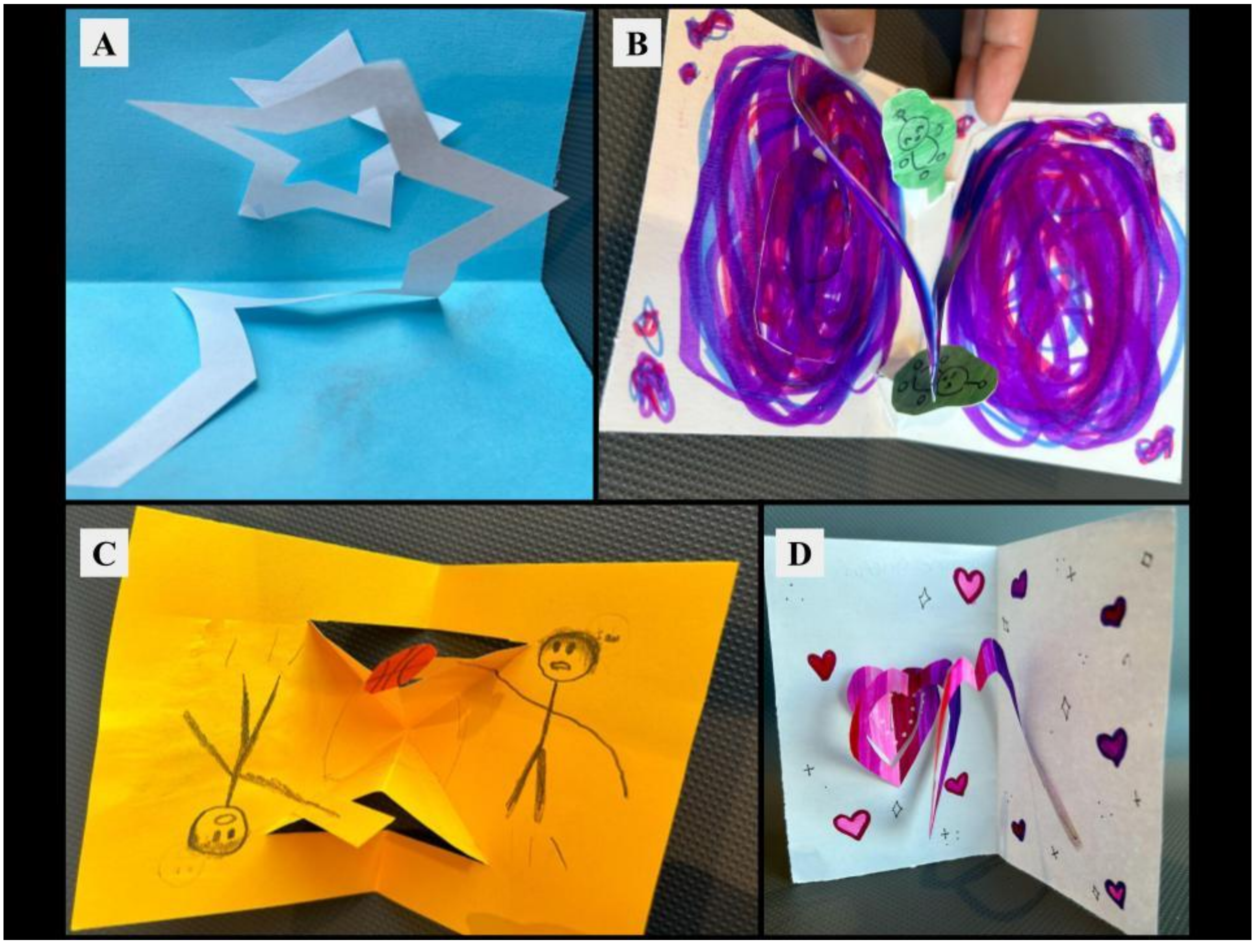

Figure 6. Student classwork exploring how to incorporate movement through levers or spirals. A) Spiral that plays with shape of a star. B) Galaxy scene that uses the spiral and lever techniques to create dimension and movement to the scene. C) Basketball tipoff that uses levers to create the movement of the players arms. D) Spiral that plays with the shape of a star.

Change in Students' Attitude Towards Science

The results of the Pre- and Post-Student Attitude Survey (SAS) show that students from the intervention group had a small increase in their attitudes towards science, but there was no statistically significant improvement of student attitudes towards science overall. When given the negative statement "Science is boring," 76% of the intervention group (N=36) disagreed with the statement overall, while 82% of the control group (N=16) disagreed with the statement initially. The intervention group showed a 10% increase for a total of 86% of students that disagreed with the statement that science is boring, while the control group demonstrated a 2% decrease for a total of 80% of students that disagree with that statement (Figure 7). A student from the intervention group noted that they "enjoyed learning folds, such as the triangle fold, because it allowed [them] to be creative which is unique for a science class." Looking at a positive statement from the SAS, such as "I find science interesting," students from the intervention group showed a 2% increase in agreement to that statement, while students from the control group showed an 8% decrease in agreement to the statement. Students from the control group reported that the most challenging part of the unit was "learning and grasping the concept of nuclear decay" and "the memorization of significant people." A Chi-Square analysis of the post-SAS results of the control and intervention produced a p-value of p=0.83. Therefore, the null hypothesis, that integrating art into a science unit does not improve students' attitudes towards science, was accepted.

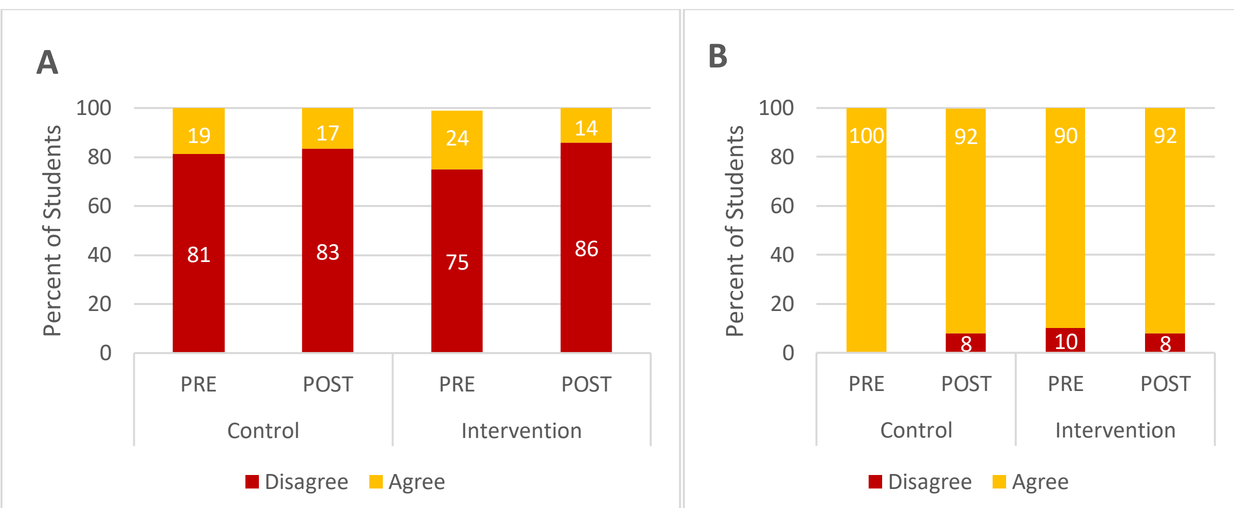

Figure 7. Change in students' response to SAS statements. (A) Change in students' response to the statement "Science is boring" for both control (n=16) and intervention (n=36), B) Change in students' response to that statement "I find science interesting" for both groups.

Students from the intervention group were observed to have higher levels of engagement compared to students from the intervention unit. Thematic analysis was used to analyze the data from the OES and four categories were created for each group. The four major themes in response to question two of the OES for the control group were miscellaneous, lab, notes, and baseball card which was a formative assessment that both the control and intervention group had to complete. The intervention group categories were paper engineering, lab, miscellaneous, and notes. The intervention group showed a strong preference for the intervention of paper engineering with 72.2% of students identifying it as their favorite part of the unit. While the control group had a much more evenly distributed number of responses for the different categories, it was noted in the teacher's reflection journal that the control group was consistently between 70 to 75% engaged in the lesson compared to students from the intervention group that were consistently between 80 to 95% engaged.

> During note taking students [from the intervention] were a little upset with how many notes they had to take, but after giving students directions for their paper engineering homework assignment, students immediately got up to get the supplies they needed and got to work on making their notes summary pop up.

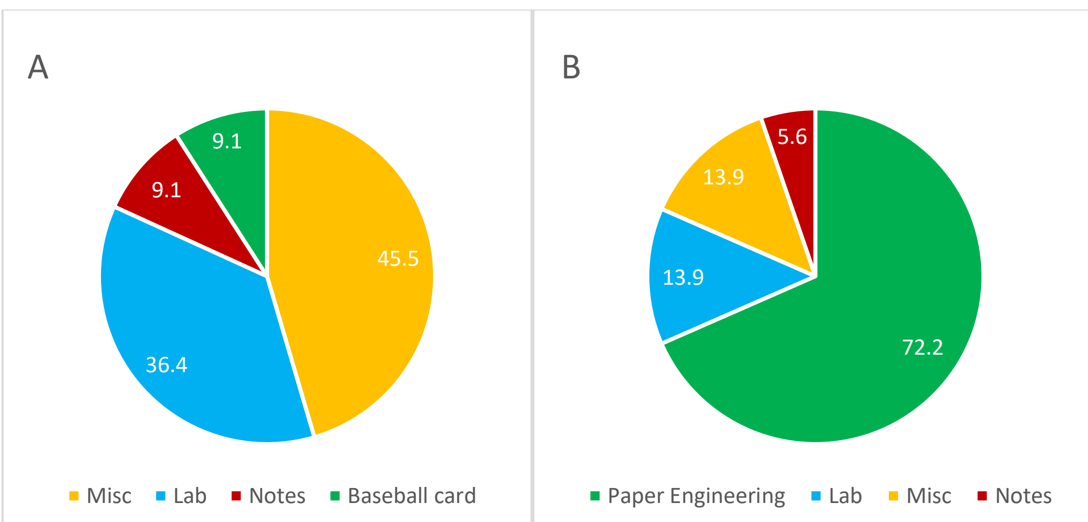

Figure 8. Percent of students who responded to the Open-Ended Survey results for question two for the control (*n*=16) and the intervention (*n*=36) group. (A) Percent of control group that identified their favorite activity was coded as miscellaneous (45.5%), lab (36.4%), Notes (9.1%), and Baseball Card (9.1%). (B) Percent of the intervention group their favorite activity was Paper Engineering (72.2%), Lab (13.9%), coded as Miscellaneous (13.9%), and Notes (5.6%). Note: Question two stated "What was your favorite activity or part of the unit? Please explain."

Student engagement in the intervention group was observed by the teacher throughout the paper engineering unit. As early as the second content-related intervention assignment, the teacher observed that “numerous (maybe 3-4) students making prototypes and experimenting with smaller pieces of paper to figure out what would work best to represent their ideas.” One student noted that “they weren't equipped with the tools to make a cylinder pop up and that they were doing the best they could to problem solve based on the methods they knew.” When the summative assessment came up for both groups, the control group had a more reserved reaction when they learned they had a unit test, but the intervention group, as written in the Teachers Reflection Journal, was observed to “burst with excitement” on creating a pop-up book for their summative assessment. Students shared with the teacher that “they were so excited to share their learning in a way other than a test.” For the final assessment, one student took the initiative to research a pop-up method that was not covered in the unit to incorporate into their pop-up book because they were genuinely interested in learning more paper engineering techniques.

Students’ Perceived Learning

The results of the Open-Ended Survey (OES) show that students from the intervention group reported more gains in their learning compared to the control group. Question four from the OES asked students to rank how they felt about the statement “I learned more during this unit compared to other units we've completed together.” The control group reported that 27% of students *Agree*, 36% *Mildly Agree*, 18% *Mildly Disagree*, and 18% *Disagree* (Figure 3). Students from the control group explained that “[they] learned a lot in this unit but have a hard time comparing it educationally to other units.” Other students echoed that sentiment when they reported that “the last unit was more in depth” and “this unit wasn’t as long as other units” which made it hard for them to compare the amount they had learned. The intervention group reported

that 8% percent of students chose *Strongly Agree*, 33% chose *Agree*, 39% chose *Mildly Agree*, 14% chose *Mildly Disagree*, and 6% chose *Disagree*. The students that chose along the spectrum from *Mildly Agree* to *Strongly Agree* explained that “the hands on just works for [them]” and that ‘the kinetic learning helped the content stick.” One student specifically wrote that they “enjoyed doing pop-ups with [their] work [, because] they helped [them] retain the notes more.”
Overall, the control group had a total of 36% of students disagree and 64% of students agree with the statement, while the intervention had a total of 19% disagree and 81% of students agree that they learned more in this unit compared to other units completed together (Figure 9).

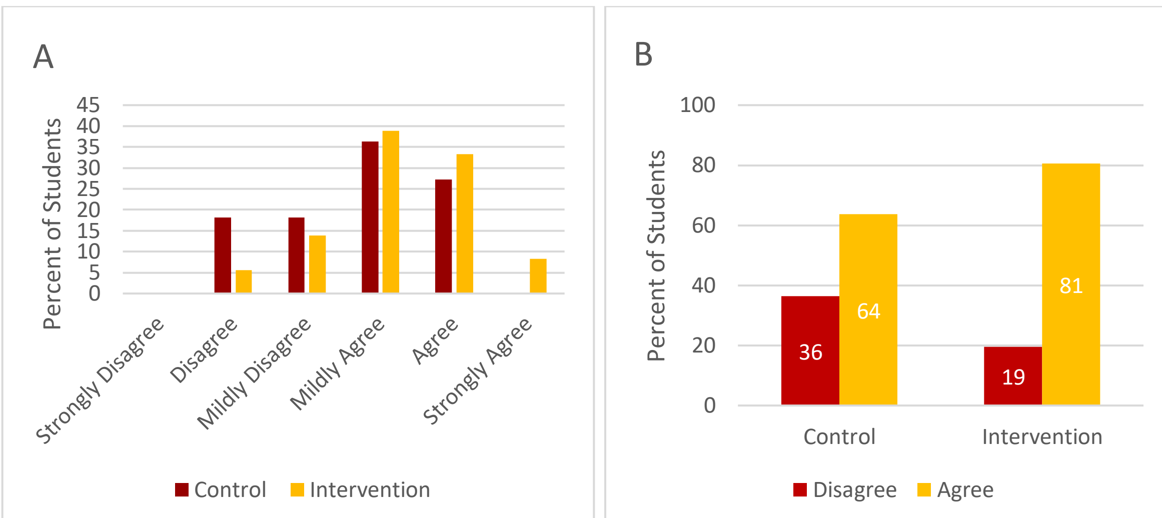

Figure 9. Student’s perceived learning on the unit for atomic and nuclear theory. (A) Percent of students that chose along the spectrum from *Strongly Disagree* to *Strongly Agree* for both control (*n*=16) and intervention groups (*n*=36). (B) Percent of students who chose *Disagree* and *Agree* overall for both control and intervention groups.

Students’ Learning Gains

Students from the intervention group experienced small learning gains as a result of the intervention, while the control group experienced larger overall gains in their learning. Pre- and Post-Content Assessment scores were analyzed for students normalized gains to determine any differences in student knowledge. Normalized gains of less than 0.3 percent were considered low, gains 0.3 to 0.7 were considered medium gain, and normalized gains greater than 0.7 were considered high (Hake, 1998). The control group had a medium normalized gain with a score of g = 0.54, compared to the intervention group which had a small normalized gain score of g = 0.13 (Hake, 1998). A two tailed independent t-test was performed on the Pre- and Post-Content Assessment scores for the control group and the intervention group. The control group had a p-value of $p = 1.5\text{x}10^{-6}$ and the intervention group had a p-value of $p = 0.03$. Both groups had a *p-value* < 0.05 which shows that there is a statistical significance between the Pre- and Post-Content Assessment scores for each group (Figure 10).

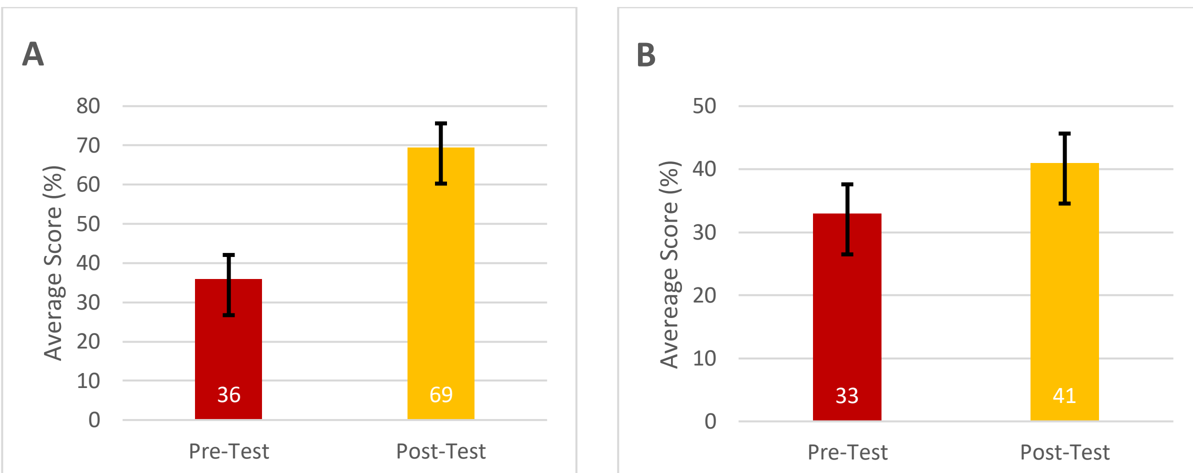

Figure 10. Average score of the control and intervention groups pre- and post-assessment scores. (A) Control pre- and post-assessment scores ($p = 1.5 \text{ x } 10^{-6}$). (B) Intervention pre- and post-assessment scores ($p = 0.03$).

A third two tailed independent t-test was performed on the Post-Content Assessment scores for both the control and intervention group. The p-value from the t-test between the two groups post-assessment scores was $p = 6\text{x}10^{-7}$. With a *p-value* < 0.05, there is a statistically significant difference between the control groups post-assessment scores and the intervention groups post-assessment scores (Figure 11).

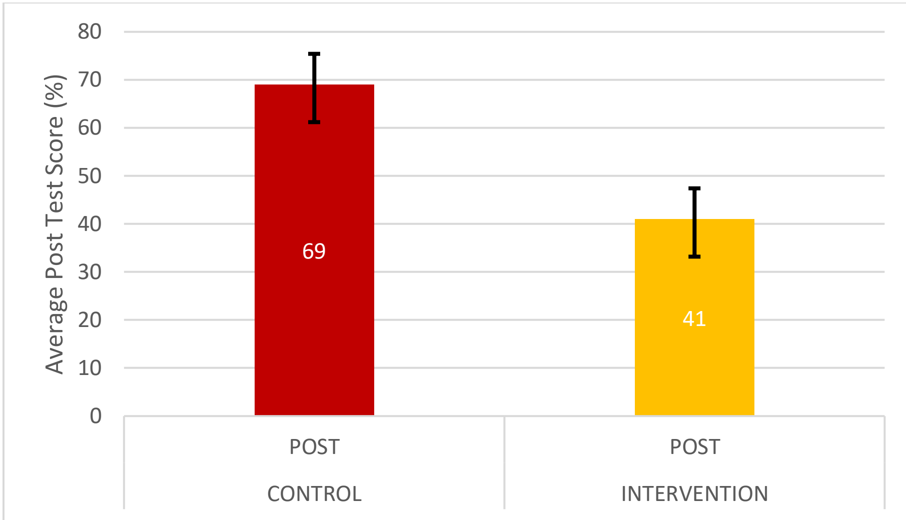

Figure 11. Average Post-Content Assessment scores for control and intervention groups (p=6x10^{-7}).

CHAPTER FIVE

CLAIM, EVIDENCE, AND REASONING

Claims From the Study

The goal of this action research project was to determine how incorporating art into a science unit impacted students' attitudes towards science and their learning gains. Looking at the results of this action research project, students from the intervention group had an increase in positive attitudes towards science. Student post-responses to the SAS showed a ten percent decrease in the number of students that think science is boring and a 2% increase in the number of students that find science interesting (Figure 1). These results mirrored the research of Togou et al.'s (2020) where they found that incorporating an artistic design element into a science content student engagement increased and boredom decreased. Typically, students in high school identify strongly as either art or science and rarely as a combination of the two. Incorporating art into a science unit creates the unique opportunity that puts science confident students in a learning disequilibrium regarding art and vice versa for the students who are artistically confident. The use of paper engineering increased the students' engagement because of the constructivist undertones embedded in the learning experiences. Therefore, all students are on an equal learning field, and it encourages students to engage in social learning which is naturally more engaging than individual learning.

Paper engineering not only increased students' attitudes towards science, but also increased students perceived learning gains and their actual learning gains. When responding to the statement "I learned more during this unit compared to other units we've completed together," there was a 17% difference between the number of students who agreed to that statement between the control and intervention group (64% compared to 81% respectively). The intervention group also showed on average a 13% increase in their learning based on their Pre- and Post-Content Assessment scores. Therefore, the increase in students' perceived learning and learning gains are attributed to the need to model abstract science concepts and the natural curiosity that is sparked in that process. Similarly, Valls et al. (2019) found that combining creative dance and science content sparks true curiosity and a need for a deeper understanding of the science content due to the need to physicalize science. In both cases, paper engineering and creative dance, created a natural need for problem solving that engaged students in a meaningful way which resulted in a better understanding of the science content and the intervention groups learning gains.

Value of the Study and Consideration for Future Research

After dabbling in paper engineering through a professional development course and based on the modest amount of research on the incorporation of the arts into science, I was very excited to conduct this research. Although the results were not expected, this experience and practice implementing an action research project was invaluable. Upon reflection, I've realized that I lean heavily toward constructivist teaching practices and am thrilled that I found a teaching strategy that aligns with my passion for the arts and that yields positive results in students learning gains. Students that participated in the intervention thoroughly enjoyed the experience and, in their feedback, suggested that I keep paper engineering and incorporate it more throughout the school year. On the other hand, students from the control group constantly reminded me that they were frustrated because they couldn't do paper engineering. Although the control group demonstrated a higher amount of learning gains, they were chosen as the control because of their consistently high performance compared to the other class periods, which held true through this research. Moving forward, I would like to start using paper engineering at the beginning of the and over time building lessons on paper engineering techniques that positively supplement the content that's being covered.

The focus of this action research project was to see what impact incorporating art into a science unit would have on students' attitudes and learning gains. Upon reflection of the results, those questions were answered. Students who participated in paper engineering had an increase in their positive attitudes towards science and demonstrated a small learning gain. However, the results also suggest that further research would be valuable. This study looked specifically at 10^{th} and 11^{th} grade chemistry classes, but it would be interesting to see the impact of paper engineering in a biology, physics, and/or Earth science class. Also, similar to the existing literature on the impacts of art on science, the sample size of this research was small, and the length of implementation could be extended. Looking forward, three actions that I would like to do to further this research are: one incorporating paper engineering into other branches of science, two expanding the sample size of the research pool, and three expanding the time of implementation.

Impact of Action Research on the Author

Mertler (2016) identified action research as an intentional "application of the scientific method to educational topics, phenomena, or questions in search of answers" (p. 6). Looking back at all the work that's been put into planning, conducting, and drawing conclusions, this action research project did just that. Lari et al. (2019) build on this definition by stating that action "have a greater awareness of their teaching practices and student needs" (p. 23). Other than labs and a few card sorting activities, there are not many hands-on and minds-on activities that can help students who identify as kinesthetic learners. As a result of the action research project, I was able to better identify students' need to have more kinesthetic learning activities and implement a teaching strategy that I thought would help meet that need. Based on the results, the strategy was successful, and I was able to gain even further insight on students' needs in the science classroom.

Throughout my educational experience, I remember arts and crafts playing an important role in my learning. I found the incorporation of art allowed for mind and muscle connection that emphasized the content through the process of creating something physical. After conducting this action research, I've been reminded that art is not everyone's favorite thing and that there are some students that prefer the more traditional structure. However, the majority of students found success and enjoyment through paper engineering, so I plan to continue using it as a teaching strategy to help students learn. The action step that I would take next would be to use paper engineering in a more strategic way where we would use paper engineering only when students would benefit from the physicality of creating models through paper engineering.

The action research process has equipped me with the necessary skills to continue finding data driven strategies that work for me and my students. With the action research process being cyclical, I now find myself towards the end of one cycle and getting inspired for the next. I now know the answer to my original research question and have identified what went well and what I would like to modify moving froward from my study. Going with the flow of this momentum, I would also love to share and, hopefully, start the flames of inspiration with my coworkers to further help more students by continuing to incorporate the action research process into a variety of classes. Regardless, I am confident that I'll be able to use this process to continue my journey as an educator and am better able to identify and meet students' needs through data driven processes.

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APPENDICES

APPENDIX A

MONTANA STATE UNIVERSITY INSTITUTIONAL REVIEW BOARD

Hello Tsuha, Beth,

Your protocol was reviewed by the IRB and has been approved.

PI: Tsuha, Beth
Approval Date: 1/23/2023
Title: The Impact of Art on Student's Attitudes and Learning in Science

Protocol #: 2023-423-EXEMPT
Review Type: Exempt Review
Expiration Date: 1/23/2028

Work described under this protocol may now commence. The PI is responsible for ensuring that the protocol accurately describes research practices being conducted.

> Review Category designation determined by the IRB can be found in the final section of your protocol.
> IRB-stamped active Consent Forms are attached within your protocol where applicable.
> Any changes must be submitted via Amendment prior to implementation.
> Per the Common Rule, research only requires Interim (annual) Review by the IRB if 1) it was reviewed via Full Committee or 2) is regulated by the FDA.
> All research is subject to post approval monitoring.
> All protocol types must be renewed 5 years after approval.
> Inform the IRB once your research is complete so that the protocol may be inactivated.

Please contact your IRB Program Manager with any questions or if you are in need of assistance. Thank you for your diligence in the care of human subjects research participants.

APPENDIX B

PRE AND POST CONTENT ASSESEMENT

Mrs. Tsuha's Graduate Research Information

My name is Mrs. Tsuha and I'm currently a graduate student at Montana State University (MSU) and am working towards earning a master's degree in science education. The purpose of my research is to see what impact incorporating art into a science class has on student's attitudes towards science and how much they learn in a science unit. For this research, all the data that I will collect will be collected anonymously through Google Forms and handouts. I will be collecting data in the form of pre- and post- content tests for two different units and a Google Form survey aimed to measure student's attitudes towards science. The data collected from these research tools will be analyzed for trends and transformed into figures that can be used to justify what type of impact art has on science education.

Participating in the following activity is completely voluntary and you can choose not to answer any questions you do not want to answer and/or you can stop at any time. Participation or non-participation will not affect your grade or class standing in any way. Proceeding with the survey/interview/questionnaire indicates your consent to participate. If you have any questions or need to contact myself or the MSU IRB, below is our contact information.

Thank you!

Mrs. Tsuha

beth.tsuha@dodea.edu

irb@montana.edu

Atomic + Nuclear Theory Pre- and Post-Test

Please answer the following questions to the best of your ability. Remember that participating in the following activity is completely voluntary and you can choose not to answer any questions you do not want to answer and/or you can stop at any time. Participation or non-participation will not affect your grade or class standing in any way.

1. Which of the following is not a part of Dalton's atomic theory?
   a. All the elements are composed of atoms
   b. Atoms of the same element are alike
   c. Atoms are always in motion
   d. Atoms that combine do so on simple whole-number ratios

2. Dalton theorized that atoms are invisible and that all atoms of an element are identical. We now know that:
   a. Dalton's theories are completely correct
   b. Atoms of an element can have different numbers of protons.
   c. Atoms are divisible
   d. All atoms of an element are not identical, but they must all have the same mass

3. The number of neutrons in the nucleus of an atom can be calculated by:
   a. Adding together the numbers of electrons and protons
   b. Subtracting the number of protons from the number of electrons
   c. Subtracting the number of protons from the mass number
   d. Adding the mass number to the number of protons

4. All atoms of the same element have the same:
   a. Number of protons
   b. Number of neutrons
   c. Mass number
   d. Mass

5. Which of these statements is false?
   a. Electrons have a negative charge
   b. Electrons have a mass of 1 amu
   c. The nucleus of an atom is positively charged
   d. The neutron is found in the nucleus of an atom

6. An atom of an element with atomic number 48 and mass number 120 contains:
   a. 48 protons, 48 electrons, and 72 neutrons
   b. 72 protons, 48 electrons, and 48 neutrons
   c. 120 protons, 48 electrons, and 72 neutrons
   d. 72 protons, 72 electrons, and 48 neutrons

Name:______________________________ Pd:_________ Date:________________________

7. How do isotopes, hydrogen-2 and hydrogen-3, differ?
    a. Hydrogen-3 had one more electron than Hydrogen-2
    b. Hydrogen-3 has two neutrons
    c. Hydrogen-3 has three protons
    d. Hydrogen-2 has two neutrons

8. What does the number 80 in the name bromine-80 represent?
    a. The atomic number
    b. The mass number
    c. The sum of protons and electrons
    d. None of these

9. Which of these statements is not true?
    a. Atoms of the same element can have different masses
    b. The nucleus of an atom has a positive charge
    c. Atoms of isotopes of an element have different numbers of protons
    d. Atoms are mostly empty space

10. Relative atomic masses are measured in:
    a. Nanograms (ng)
    b. Grams (g)
    c. Angstroms (Å)
    d. Atomic mass units (amu)

11. If E is the symbol for an element, which two of the following symbols represent isotopes of the same element?

A. $_{12}E^{24.}$ **B.** $_{13}E^{24.}$ **C.** $_{11}E^{25}$ **D.** $_{12}E^{25}$
    a. A and B
    b. C and D
    c. A and D
    d. B and C

12. Which of the following is not true concerning an alpha particle?
    a. It has a mass of 4 amu
    b. It has a 1+ charge
    c. It is a helium nucleus
    d. It contains two neutrons

13. Ionizing radiation that is negatively charged is:
    a. Alpha radiation
    b. Beta radiation
    c. Gamma radiation
    d. X-rays

14. Which type of ionizing radiation can be blocked by "normal" clothing, or just skin?
    a. Alpha particles
    b. Gamma radiation
    c. X-radiation
    d. Beta particle

APPENDIX C

OPEN-ENDED SURVEY

<u>Open-Ended Survey</u>

Please answer the following questions. Data collected from this survey is anonymous and participation in this research is voluntary. Participation or non-participation will not affect your grade or class standing in any way.

1. After completing this past unit, would you rate your experience in science as positive or negative? Please explain.

2. What was your favorite activity or part of the unit? Please explain.

3. What was the most challenging part of the unit? Please explain.

4. I learned more during this unit compared to other units we've completed together.

    a. Select the statement that best describes how you feel about the statement above.

       SD ……… D ……… MD ……… MA ……… A ……… SA

       SD= Strongly Disagree, D = Disagree, MD= Mildly Disagree

       SA= Strongly Agree, A= Agree, MA= Mildly Agree

    b. Please explain your reasoning for choosing the statement you chose above.

5. Is there anything else that you would like to share with me about your experience in this past unit?

Name:________________________________ Pd:_________ Date:_________________________

15. Which of these naturally occurring radioisotopes would be most useful in dating an object thought to be 25 thousand ($2.5x10^4$) years old?
    a. carbon–14, $t_{1/2}$ = 5.715×10^3 years
    b. thorium–232, $t_{1/2}$ = 1.4×10^{10} years
    c. phosphorus–32, $t_{1/2}$ = 14.3 days
    d. radon–222, $t_{1/2}$ = 3.82 days

16. A piece of wood, which was found in an ancient burial mound, contains ¼ (one-fourth) as much carbon–14 as a piece of wood cut from a living tree growing nearby. Using the half-life (t1/2) for carbon–14 located in your reference tables, determine the approximate age of the ancient wood.
    a. 1432.5 years
    b. 2865 years
    c. 5730 years
    d. 11430 years

17. If an isotope undergoes beta emission:
    a. The mass number changes
    b. The atomic number changes
    c. The atomic number remains the same
    d. The number of neutrons remains the same

18. In nuclear fission:
    a. A large atom is split into two or more smaller atoms
    b. Two or more smaller atoms fuse together forming a larger atom
    c. A chain reaction cannot occur
    d. Energy is absorbed

19. Nuclear fusion:
    a. Occurs when two light nuclei unite to form a new larger atom
    b. Occurs at very high temperatures
    c. Occurs in the sun
    d. All of these

20. Radioisotopes taken internally for medical reasons:
    a. Must be eliminated from the body slowly
    b. Should be fissionable isotopes
    c. Should have stable nuclei
    d. Should have a short half-life

APPENDIX D

STUDENT ATTITUDE SURVEY

Science Attitude Survey (SAS)

Please answer the following questions. Data collected from this survey is anonymous and participation in this research is voluntary. Participation or non-participation will not affect your grade or class standing in any way.
SD= Strongly Disagree D= Disagree MD= Moderately Disagree,
SA= Strongly Agree A= Agree MA= Moderately Agree

Statement	SD	D	MD	MA	A	SA
The science we learn at school is useful in other subjects.						
Understanding the science we're doing is important to me.						
Science is boring.						
I'd like a job that involves using science.						
Many of the things we learn in science are useful elsewhere.						
I like learning science.						
I find science difficult.						
I might do something related to science after I leave school most days.						
School science is relevant to life in today's world.						
I look forward to doing science.						
I like to know the thinking behind the science I'm studying.						
I'm good at science.						
I avoid science when I leave school most days.						
Everybody will need to know some science in their adult life.						
I find science interesting.						
I plan to carry on studying science when the time comes to choose.						
Learning in science is important for getting a job in the future.						
I enjoy studying science.						
I can imagine choosing a career connected to science.						

The statements used were taken from the *University of Cambridge Faculty of Education – Attitude Questionnaire Science* (https://www.educ.cam.ac.uk/research/programmes/episteme/epiSTEMeScienceAttitudeQuestionnaire.pdf).

APPENDIX E

REFLECTIVE TEACHING JOURNAL PROMPTS

Reflective Teaching Journaling Prompts

Date:______________ Class Period:__________________

1. Overall, how would you describe your student’s attitudes in class today. Please explain.

2. What percent of my students were actively engaged and participating in the lesson today?

3. Have the students grown since the last lesson? Please explain.

4. Any other comments?