

INTEGRATING BIOLOGY SUBJECT LESSONS INTO A
HIGH SCHOOL VISUAL ARTS CLASSROOM

by

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ABSTRACT

Students at Thunder Ridge High School in Idaho Falls, Idaho were having difficulty integrating compelling subject matter into their artwork, often copying ideas from Google or Instagram. Topics in biology were introduced to create inquiry surrounding the selection of subject for student projects. The literature base for this project strongly supports the integration of art and science as a means of building relevance and interest among students in science and art topics. This study was developed to determine if student work improved when provided artistic subject in biology topics compared to projects where students developed artistic subject independently. Students in either Art 1 or Ceramics 1 visual arts classes were expected to complete four projects over the course of a trimester. Students created two projects related to subjects in biology and two projects were developed by students independently. Qualitative surveys and interviews were employed alongside quantitative project rubrics and biology content assessments to determine the effect on student perceptions and performance during biology and art integration.

INTRODUCTION AND BACKGROUND

In 2017, the state of Idaho adopted new visual arts standards. The change in legislation served as an attempt to move away from the prescriptive objectives used previously and develop a set of standards that aligned more with the skills-based approach of Common Core. Where curricula of years previous might require students to develop an attitude or specific practice within visual arts, the new standards ask students to undertake rigorous explorative and inquiry-based methods. The new standards are aimed at providing students with the skills necessary to create and present art, interpret feedback within the artistic community, and build connections between bodies of artistic work (State of Idaho Department of Education, 2015). The challenge of providing students with adequate parameters for artistic inquiry while allowing them the opportunity to explore infinite resources regarding artistic subject matter was the initial impetus to integrate science topics into my visual arts classes. Ideally, the biology-based subjects used by students would serve as an adequate launching pad for students to ideate and create artwork appropriate for viewing by an audience outside of themselves.

After three years of teaching middle school science, I took up a position teaching high school ceramics in the fall of 2018 at Thunder Ridge High School in Idaho Falls, Idaho. Thunder Ridge High School was recently founded in 2018, and is one of three traditional high schools in Bonneville Joint School District 93. The school celebrated its first graduating class in the spring of 2019, so much of the demographic information regarding the school remains to be seen. Thunder Ridge High School has an enrollment of 1,377 students, with 24% of the students identified as racial minorities: 20% Latino,

2% Multi Racial, 1% American Indian, 0.5% Asian, and 0.5% African American.

Socioeconomically, 35% of students have been identified as economically disadvantaged.

In a typical trimester, I have two Art 1 classes, two ceramics classes, and a Practical Arts class. The Art 1 class serves as an introduction to visual art practices and techniques based on the Idaho Visual Arts Standards. In Art 1, students have access to a breadth of materials to incorporate into their artwork and a great deal of liberty to create whatever project suits their interest. My Ceramics classes are required to take Art 1 or another art prerequisite course, and are limited to a clay medium, though Ceramics also follows the Idaho Visual Arts Standards. My Practical Arts class is designed for students with developmental disabilities and has no set standards.

When I began teaching Art 1 and Ceramics courses, I initially allowed students to create their projects independently, with most of my support aimed at helping students in construction and technical skills. Student work covered a breadth of artistic subject matter. Inspirational quotes, whales, cacti, and soccer balls stand as examples to the topics covered in student projects. When I would ask students what had inspired their work, they would often tell me that they had found the idea on the internet, they had seen a classmate make something similar in another class, or “I just thought it would look cool.” In this respect, I found the majority of my students failed to meet the Proficient level of mastery of the Idaho visual arts standard, asking students to “Shape an artistic investigation of an aspect of present-day life using a contemporary practice of art or design” (State of Idaho Department of Education, 2015, p. 2). Students were quite content taking projects on face value and took little time to develop subject in the

creation of their projects. This would make it rather difficult for students to progress beyond a Proficient level of work to Accomplished or Advanced according to the standards.

Research Questions

Eager to improve the quality of work of my students and anxious to provide subject matter that required more than superficial understandings, I developed the following question: How does the integration of biology instruction in a high school visual arts classroom affect student understanding of the artistic investigative process? Questions also examined over the course of this project include: 1) How do students integrate their understandings of biological phenomena into their artistic expression? 2) How do students relate scientific inquiry to artistic inquiry? 3) What do students take away from biology instruction in a visual arts classroom?

CONCEPTUAL FRAMEWORK

The integration of art and science is not a new concept, though the fields of art, science, and education all share an understanding that there are still novel concepts waiting to be discovered in interdisciplinary practices. Analysis of the work of the foremost thinkers, from Leonardo Da Vinci to Cheng-Dau Lee, demonstrate the potential breadth for creative scientific work (Tamir, 2000). In the field of biology, the diagrams and naturalist drawings of Charles Darwin stand out as exemplary artifacts to the worth of artistic observation and expression in a scientific field. Many within the field of art see much to be gained from the formulaic processes of scientists just as there are those working the fields of science who appreciate the creative and empathetic qualities of

professionals working in the visual arts. For educators invested in integrating the qualities of both models of thinking, it becomes quickly apparent that the underlying assumptions of both art and science cannot go without proper scrutiny by both educators and students alike. A consensus emerges asking both disciplines to embrace new methods of understanding (Hawkins, 2000). The premise of this project rests on the similarities in the artistic and scientific processes with the aim of promoting discourse between the two disciplines and elevating accessibility and quality of work for both methods of understanding.

Art Education

Practices among art educators are ripe for change in K-12 education. English, math, science and other core subjects have taken adoption of Common Core as an opportunity to reconsider fundamental strategies for instruction in these content areas. Students who find strength in observational and creative strategies that abound in the arts struggle to find connections with other subjects. Accounts such as those by Michele K. Sommer (2013) resonate with many who have difficulty connecting their visual-spatial strategies with practices in other content areas. As a young girl, the praise of a single art teacher was the only source of vindication Sommer had to validate her work in school, though she continues to use her artistic strategies in her work as an educator in order to connect with students and their ideas. Beyond finding strategies to connect artistic skills to work in other subjects, there exists a need for educators to develop curricula that embeds meaning and relevance into student artwork.

Current attitudes in art education propagate lessons and projects that fundamentally limit student outcomes and understandings. Students complete the same assigned art projects with the same parameters as those who have studied before them, resulting in stagnant, recycled products (Gude, 2013). The focus in many of these cases is not built around students investigating methods to create meaning in their work. Instead, students are asked to complete projects as prescribed and walk away with generic, unenthusiastic perceptions of what it means to be a productive artist. Gude presents an example in her analysis, how students were shown examples of Impressionist artwork and then asked to adopt strategies of Impressionist artists, playing with light and painting en plein air. Student projects, in this case, were derived from *National Geographic* images and no students were observed playing with light as they had been instructed, showing failure to adopt artistic strategies of Impressionists on a fundamental level. Many art educators have come to experience the self-inflicted disappointment of seeing student work not turn out the way they had planned, presenting an opportunity to modify teacher expectations and strengthen student outcomes.

Much of the dialogue in art education today surrounds strategies to engage students in artistic investigations that explore relevant social subjects. Teachers who have found success in this strategy have developed projects that allow students to “explore issues relating to identity, personal narrative, or community” while providing open-ended project expectations and student-specific feedback (Cummings, 2012, p. 19). This aligns with the views of those working to modify dialogue within art education who seek out opportunities to present diverse and alienated narratives within the classroom, especially

those related to race and socio-economic disparities. These strategies would move away from prescriptive traditions of art education found in the past and instead “balance ‘academic tongue’ (theoretical/philosophical vs. K-12 language) with a feminist language focused on care of others, creating a classroom space and dialogue where diverse cultural and lived experiences of all are honored” (Chapman, 2006, as cited in Kraehe, Acuff, Slivka, & Pfeiler-Wunder, 2015. p. 6). Integrating such practices not only recognizes the influence that society and cultures have on individuals, but these strategies also enable students to connect their experiences within their community to their art and other individuals (Leake, 2012). By creating projects and artwork based on a student’s local community, students are able to gather artifacts and insights that can be used to better develop and critique artwork (Bertling, 2013).

The focus of art education moving forward centers around providing students with ample opportunities to research interdisciplinary understandings and then apply those understandings to create student-centered bodies of work. Ultimately, an art project should become an opportunity for students to mesh their “skills, talents, and intellectual and aesthetic interests into a functional whole,” while connecting art to other subjects and modes of thinking more than art education methods used previously (Eubanks, 2012, p. 52). In building this bridge between art and other disciplines, educators are better equipped to apply relevant vocabulary, not only for art, but for the subject that is being examined and integrated as well. While integration of other subjects will ultimately change the manner in which art is carried out, there are guidelines within art education that should be adopted to facilitate stronger investigations on the part of students. Art

educators need to set their students up for opportunities to generate new understandings and considerations surrounding subjects, and “not be instructed to *illustrate, symbolize, or represent* (i.e. RE-present) things (such as ideas, beliefs, emotions) that are already fully formed, fully understood” (Gude, 2013, p. 11). Educators that present art and the subjects it examines in an exploratory light provide their students opportunities to adopt divergent thinking strategies—strategies that often come to use in other disciplines that require creative and critical thinking skills. Art should not be demonstrated as a matter of facts, “but rather multiple possibilities and perspectives ... students [are] active in generating” (Chin, 2013, p. 28).

When teaching art, ultimately students should be allowed to develop their own conclusions surrounding the subject they are investigating, calling on educators to adopt a decentralized approach to curriculum building. Planning for a decentralized learning experience may not look like traditional methods employed by art educators of the past. Decentralized learning produces a series of rhizomatic experiences, or a continuing network of understandings and insights that is built off of a student’s previous experiences or observations (May, 2011). This strategy introduces many impromptu teaching opportunities and requires teachers to present timely and student-specific feedback. In this manner, students understand other subjects and phenomena by connecting or disconnecting ideas with other thoughts that may share the same space, building a network of interconnected concepts that support one another. May’s analysis of a decentralized network acknowledges the affective environment created in a classroom, between teachers and students, and the importance of teachers to develop

strong convictions in their students, though not determine a definitive interpretation of any given subject. This provides a strong contrast with the underlying assumptions found in science, where facts are immovable and based entirely in shared, calculated observations. However unique and challenging this combination of art and science presents itself, economic, political, and curious impulses continue to bring these fields closer together. For many, art serves as the accessible medium to complicated scientific concepts among students who would otherwise never find success in traditional learning environments (Wynn & Harris, 2012).

Science Education

The current practices of science education also require the scrutiny of stakeholders, as many have noticed a considerable difference from the practices of scientists and the methods that are used to convey science within our K-12 schools and a general lack of diversity within the ranks of practicing scientists today. The adoption and analysis of the Next Generation Science Standards (NGSS) provides appropriate framework for teachers to properly integrate science practices into learning environments and effectively increase science literacy and interest in STEM careers (Alberts, 2013). Aside from finding stronger application of scientific practices and mindsets within science education, there exists in the current body of literature a question regarding the fundamental inclusiveness of science (Feinstein, Allen, & Jenkins, 2013). To this end, we recognize a breadth of strategies and mindsets that can be adopted in an attempt to help more students find success in the fields of science.

Transition to NGSS is still a relatively new occurrence, so there is much to be seen regarding the success of NGSS implementation. In its aim, the NGSS works to launch 3 Dimensions of instructional practices: 1) “Help students understand how scientific knowledge develops” and build “links” between science and engineering through science and engineering practices, 2) “Connect knowledge from the various disciplines into a coherent and scientific view of the world” through crosscutting concepts, and 3) Integrate disciplinary “core ideas for the physical sciences, life sciences, land earth and space sciences because these are the disciplines typically included in science education in K-12 schools” (National Research Council, 2011, pp. 3-5). Early adopting states only began assessing students within the last few years, leaving many blind spots surrounding teacher effectiveness in adopting the new standards. In both cases, Friedrichsen and Barnett (2018) and Smith and Nadelson (2017), teachers were considering how they might develop a three-dimensional curriculum—science and engineering practices, crosscutting concepts, and disciplinary core ideas as prescribed by NGSS—though teachers have found difficulty in sufficiently integrating all three components in their final curriculum. In the case of Friedrichsen and Barnett, teachers in a common professional learning community focused in biology instruction found it difficult to align their interpretations of NGSS. Ultimately, these teachers were unable to accurately assess according to NGSS guidelines, leaving out crosscutting concepts and engineering practices while also separating the three dimensions into three separate assessments instead of meshing them all together into a single, comprehensive assessment. For elementary teachers in the case presented by Smith and Nadelson,

teachers felt that they were at a lack of the necessary professional development, school culture, and instructional resources to carry out curricula in line with NGSS. The NGSS stands as a strong concerted effort to align and strengthen science education among young people, though there still remains a social disconnect between work of scientists and the will of the general public.

The scientific community desires to grow a new and diverse generation of scientists (Bowman & Govett, 2015). In order for science education to become the integrated, experiential learning phenomena that we wish to impart to students, scientists and educators must bridge the seeming irrelevance of scientific knowledge and thinking with the relevant understandings and experiences students encounter from one day to the next. Scientists must begin to recognize the subjective qualities of scientific research. In his analysis of John Dewey's philosophy surrounding science, Brown (2015) assesses the accuracy of the scientific community's attempt to build a "wedge" between the values that underlie scientific inquiry and the actions of scientists in attempting to answer scientific questions. To this assessment, Brown (2015) offers the following consideration:

Our judgements are not mere attempts to mirror a static world beyond us, but are attempts to manage and change the world to render the precarious stable, the problematic straightforward, the doubtful trustworthy. Knowing and doing are intimately connected; the act of knowing modifies the thing known. We can thus only answer the question of what we know by appealing, in part, to what we care about—ethically, politically, and socially (p. 70).

With this in mind, we understand that people more often investigate problems that affect them personally. Movements in science education have recognized that education in science should reflect socio-scientific questions, creating stronger messaging from both science communicators and science educators that promote scientific understandings in

solving social problems (Baram-Tsabari & Osborne, 2015). In her analysis, Scott (2016) recognizes a certain frustration among scientists with the public's "general lack of interest in experiential learning from other disciplinary contexts than one's own" (p. 72). While the majority of students will not become scientists, we should aspire for them to become "competent outsiders," able to make scientific decisions about issues that resonate with them. In fact, non-scientists typically interact with specific manifestations of science rather than science as a whole. On a fundamental level, students need to be able to 1) Know science, 2) think scientifically, and 3) appreciate science (Feinstein, et al. 2013) As science educators seek to fulfill these aims in their students, it is important that we develop strategies to help our students know, think, and appreciate science, and consider how we might make these ideals more accessible to our students.

Science educators will have to fundamentally change the way they interact with students, select topics for discussion in their classes, and propagate relevance in order to appeal to the range of young people that now make up our schooling population. Rather than dispensing scientific information to a class, teachers must find methods of "engaging with the diverse voices of students in such a way that these voices are respected and enter into the joint construction of knowledge" (Wegerif, et al., 2013, p.11). The current efforts within science education focus on the improvement of pedagogy in the attempt to draw better results from students, though does nothing to seek out students who do not continue schooling after high school, and whose social disenfranchisement push them away from becoming involved in studying science (Dierking, 2013). Bias continues to persist within scientific practice and science education. The indisputable neglect on the

part of the science education community to reflect on the inequities facing women in science education gives great cause for practitioners and researchers to consider how they might modify their instruction and language to assert a feminist framework (Hussenius, Andersson, Gullberg, & Scantlebury, 2013)

“Collage”

When assessed by Brown (2015), John Dewey suggests that the practice of creating art provides “propositions” that are shown to be either “valid” or “invalid,” while science provides “judgements” that are determined either “true” or “false” (p. 67). When presented in this fashion, the two disciplines of art and science ultimately reach two very different ends, though they pass through two very similar structures. In art, investigators take in all manner of observations and process these thoughts to develop a product that speaks to the similar or dissimilar experiences of an audience to convey an idea, which is either received or rejected. In science, investigators curate and cultivate measurable data to explain observations of activities as they happen under natural or fabricated circumstances with conclusions being found to be true or false. In either case, people create an argument that is then assessed by others and then approved or disproved.

The methods of inquiry as proposed by Dewey and presented by Brown (2015) hold up in both artistic and scientific investigations alike. This process is not mutually exclusive, and there are many instances where artists and scientists have taken the opportunity to share in the experience of embarking through the entirety of the pattern of inquiry. Assessment of Figure 1 demonstrates the similarities in language that investigators might use to find a conclusion in either art or science. The integration of

these scientific ideas brings “information from different disciplines into the same schemata,” providing students the opportunity to assess the entirety of a subject’s details in a single assessment (Marshall, 2005, p. 232). The concept of “collage” as observed by Stafford (1999) is a strategy found most effective by professionals working to integrate the strategies of science and art. She describes, “Collage, as a process of transforming ephemera by cutting and pasting it into momentarily stable configurations, is, therefore, a particularly effective technique for capturing the chimera of consciousness in action” (Stafford, p. 252). To this end, we can observe literal collage or, as might be experienced with the integration of science and art, conceptual collage, where ideas are presented next to each bringing cognitive recognition to the potential connection between the visual concepts.

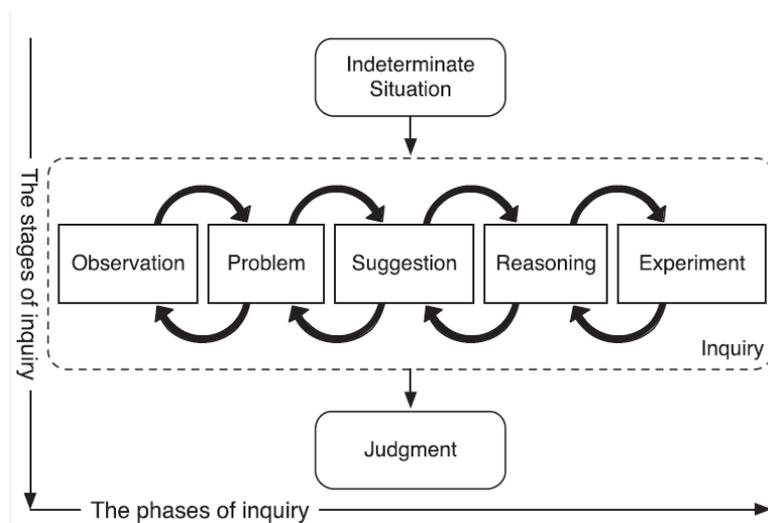


Figure 1. "The pattern of inquiry" (Brown, 2015, p.66).

Marshall (2005) documents instances where we see this collaging intersection between science and art. Thomas Grunfeld’s *Misfit (St. Bernard)*, (1994) attaches the taxidermied head of a sheep to the body of a St. Bernard dog, conjuring a mythical reality

reminiscent of something a person might observe in a natural history museum. Mark Dion shows organization principles found in specimen collection in his work, such as *Cabinet of Curiosities* (2001). Dion's presentation pairs natural and human elements, creating a commentary surrounding natural laws and cultural experiences. In Mark Tansey's *The Enunciation* (1992), we observe a painting with the passing of two trains, which "references Einstein's legendary epiphany, which took place on a train and led to the Theory of Relativity" (p. 238). The depiction of Marcel Duchamp observing his feminine alter ego, Rose Selavy, on the opposing train draws a connection between Duchamp and Einstein in their founding of disruptive principles in their respective fields. Marshall poses these examples as instances where artists have found the opportunity to model conceptual thinking through art creation "to integrate ideas and conceptual processes with techniques, materials, and visual forms and make the vital connection between visual images and ideas" (p. 240).

The practice of collaging present benefits to artists and scientists alike. Scientists working in fluid mechanics regularly work to develop methods that present the visual qualities of their work. Recognition and representation of "coherent structures" or observable patterns within materials is a unique opportunity for scientists to adopt an artistic outlook in creating appropriate visualizations (Bardakhanov & Kozlov, 2000). In these instances, scientists must consider how the elements of a visual representation solidify the underlying scientific concepts in the mind of the audience instead of confusing or misstating conclusions. Additionally, the findings of scientists can be portrayed in a manner that appeals to the general public. The work of Carol Ruckdeschel,

for instance, depicts the ecological world that Ruckdeschel immerses herself through her professional work as a biologist via illustrations and stories (Eubanks, 2012).

Collage, or the interdisciplinary practice of art and science, allows for groundbreaking strategies of inclusion in the process of creating new knowledge or understanding. Students that are provided the opportunity to capture scientific phenomena through artistic expression have a stronger interest in developing understandings in science (Hegedus, et al., 2016). When instructed in local, relevant science concepts and given the opportunity to express their concern through art, students become social and scientific activists, increasing their knowledge of both artistic and scientific concepts (Bertling, 2013). Art and science integration not only increase student memory of conventional science concepts, but also creates new understanding among learners and practitioners in the fields of art, science, and education (Hardiman, JohnBull, Carran, & Shelton, 2019). By effectively humanizing science instruction through art, we can diversify the practices and constituents within science education, thereby increasing the scientific literacy of society as a whole.

METHODOLOGY

This study was developed to measure student perceptions surrounding the integration of biology subject lessons into a high school visual arts curriculum, noting student attitudes, scientific understandings, and creative approaches in extracting and expressing artistic voice. In seeking to understand the use of biology principles as subject matter for artistic inquiry, data was gathered to develop conclusions surrounding the integration of scientific understandings into student artwork, determine how students

relate artistic and scientific inquiry, and understand what students took away as lasting understandings from embedding scientific concepts into their art.

A total of 19 students participated in the study, made up of 13 students participating through the Art 1 course and six students participating through the Ceramics 1 course. Of the students examined in this study, 12 were girls and seven were boys, reflecting the general trends of higher female enrollment than males in art classes. One student operated within the class utilizing modest accommodations according to their individualized education plan, so their final project scores are not included in analysis for the findings of this study. The composition of the students according to year was made up of six freshmen, seven sophomores, four juniors, and two seniors.

Treatment

This study began at the start of the second trimester of the 2018-2019 school year on November 26, 2018 and concluded with the end of the trimester on March 1, 2019. Over the course of the trimester, students were assigned four projects to be completed. The first and last projects assigned were self-led artistic investigations while the second and third projects examined topics in biology—cellular biology and ecology respectively. Self-led projects were projects where students had sole discretion to create a piece of artistic work that examined any possible subject that the student could generate. Biology-based projects were limited in their scope so that students were required to relate the subject of their artwork to a scientific concept based in cells and ecology.

At the beginning of the course, all students were refreshed on the elements of art and principles of design for a basic understanding of artistic principles. For each project

all students were required to follow the same planning guidelines (Figure 2), asking students to ideate eight different project concepts before deciding on a final idea. Once students settled on an idea for their project, they then had to draw up a full-page sketch citing reference, materials, and measurements that would be used to create each of the four projects. In addition to creating four projects, students were required to document the progression of their work, submitting pictures of their work along with an artist statement for each of the projects. Projects were spaced out equally over the course of the trimester. All project materials were submitted via Google Classroom and assessed using the Art Project Rubric (Appendix A).

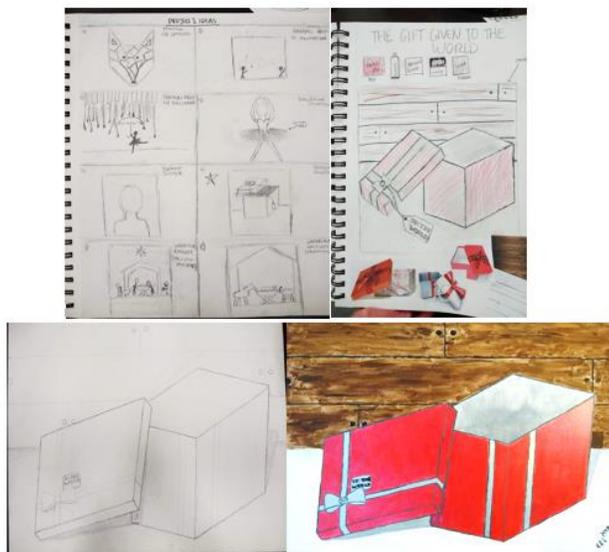


Figure 2. Student project components.

Both Projects 2 and 3 began with a two-day presentation using Google Slides and lecture, where we discussed cellular biology for Project 2 and ecology for Project 3 (Figure 3). For both of the presentations, students were asked to take notes over the general points when discussing cellular biology and ecology with an emphasis on capturing the visual elements that students found particularly interesting and that they

might consider incorporating into their project. Students were provided access to presentation materials following each presentation via Google Classroom, and were encouraged to look into these materials as well as researching topics of interest on their own. Students were assessed on their understanding of these basic cellular biology and ecology concepts both before each biology lecture and after the submission of each project.

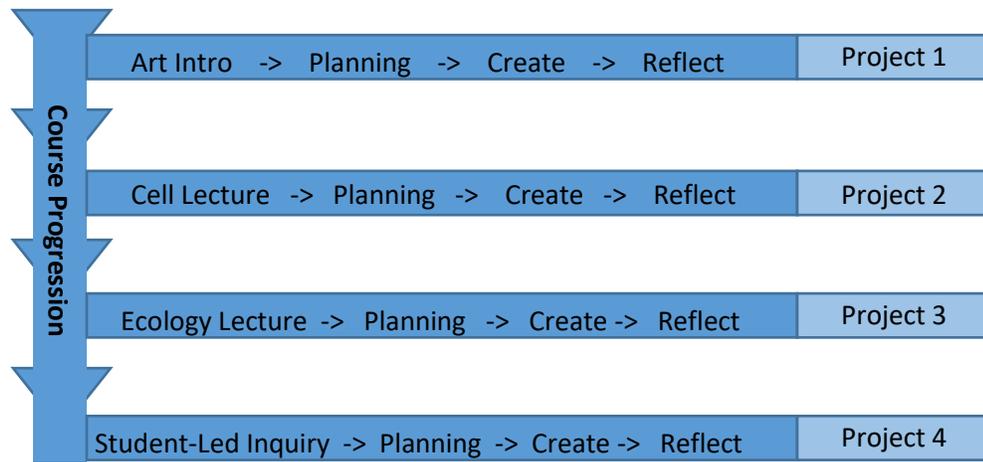


Figure 3. Course progression.

Instrumentation

The Student Pre and Post Art/Science Surveys (Appendices B & C) were used to gather quantitative and qualitative information regarding student perceptions of art and science integration prior to the beginning of the Project 1 and directly following the conclusion of Project 4 to measure change of student perceptions related to science and art integration. These two instruments are mostly the same, though some modifications were made on the Pre-Survey for the Post Survey to reflect potential changes in perception over the course of the study. For example, Item #1 in the Pre-Survey asks students if they had considered using science as subject for artwork in the past while Item

#1 on the Post Survey asks students if they would consider using science as subject for artwork in the future. These items were introduced to measure any polar differences in student attitudes towards science and art integration following participation in the study, as positive or negative answers would help determine if students viewed the experience favorably and would consider continuing investigating science through art in the future. Items #2 and #4 on both Pre and Post Surveys ask students to rate their understanding of the scientific and artistic inquiry processes on a scale of 0 to 4 by use of a semantic differential assessment items. In these cases, lower rankings would correlate with a lack of understanding of science and artistic processes, while a higher ranking would indicate confidence in complete understanding of either process. In Items #3 and #5 students were asked to substantiate their rankings for the previous items to provide qualitative insight into student rationale for selecting their numeric ranking. Item #6 was the same for both surveys, asking students to describe similarities between the scientific and artistic inquiry methods. Pre and post comparison of Item #6 will demonstrate understanding of science and art concepts as well as student takeaways related to science and art integration. Item #7 differed between Pre- and Post surveys. In the Pre-Survey, Item #7 asked students what ideas they use in determining subject for their artwork previous to investigating science as artistic subject matter. Item #7 on the Post Survey asked students frankly what they had taken away from using science as subject in their artwork to provide more qualitative understandings surrounding student takeaways regarding science integration in their visual arts curriculum. Items #8 and #9 ask students to list the steps of the scientific and artistic inquiry processes. While neither process was explicitly taught over

the course if the trimester, it should help inform conclusions regarding students' perceived relations between scientific and artistic inquiry methods. Item #10 on Pre and Post Surveys was the same, asking students to rate their excitement regarding the use of science to better understand art by use of a semantic differential on a scale from 0 to 4. Lower rankings indicate a lack of excitement towards integrating science while higher rankings would suggest total or complete excitement towards science integration in art. Pre and Post Surveys both included a qualitative Item #11 asking students to justify their ranking for Item #10. The Post Survey included an additional item, Item #12, that asked students to select a biology-based project they completed and describe how they used their scientific understanding in order to create the project.

Pre and Post Assessments covering topics in cellular biology and ecology (Appendices D & E) were used to measure student understanding of science concepts over the course of Projects 2 and 3. The Cells Pre and Post Assessment was developed to measure growth or decline of student understanding of basic cellular biology concepts. In this assessment students were asked to explain cell theory, list organelles, and describe basic cellular processes, among other fundamental cellular understandings. The assessment includes Item #7, asking students to name their favorite thing they know about cells, though this item was not involved in calculating growth since any answer related to cells would be marked correct. The Ecology Pre and Post Assessment measured student understanding of ecology principles. Assessment items asked students to explain basic ecology principles, describe methods ecologists use to extract scientific information, and diagram food chains and webs. The Ecology Pre and Post Assessments

had two more assessment items than the Cell Pre and Post Assessments, though both should show adequate assessment of the basic concepts covered in the biology subject lessons.

Student Interviews (Appendix F) provided insight into student mindsets surrounding science, art, and the integration of the two subjects. Items #1 and #3 asked students to quantify their understandings of high school biology and art. Correlated with student performance on Cell and Ecology Assessments as well as Art Projects, these items allow for cross reference between actual student performance and their perceived abilities. For Items #1 and #3, Items #2 and #4 ask students to provide an explanation regarding why they provided their ranking for the previous question. Items #5 and #6 asking students to recount their experiences inside and outside of school to help inform conclusions regarding strategies students use in integrating science with art and ultimate takeaways from the experience. Asking students to identify ways that biology and art might support learning in either subject, and what they like and dislike about the integration of the two subjects in Items #7-#10 helps build strong qualitative conclusions surrounding how students relate the two creative processes. When asked how science and art help students achieve their goals in Items #11 and #12, students demonstrate their motivations or lack of motivation for performance in either subject.

Assessment of art projects allows for the ultimate interpretation of how exactly students integrate their scientific understandings into their artwork. Identifying symbolism and elements within the artwork aids in determining if knowledge seen in cell and ecology assessments equates to strong and valid artistic expressions. Cross

referencing Art Rubric performance on self-led projects versus biology-based projects captures quantitative data to suggest or deny the growth of student understanding of both subjects through interdisciplinary practice. Correlation between student project success and perceived understanding of science and art concepts as well as excitement following the study can confirm or deny the ability of this curriculum in motivating students to consider scientific subject when developing artistic inquiry. Self-led projects were used for comparison against biology-based projects.

The teacher journal compiled over the course of this study provides insights into the teacher's perspective. Qualitative observations from a teacher regarding student success and failures in addition to teacher challenges and realizations provide potentially valuable insight into modifications that might be considered to procure stronger results from students. The teacher journal also provides supplemental considerations regarding the final outcome of the study.

Analysis and cross-comparison throughout this study utilized a Wilcoxon signed ranked test in order to posit significance of results, given the rather small sample size. Professor review of Pre Post Art/Science Surveys and Art Project Rubric and triangulation of results compared against Student Interviews provided validity of findings regarding the gathering of data throughout this study (Table 1). The Montana State University Institutional Review Board approved student participation in this study prior to project commencement (Appendix G).

Table 1
Data Triangulation Matrix

	Pre/Post Student Survey	Project Comparison	Student Interviews	Teacher Journal	Cell/Ecology Pre/Post Assessments
How does the integration of biology instruction in a high school visual arts classroom affect student understanding of the artistic process?					
How do students integrate their understandings of biological phenomena into their artistic expression?	X	X	X	X	X
How do students relate scientific inquiry to artistic inquiry?	X		X	X	
What do students take away from biology instruction in a visual arts classroom?	X	X	X	X	X

DATA AND ANALYSIS

Scores for projects varied rather little over the course of this study, though subtle trends appear to provide some support for science integration benefiting artistic practice for students (Figure 4). Student performance on biology-based projects averaged a score of 44.7/50, approximately one point greater than scores from self-led artwork where the average score was 43.7/50, though this does not present a significant statistical trend. In comparing self-led to science-based projects, the rubric category of “Subject” saw the greatest increase in score between the project categories, going from an average score of 3.8/5 on non-science projects to 4.2/5 on biology-based projects. This does not present a significant difference between the two project classifications. It is in this case arguable that simply having a prompt benefits the quality of student work. For the sake of clarity, the work of four students is provided in this analysis in an attempt to convey the progression of student work over the course of the trimester.

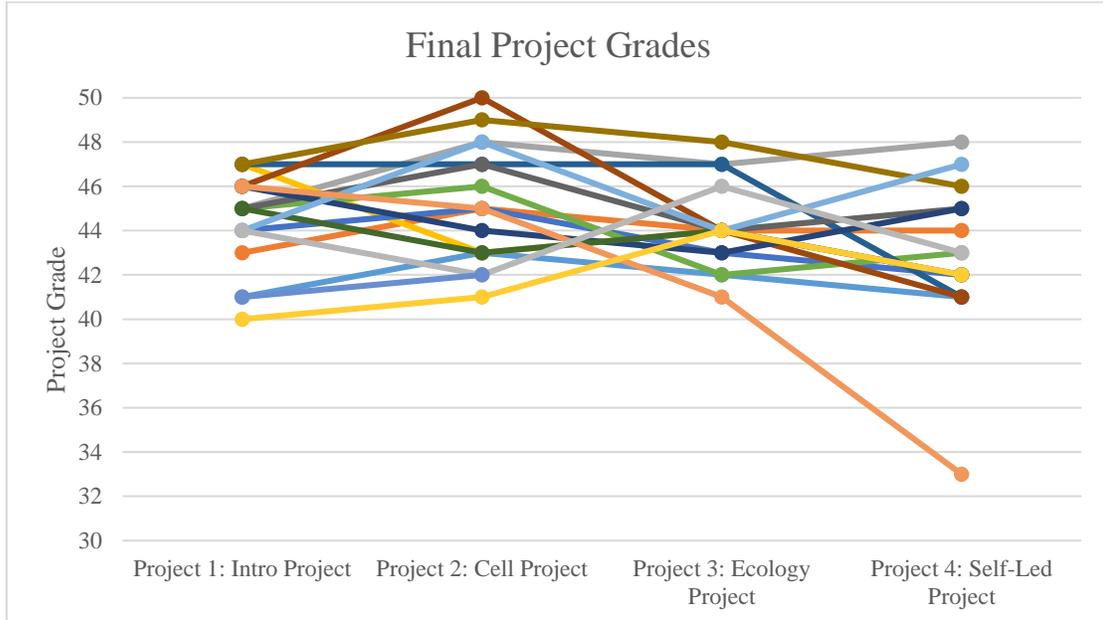


Figure 3. Project grades over the course of the trimester. Each colored line represents the progression of a single student’s project grades over the course of the trimester.

Project 1 collected a variety of subject matter among students, reflecting trends that I have observed previously in art classes where students struggle to find compelling subject matter for their work. Shown in Figure 5, Student A centered her work around the celebration of Christmas with a red gift box. While the subject was timely given the time of year the project was created, the composition of the piece is rather simple and leaves little for the audience to consider outside of the image presented. In this case, it would be rather difficult to ascertain the student’s intended meaning behind the piece which “symbolizes God’s gift to the world, His son, Jesus Christ.” Student B copied an image of a tattoo from the internet and submitted it as her original work, though she managed to integrate her love of watercolor as a medium in the production of her work. Student C integrated her love of travel and took the advice of her older sister to create the continents out of flowers. The student in this case shows little mastery over the elements of art or the

principles of design covered in class, choosing to leave her piece relatively plain. Student D relayed that he did not consider principles of design or subject in his work, stating “I didn't even think about people who might look at the project.” With this being the first project that students attempted in Art 1 and Ceramics 1 classes, students showed room for improvement generally around implementing dialogue within their work by integrating principles of design (balance, scale, contrast, etc.) and exploring use of artistic elements (color, line, value, etc.) in both conventional and non-conventional ways. The focus of biology subject would be provided in the following two projects to allow students to explore methods of artistic expression.

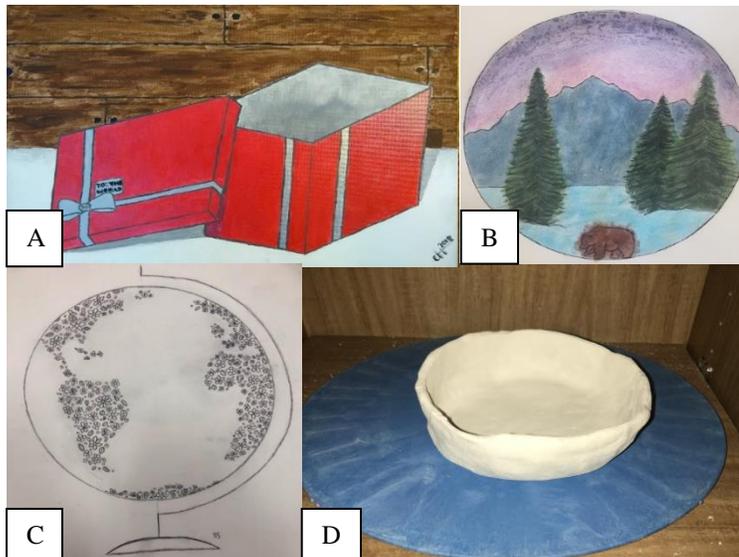


Figure 4. Project 1 composite.

Treatment began with Project 2 where students examined cells as subject matter in the first of the two art projects examining topics in biology. Analysis for this project focused on student messaging surrounding the subject of their work. i.e. cells. Where subject in Project 1 was rather general and left to interpretation, students recognized

specific concepts related to cells that they tried to convey through their work. Student A developed her work around the pun of “cell” phones and the fact that cells interact and communicate with one another. The composition is still very simple, though the concept reads very clearly, and the integration of humor demonstrates an understanding of audience, something that might not have been entirely present in her previous project. Student B’s Project was “mainly focusing on earth, because that is where most living things live.” Conceptually, the subject for this piece is rather nuanced, though the emphasis that Student B attempts to incorporate in her piece does not read as clearly as the student might have intended. The connection between the subject and the final concept is very clear, though Student B could have developed the composition further. Student C took a methods-based approach in this project, considering how she might symbolize “what a cell may look like.” The effect embodies strategies that many students utilized in trying to convey cellular imagery, with splatters, blotches, and oozes showing up in a number of student works. The almost primordial quality of her work lends itself to the essence of unicellular organisms swimming around, making the piece rather successful when provided context. Student D really challenged himself to develop the concept of his work to display the extremely particular concept of tonicity within cells as teachers often demonstrate when discussing osmosis. In this project, he symbolizes isotonic, hypotonic, and hypertonic solutions by distributing shapes throughout the surface of the piece. The subject reads quite directly from the imagery used by biology teachers, showing room for further interpretation on the part of the student, though the student expressed confidence that his idea made sense saying, “I think that if people were

to look at my project they could understand the meaning of it if they were told it was related to biology.”

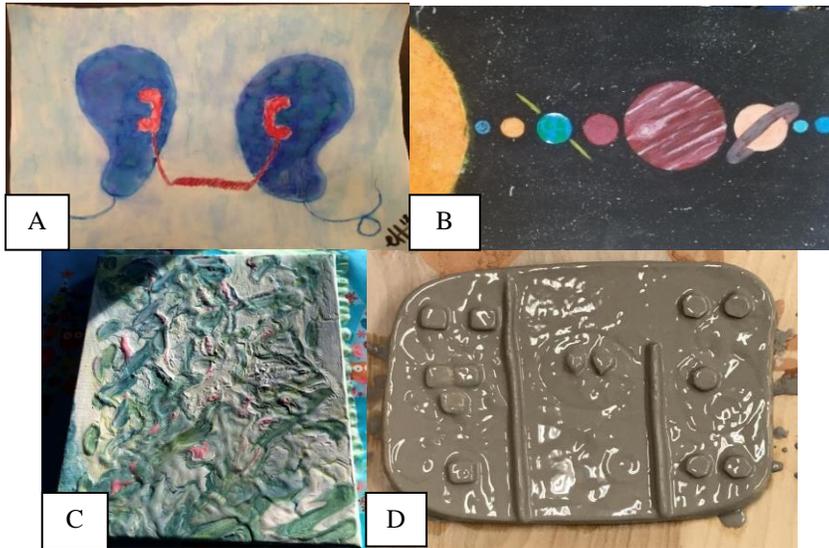


Figure 5. Project 2 composite.

Grades for Project 2 were the highest on average among all projects throughout the trimester. This may be because of the general familiarity students have with cellular concepts, as seen in student Pre/Post Cell Assessments when compared to Pre/Post Ecology Assessments. Utilization of bold patterns, shapes, and splatter was a pronounced trend in ten student (53%) projects for this assignment. These manifestations demonstrate a student understanding that there exists a uniformity among cells and their structures, though their behaviors or existence may at times seem chaotic or left to chance. This observation is not stated in student artist statements explicitly, though the implicit qualities of student work demonstrate this artistically.

Students in Project 3 sought out ecology concepts to utilize as subject for their artwork. The greatest trend to emerge from this project was students illustrating

relationships between two organisms, a basic principle of ecology. This connection showed up in the work of eight students. Perhaps the strongest representation of this idea came from Student A, who developed an animation depicting the symbiotic relationship between a clownfish and an anemone, and the predatory nature of sharks towards other fish. The emotive heart that she inserts at the end of her video demonstrates a connection that does not actually exist in science, though we can certainly interpret this to mean the two creatures share a deep connection. Student A recognized this as being “a prime example of ecology.” Student B was one of two students who felt the depiction of a single animal was relative to the concept of ecology. No artist statement was provided by the student to describe what creative decisions went into this project. The project itself poses an interesting spectacle, with its fun characterization and bold shapes, though further development could have produced subject that was more in line with the ecology principles, and many elements of art seem to have been neglected. Student C attempted to draw a connection between the mechanization of human society and our reliance on plants. At some point, this student came to the conclusion that “We have made things to help us so we don't need to use nature as much.” However unfounded this conclusion may be from a scientific perspective, the lack of artistic elements and principles of design shows an inability to merge these two concepts, the mechanization of society and nature, into a single composition to convey a clear message or principle. The visual metaphor created by Student D was created by incorporating principles of design from their Project 2, where he created symbols with shapes that are meant to represent scientific bodies. Where in the previous assignment, these shapes represent the movement of molecules

according to turgor pressure, Student D in this case chose to use these shapes to demonstrate a food chain. The configuration of shapes and the loopy lines would not be considered conventional by scientific standards, but in this case it brings a sort of craziness that one might expect to witness were they a scientist in nature observing a food chain in action.

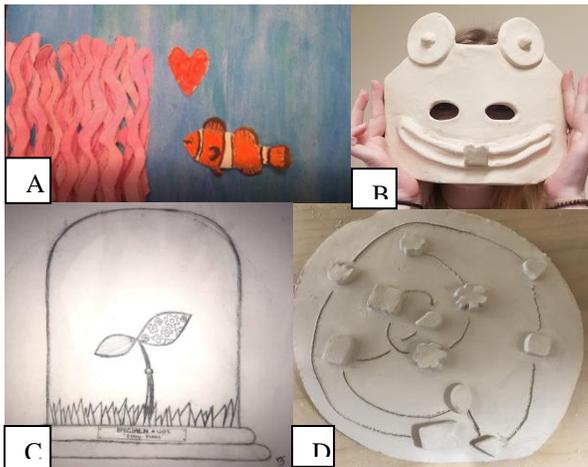


Figure 6. Project 3 composite.

Scores for Project 3 fell from Project 2 for most students, 63%, with “Audience” grades from the Art Project Rubric decreasing the most, falling from an average score of 4.1 to 3.5, with “Subject” scores decreasing as well, from an average of 4.3 to a 4. Student C is a good example of how this came about. A strong cell representation in Project 2 along with articulated and specific writing scored higher than either an ecology principle that lacked specificity or a fabricated concept related to ecology that lacked resonance and relevance with the audience. It would seem in this case that concept mastery demonstrated in Ecology Pre/Post Assessment did not translate into strong artistic subject for students.

Project 4 saw the lowest scores among the projects and saw a general return to

creative methods found with the start of Project 1 where students often would adapt found ideas to suit the needs of the project. In this same project, students spoke a lot about how the artwork they created held a great deal of relevance for them personally or allowed them to express emotions that they perhaps felt they could not demonstrate in the previous biology-based projects. In Figure 10, Student A found an opportunity to create a piece out of wood, nails, and string, showing a Converse shoe positioned next to a pointe ballet slipper. She stated how she had always wanted to create a project like this, “and it gave me an opportunity to create one with a subject that really meant something to me.” The contrast and implicit dialogue between the two objects show a great deal of growth from her original box painting in developing principles of design in her work. Student B created a drawing contrived from popular meme culture among teenagers, showing Patrick Star from *SpongeBob Squarepants*. In a way, this shows regression in the student’s work over the course of the trimester, and this was reflected in her Project 4 grade. The concept and character that she utilized in her piece were borrowed, though she expressed a strong connection to the culture surrounding the character’s personality and validates her creative decision in trying to make other people laugh who might appreciate the meme. Student C also borrowed the creative concept that underlies her final project. Created during Black History Month, she decided to replicate a door decoration with adapted materials based on an image she found online that a teacher had created. Again, we see high relevance relative to the student given the month-long celebration, though a degree of appropriation in this case may not set well with Black audiences. I do think that the project serves as an attempt to branch out and seek relevance among other audiences,

which demonstrates a fair amount of creative risk, though it would be ideal in creative projects for her to develop her own ideas. Student D demonstrated a great deal of artistic growth over the trimester. While initially making a poorly fashioned bowl, his Project 4 demonstrated strong design principles with an architectural piece that was well-finished. Student D assessed his audience would see “many different types of buildings” given the familiar qualities in the columns and round structure. The variety and repetition in the piece provide a stronger implementation of principles of design when compared to previous projects.

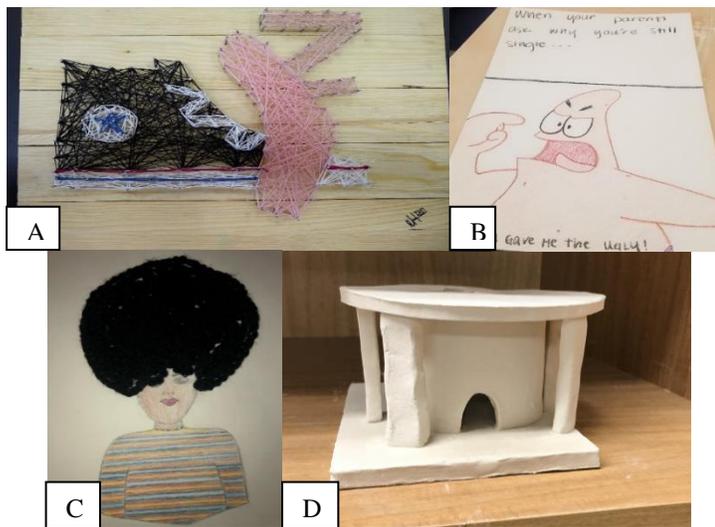


Figure 7. Project 4 composite.

Student Pre-Post Art/Science Surveys measuring student attitudes and perceived understandings of artistic and scientific methods show trends surrounding the development of student insights related to the integration of science and art in a high school visual arts classroom. Of the students ($N=19$) assessed, nine (47%) grew in their appreciation of science as subject matter for artistic work and four (21%) maintained their satisfaction investigating scientific subject matter in their art, however, excitement

regarding the use of science instruction to learn more about art declined in ten students (53%), stayed the same for eight students (42%), and increased for only one student (5%). While students appear to appreciate the discussion and examination of science subjects in artwork, the majority of students did not enjoy the use of science as a means to explore methods in art in this trial. To convey the thoughts of one student whose rankings shifted from a ranking of 4 for excitement, the highest on the scale, to 0, the lowest, she began the course saying, that she was excited “to see how they relate,” and later expressed, “I don’t want to learn about science in art class.” Student perceived understandings of art and science increased over the course, though it would seem that the introduction of science material through lectures and discussions did not satisfy student desires to perform and observe science. The lack of experiential observation on the part of students and the absence of discourse surrounding biology subjects is a likely reason for this decline in excitement.

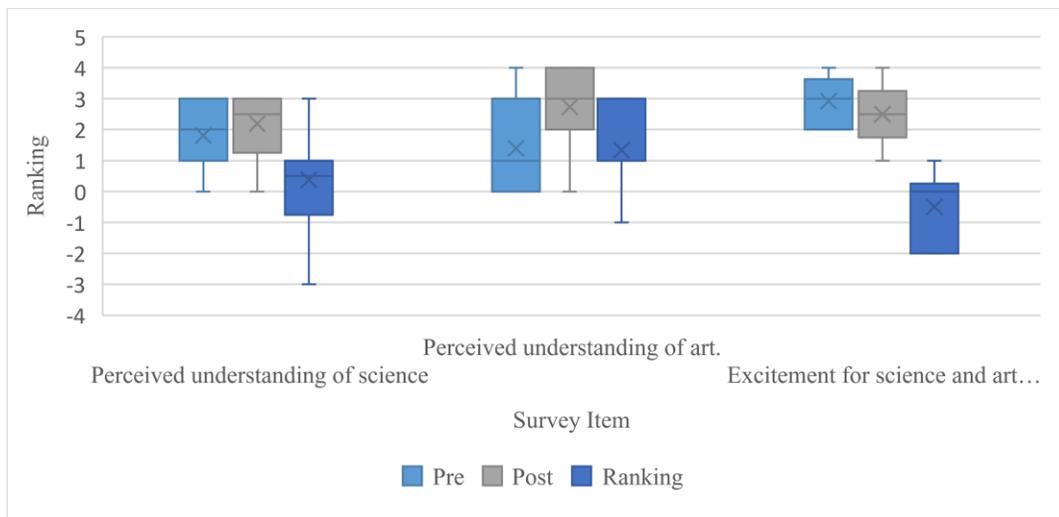


Figure 8. Student attitudes regarding science and artistic inquiry.

In pre-assessment utilizing Student Pre-Post Art/Science Surveys, five students (26%) stated that they had explored science as subject in their artwork previously while the remaining 14 students (74%) said they never considered using science in their artwork. One student's reply perhaps describes the general student understanding previous to the study, stating, "No, I never thought those subjects could go together." At the end of the study, students who saw science as a worthwhile subject for art found science "...is something everyone wants to know more about," and "Science has very interesting shapes and looks you can incorporate into many art forms." Over the course of the trimester, these attitudes and understandings shifted, with 13 students (68%) stating that they would be interested in exploring science topics in future art investigations. This arguably presents a significant shift in student perceptions regarding the integration of science topics into art subject, though the sample size was not large enough to conclude that pre to post assessment yielded any significant change in the data (Wilcoxon signed-rank test; $N=10$, $W_{crit}=5$, $W=5.5$).

Items #2 and #3 of the Student Pre-Post Art/Science Survey demonstrate a positive shift of student perceptions over the course of the trimester regarding understanding of the scientific inquiry process, though verification of perceived significance in this data could not be confirmed (Wilcoxon signed-rank test; $N=14$, $W_{crit}=15$, $W=22$). Students showed an average score of 1.74 on a scale from 0 to 4 to describe their confidence in understanding of the scientific inquiry process in pre-assessment, compared to an average score of 2.37 in post-assessment, showing a 28% normalized gain in confidence surrounding scientific inquiry. During pre-assessment, the

seven students (37%) who scored themselves lower, 0 through 1, substantiated their score with a statement declaring a lack of understanding regarding scientific inquiry or feelings of inadequacy in understanding science in general. Six students (32%) who scored themselves higher, 3 through 4, stated that they had experience and interest in science, so they felt confident in their knowledge of the topic. Six students (32%) who scored themselves 2 displayed mixed comments of confidence and uncertainty regarding their knowledge of the scientific inquiry process. In post-assessment, eleven students (58%) rated themselves a 3 for confidence, because “it’s pretty simple” and “because after refreshing my memory I remember.” Three students (16%) scored themselves 0 or 1 because they’ve never heard of the process or they didn’t understand most of it. Of the four students (21%) who rated themselves a 2, responses were equally confident and uncertain about their knowledge of the scientific investigative process. It would appear in this case that simply discussing or annotating science in artwork provides added confidence to students regarding their scientific understandings.

The methods chosen for this study did not foster much growth in the way of understanding any technical steps or processes used by scientists or artists to conduct their work, as concluded after reflecting over data for Items #8 and #9 for Pre Post Art/Science Surveys. This likely derived from the lack of experience in discussing and practicing scientific skills, rather than scientific facts, in combination with artistic inquiry methods. Perhaps with further immersion into biology-based practices and observations, students could have built a stronger connection between the two disciplines. Seven students felt comfortable articulating the steps with artistic and scientific inquiry in both

Pre and Post Surveys, and one student grew in their understanding of artistic and scientific inquiry respectively when comparing the same results. For both scientific and artistic inquiry, there were eleven students who left the question blank or wrote in “IDK” as their response.

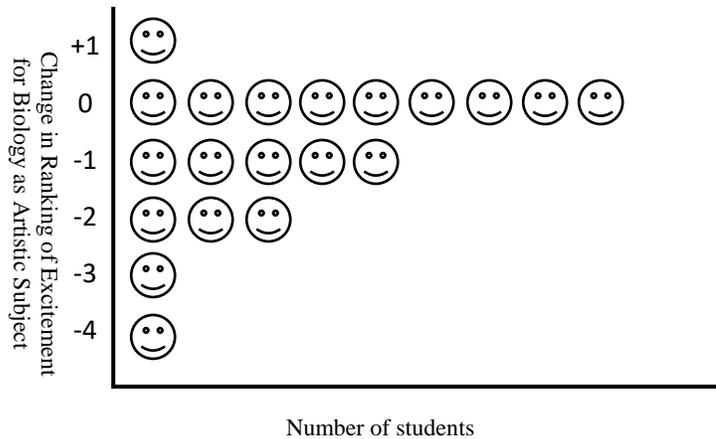


Figure 9. Change in ranking of student excitement for use of biology in art.

Excitement regarding the use of science in an attempt to better understand art, as measured by Item #10 in Pre Post Art/Science Surveys, showed a general decrease from the beginning to the end of the study. Of the nineteen students surveyed, only one (5%) felt more excited at the prospect of using science to better understand art, eight (42%) showed no difference in their excitement after the study, while ten (53%) students saw their excitement rankings drop, in one (5%) case by a factor of four. It is interesting in this case to see how justifications for student rankings changed in Item #11. At the beginning of the study, students were eager to see how they might draw connections between the seemingly disparate disciplines. Students remarked, “Science has never been my favorite subject, but art is really fun so putting them together should be exciting,” and “I like using different subject in different classes. It shows how the things you learn in

one class can help you in another class.” Only three students (16%) expressed concern over the integration of science in art class, though the 16 (84%) other students all voiced excitement and interest over the methods that would be uncovered throughout the course. Post Art/Science Surveys revealed a different story, where eight students (42%) who expressed support for the idea, such as “I love science and learning new things in that subject. I also love art so combining the two is so fun and exciting,” or “I think it’s an effective way to better get across certain messages in a way that’s easy to understand.” Two of these students proposed minor adjustments to the concept, like drawing stronger connections between science and art throughout the course and finding ways to better activate student emotions in artwork. Seven students (37%) did not want to consider science when creating future artwork. Students reached this conclusion saying, “I have never really liked science,” and “I don’t love science and it isn’t fun to use something you don’t like.” Three students did not validate their response for Item #10.

The final Post Survey item, #12, asked students to identify how they had used their scientific understandings to develop one of their biology-based projects. The question solicited an interesting response: No two students used the same science concept to create their biology-based art project. Eight students (42%) chose to discuss subject for this question, though ideas about cells ran the breadth of basic cellular concepts, such as cells working together or the reproduction of cells. Five students (26%) discussed the concepts they gathered from ecology that they integrated into their project, such as symbiosis and “how some animals live.” One student (5%) said that they did not connect

their project to a science concept, one student said they did not know the answer and three students did not respond to Item #12.

When asked about their understanding of artistic inquiry methods using items #4 and #5, students demonstrated significant growth in perceived understanding (Wilcoxon signed-rank test; $N = 17$, W -value=13, $p < 0.05$). Pre-assessment data saw an average rating of 1.47 on a scale of 0 to 4, and post-assessment data showed an average rating of 2.72, demonstrating a 49.4% normalized gain in perceived understanding of artistic inquiry methods. The ten students (53%) in pre-assessment who scored themselves a 0 or 1 justified their ranking for a variety of reasons, though student remarks tended to sound like, “I haven’t taken a proper art class before,” and “I have no idea.” The four students (21%) who ranked themselves a 2 believed that they had a “basic” understanding of the topic. Students who ranked themselves a 3 or 4 (26%) stated that their experience in prior art classes or instruction in their current art class gave them the confidence to rank themselves higher. Post-assessment showed a significant shift in student perceptions, with just three students (16%) ranking themselves as a 0 or 1, three students (16%) ranking themselves as a 2, and 13 students (68%) ranking themselves a 3 or 4. Students ranking themselves a 0 or 1 all stated they did not know what the artistic inquiry process was. Students who ranked themselves a 2 all increased their ranking from earlier in the trimester and stated that they now had a “basic” understanding of art methods. Those students that assigned themselves a rank of 3 or 4 generally stated that they felt the class taught them the concept or that art is rather easy in general.

Little change was seen in the data gathered from Item #6 on the Student Pre-Post Art/Science Survey that asked students to describe the connections between scientific and artistic inquiry, with most students understanding inquiry in art and science both involve steps, and the same number of students not knowing how methods in scientific inquiry are related to those in artistic inquiry. Of the 19 students assessed, ten students (53%) in pre-assessment mentioned how both processes involved steps compared to eleven students (58%) in post-assessment. In both pre- and post-assessment, six students stated they did know of a connection between the two processes. In both pre- and post-assessment there were two students (11%) who identified “new perspectives” or “fresh ideas” as the connection between art and science. The answer of “tools” that showed up in one student’s answer in pre-assessment did not show up in post-assessment.

Item #7 in Art/Science Pre Surveys asked students to reflect on what ideas they would use prior to the class when deciding to create art. Within the 19 students assessed, nine (47%) stated that their creative ideas came from “whatever looks good” or something they liked that they had seen on social media, seven students (37%) stated that they based their art off of their passions and experiences and three students (16%) stated that their good ideas usually “popped into their head.” This aligns with the research that most students create art and research science regarding topics that have relevance within their lives.

The altered Item #7 for the Art/Science Post Survey asked students to consider what they took away from their integration of science subject into their artwork. Ten students (53%) in this study determined that art can be used to portray a wide range of

ideas and that science, or any other subject for that matter, could be turned into art. Three students (16%) said that they had learned more about science through the process of science integration and two students (11%) stated that the process allowed them to be more creative and “think outside the box.” Four students (21%) in this study stated that they felt they had learned nothing or they had learned that science and art should not be taught in the same class. It would seem in this case that the novelty of providing science as subject for artistic inquiry was enough to make students consider how they shape artistic investigations surrounding science as well as other subjects.

Pre- and post-assessments measuring student understanding of basic concepts examined in cellular biology and ecology show growth in retention of science concepts for most students. Of the students ($N=19$) assessed, 14 (73%) grew in their understanding of cellular biology concepts, and 17 (89%) grew in their understanding of ecology principles. Data from pre- and post-assessments suggest these results to be statistically significant (Wilcoxon signed-ranked test; Cells: $N=19$, $W=4.5$, $p<.01$; Ecology: $N=19$, $W=2$, $p<.01$). In the Cell Pre-Post Assessment analysis students saw a 21% normalized gain in their overall score, and in the Ecology Pre-Post Assessment analysis students saw a 45% normalized gain in their overall score.

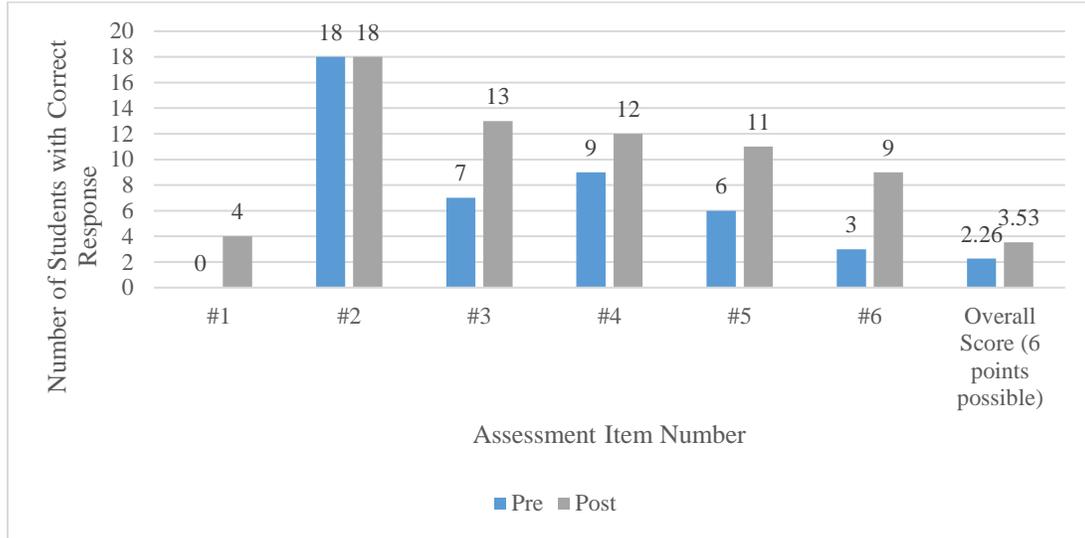


Figure 11. Cell Pre-Post Assessment Performance

Examining the Cell Pre-Post Assessment data, it is observed that student performance increased on all but one assessment item. Pre assessment of student knowledge showed no students (0%) able to recount the components of cell theory, while later assessments proved four students (21%) capable of identifying the sections of cell theory. Aggregate data for the test group showed no change in performance for Item #2 in Cell Pre-Post Assessment data, suggesting students were well aware that microscopes are used in examining cells both before and after the study. Seven students (37%) in pre-assessment were able to identify five organelles for Item #3, with eight students (42%) attempting the question, but unable to recount the necessary five items, and four students (21%) deciding not to attempt the question at all. In post-assessment, 13 students (68%) successfully identified five organelles, three students (16%) showed an attempt to correctly answer the question, and three students (16%) did not attempt to answer the question. For Item #4, of all students, nine (47%), who were able to identify a cellular process in pre-assessment were also able to identify a correct answer in post-assessment,

with three additional students, 12 students (63%) were able to successfully identify a cellular process following treatment. Eleven students (58%) were able to correctly describe “mitosis” or “cell division” in post-assessment data. For Item #5, six students (32%) were able to properly describe cell division, even using vocabulary, “mitosis,” in pre-assessment, and five students (26%) attempted to describe the process, with eight students (42%) choosing not to attempt the question. Only three students (16%) were able to describe the importance of stem cells in initial assessment, though this number tripled to nine students in post assessment. When asked about their favorite fact about cells, students had a range of answers in pre and post assessment. Most of these responses circulated around the number of cells that make up an organism, the idea of cells working together, and “the mitochondria is the powerhouse of the cell.” This fact about mitochondria showed up in pre assessment, though did not show up in post assessment.

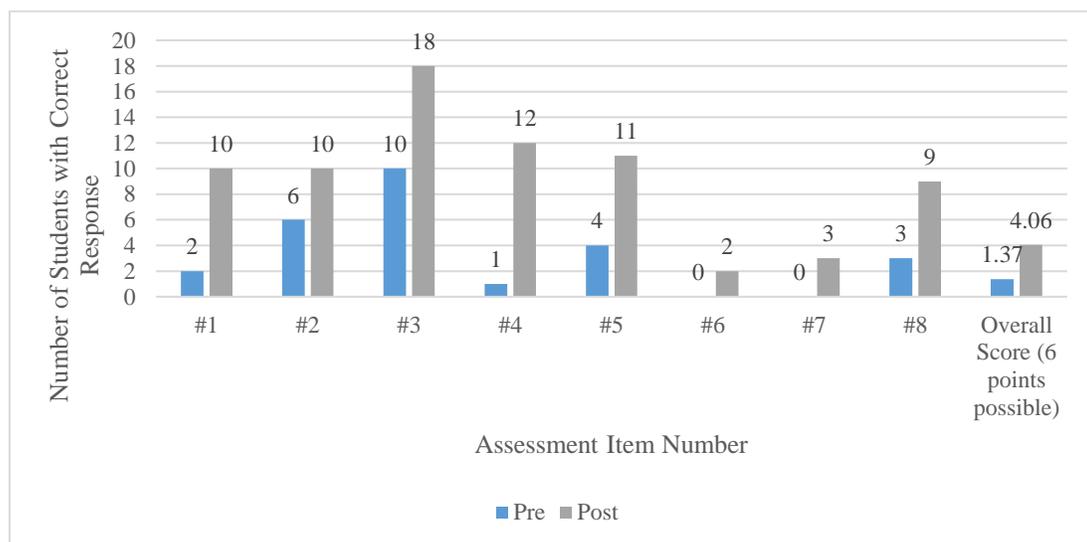


Figure 12. Ecology pre-post assessment performance.

Pre-Post Ecology Assessment yielded greater gains for student improvement than those for Pre-Post Cell Assessment. In pre-assessment, only two students (11%) were

able to properly articulate the purpose of ecology on Item #1, compared to ten students (53%) in post assessment, creating a 47% normalized gain in student performance. For Item #2, six students (32%) were able to state “observations” as the means by which scientists study ecosystems in pre-assessment, and ten students (53%) were able to identify the correct answer in post-assessment. Item #3 showed almost complete mastery of food chains from pre to post assessment, with ten students (53%) initially able to create a complete food chain to 18 students (95%) being able to create a correct food chain. Upon initial assessment, only one student (5%) was able to develop a complete food web, though in post-assessment 12 students (63%) were able to create a correct food web, showing a 61% normalized gain in student performance for Item #4. After completing the project centered on ecology subject, 11 students (58%) were able to properly identify a natural cycle that occurs in an ecosystem compared to the four students (21%) in pre-assessment who were able to correctly identify a natural ecological cycle. Overall, results for Item #5 showed a 47% normalized gain in recollection of ecological processes. For Items #6 and #7, little growth was shown in student understanding of the underlying ecological concepts. No students were able to state the meaning of a “niche” for Item #6 or describe “sustainable development” for Item #7 prior to the ecology-based project with only two students (11%) and three students (16%) respectively able to answer the questions following the ecology project. Normalized gains were extremely low, with 12% for Item #6 and 19% for Item #7, showing little growth in understanding for the large majority of students. Item #8 asking students how ecologists utilize population data in order to study ecology saw correct responses jump from 3

students (16%) correctly answering the question, with incorrect responses going mostly unanswered, to 9 students (47%) of students correctly assessing the use of population data in ecology research. Overall, the Ecology Pre/Post Assessment performance demonstrates strong growth in understanding among students in basic ecology principles over the course of this study.

Student interviews captured during the creation of Project 2 show how students insights developed in the intermediate phase of the study. This is demonstrated in ratings of student confidence for Items #1 and #3, asking students to quantify their comfort working with biology and art concepts. When compared to survey items in Pre and Post Art/Science Surveys, this demonstrates a gradual growth in student confidence over the course of the trimester (Table 2). Overall, confidence in biology and art was relatively equal during the interview. Eight students (42%) who rated themselves as a 3 or 4 for understanding in biology said they “Understand most, but not everything.” Five students (26%) rating themselves as a 2 expressed need for help or confusion in understanding biology, and six students (32%) who rated themselves as a 0 or 1 explained how they had “never taken a high school biology class before.” Seven students (37%) who rated themselves as a 3 or 4 for confidence in art felt their frequent enrollment in art classes and experience gave them confidence in their score. The six students (32%) who rated themselves a 2 felt there is “not much to understand” and discussed how this was their first art class. Six students (32%) who rated themselves a 0 or 1 stated that their general lack of talent in art did not provide them confidence in their artistic knowledge.

Table 2
Art and Biology Confidence Progression.

	Pre-	Interview	Post
Biology Confidence	1.74	1.97	2.37
Art Confidence	1.47	2.1	2.72

Items #5 and #6 in the Student Interview asked students to summarize their experience learning in science and art. In both art and science, three groups emerged: newcomers, class takers, and enthusiasts. Newcomers expressed a lack of knowledge for the subject having never taken a high school class in the subject, class takers had high school experience studying in the subject, and enthusiasts had extensive experience working in the subject in addition to classes taken in high school. For biology, four students (21%) were taking the class with no prior experience studying biology, twelve students (63%) had taken biology classes in high school, either biology or anatomy and physiology. Three students (16%) had experience studying biology out of school, such as working at a science camp or competing in 4-H. For art, four students (21%) had never studied art in high school prior to this course, eleven students (58%) had studied art, whether in drawing or ceramics. Four students (21%) had extensive experience working in art outside of school, such as taking private lessons or helping a stepmother who works as a tattoo artist. For both subjects and classifications, student self-scores in subject understanding correlated with student prior experience.

When students were asked how art could help them to understand biology and how biology could be used to understand art, students found several opportunities to bridge the two subjects. Examining crossover from art to biology, students believed that there was a strong opportunity to utilize art concepts to help visualize science behind

biology principles. Several students expressed a belief that this integration could offer up new perspectives and skills that might increase the quality of student artwork.

Considering how biology can help students better understand art, many students saw the breadth of concepts examined in biology as exceptional subject for artistic work. Other students suggested the methods and research found in biology could help uncover new understandings in art. In either case, art helping biology and biology helping art, there were five students who could not think of how the two subjects could help one another.

Students found a variety of reasons to enjoy the integration of biology into their art curriculum. The greatest consensus among students was that this experience provided a challenge that brought about new ideas and understandings. Other students saw the integration of biology in art as a chance to better understand science than they had previously, or in the case of two students, this was a good chance to learn about both subjects at the same time. One student particularly enjoyed the discussions that came about in the class.

Of course, with the proposition of new practices, there come perceptible drawbacks to introducing a rigid framework like science into a typically free-thinking environment like art instruction. The number one criticism of this study was the limitation to science in subject matter. Eleven students (58%) felt that this at times took the focus off of art and invariably limited their scope of expression. Five students (26%) found the process to be difficult, and coming up with ideas was challenging. For the 16 students (84%) in these two instances, a rating of 1 through 3 in understanding in biology was expressed in eleven of these cases and seven of these students rated 1 through 3 for

understanding in art. Among the 12 girls who participated in this study, 11 (92% of girls) stated how they found the integration of science content to be limiting or difficult to understand, while four of the seven (57%) boys stated similar claims. Five students out of 19 (26%) during interviews stated how they enjoyed the process and could not think of any reasons not to enjoy biology integration in art.

Relating science to student personal goals brought a realization that many students do not have plans to study biology in any extensive fashion. Only four of the students (21%) in this study stated that they would be pursuing careers based in biology, such as becoming a doctor or nurse. Seven of the 19 students (37%) believed that further understanding biology would help them better understand personal aspects of their life, like enjoying time with their family outside and understanding more about the world. Two students (11%) believed that simply studying biology would make them better at studying other subjects. Six students (32%) could not consider how studying biology would help them achieve personal goals.

The social-emotional capabilities of art showed when asking students how they considered art might help them with their personal goals. Ten students (53%) saw art as being “peaceful” and a healthy means of expressing one’s self. Four students (21%) identified art as a chance to improve their creative talents that could potentially lead to a fulfilling career in an artistic field.

Reflecting on the experience when flipping through the compiled teacher journal, many lessons came about after carrying out this study. The early anticipation expressed by students set expectations regarding outcomes rather high amongst teacher and students

alike. The trimester served as an introductory experience to art to many students, and the open-ended nature of the art projects seemed to be both a blessing and a curse. It was difficult to impress on students the importance of having a range of ideas to choose from when developing work. Students were often content settling on their first idea, so asking them to go back and consider another perspective or composition was often met with a heavy sigh or pronounced objection to the practice. After the first biology subject lesson on cells, it became clear that the lesson, while enlightening in content did very little to inspire students to think about science differently. Students were very engaged during both the cell and ecology lecture, asking questions and providing personal stories, though the lecture offered few new insights for students, making it difficult for students to acquire exciting perspectives surrounding either science subject. It caused me to consider how, with extensive planning and support, an immersive biology experience might better suit the needs of the students to find exciting biology subject to develop into artwork. As Project 2 pieces began to develop, it appeared that there was an equal mix of students who found new ways to view cells and those who saw the project as an assignment that needed to be done. Student connections and fascinations with animals seemed to serve as a strong motivator in Project 3, making it seemingly easier to motivate students to put together new ideas by combining science and art concepts. By the end of the trimester, it seemed that many students were tired and perhaps worn out. In overhearing discussions with students, most students were content with their work, though I as their teacher had certainly hoped for a more profound realization among my students.

INTERPRETATION AND CONCLUSION

Investigation of the research question surrounding student integration of biological phenomena and artistic expression showed students merged their scientific and artistic understandings in both literal and figurative manners. While some students chose to express their science knowledge rather explicitly, whether through a pun or visual diagramming, other students chose to depict their ideas in more interpretive ways, such as the attempt at pour painting or playing with scale beyond recognition. These scientific understandings grew over the course of the study, consistent with the findings of Bertling (2013). This study was not framed around the concept of community as it was in the case of Bertling's study, though it demonstrates how the integration of art and science concepts allows students opportunities to work with science ideas in an interpretive manner, thus solidifying scientific understandings. A normalized gain of 21% in understanding of cell concepts and a 45% normalized gain in retention of ecology concepts demonstrates significant improvement for student knowledge related to biology understandings. Student confidence in understanding of science content consistently grew over the course of the study, though significance of this growth could not be confirmed. Growth of actual biology content knowledge over the course of the study aligns with this boost in confidence, likely due to teacher lectures and student interaction with biology concepts in their artwork. Growth of student confidence regarding artistic knowledge did show significant growth in this study. The growth of confidence in artistic knowledge throughout this course creates a rather comforting effect, since this was ultimately an art course.

In response to my question on how students relate scientific inquiry to artistic inquiry, it was found that students recognize the connection between art and science in their similar structures of inquiry, though it cannot be said whether or not students utilized this knowledge in order to develop their projects for the purpose of this course. Consistent with the thoughts of Paula Eubanks (2012), there were instances where students were able to mesh their artistic curiosity with scientific understandings in order to create a product of which they took great pride. Student A's animation being a "prime example of ecology" shows that students did take opportunities to create work that satisfied biology subject requirements, though also provided student gratification. Student Interviews show that students do see the value in integrating the subjects of art and science, given the opportunity to create new knowledge and better understand science concepts for visual learners. Students do ask that they be given the opportunity to further embed emotional and personal content into their artwork, showing opportunity to develop this concept to better seek relevance among high school students.

To answer the research question asking what students took away from biology instruction in a visual arts classroom, it was found that students took away an improved understanding of science and increased confidence in both scientific and artistic knowledge. While performance on projects remained rather consistent throughout this study, there was a significant decrease in excitement surrounding the use of biology subject in student artwork by the end of the trimester. The neglect of student feelings and considerations likely plays into this when reflecting on the words of Chapman as assessed by Kraehe et al. (2015) as they ask us to consider the diverse lived experiences of

students when developing dialogue in the classroom. The lack of choice for students in this case was enough for a large portion of students to not consider using science in future artwork. By a large majority, though, students still see art as an opportunity to self-reflect, develop their creativity, and express their emotions.

VALUE

If more students are to find professional futures in science, then the practice of creating, discussing, and learning science will have to become more palatable for young people before they are turned off from studying subjects in science beyond their high school education. The dialogic and emotional qualities of art consistently appeal to young women, which is quite blatantly demonstrated in the throngs of young ladies who sign up for art classes. Of the 15 students who found science limiting in subject for artistic investigation, 69% were girls. While the sample size that was assessed in this study is quite small, this trend certainly reflects itself in the fields of science today. This study is by no means conclusive, in fact it could be said that it creates more questions than answers, though it should give pause to consider how we might modify science instruction to meet young people where they are instead of expecting them to commit themselves to a life of emotional stagnation.

Solutions likely lie in science educators' abilities to create fulfilling and encompassing experiential learning opportunities for young people to develop scientific understandings alongside expressive and emotional competencies. This will also occur as we take more time to listen to the disenfranchised and silenced voices that have historically sat out of scientific conversations. Scientists need to feel more comfortable

asking questions steeped in empathy and understanding for the population with which they wish to share their scientific knowledge. As more women join the workforce of practicing scientists, it would only make sense that we see the language and practices within science change.

Art has an ability to speak to almost anyone, or to say that more correctly, good art has an ability to speak to almost anyone. If the interest of science educators is to engage and cultivate scientific literacy, especially among laymen who will never enter into a science-based career, art may stand as a worthy solution to convey layered and nuanced understandings even within science. Integration of science and art consistently demonstrates growth in understanding for both disciplines, making it an appropriate intersection for researchers in science education today.

Personally, this project solidified the importance of students acquiring relevant and immersive experiences, not only in learning art, but learning science as well. Asking students to cultivate care and insight around subject that has seemingly distant relevance in their lives and with which they have only academic knowledge does not provide students their best opportunity to reflect their artistic skills. I have made it a goal to make sure that students are provided vibrant, introspective opportunities to acquire subject knowledge prior to ideating for art projects. Students need to be able to view the intersections of disciplines as they are happening, where they can remove the divisions that are too often imposed, especially in fields like art and science. Providing students opportunities to collect relevant observations and scientific skills that can be voiced through artistic expression will widen student interest in science and art, allowing

consideration for students to further pursue professional or personal interests in both disciplines.

Moving forward, I would like to develop curricula and lessons for students that cultivate curiosity and growth in understanding of art and science through shared experiences. If I want students to explore cells as subject matter, we will go talk to a cellular biologist, examine cells under a microscope, and consider the variety of roles that cells play in our lives. If I want students to examine ecology to shape an artistic investigation, we will camp in the woods, gather data about animals and plants, and sketch directly from nature. The excitement that many science professionals develop around their work came from a unique and enriching experience that made them feel capable of pursuing scientific investigations as a calling. The depreciation of excitement over the course of this research was the biggest wake-up call for me to change my instructional practices. Students should feel excited and capable when learning about art and science, and I believe that providing these external learning opportunities will provide adequate curiosity and experience to sustain student-led investigations in art and science beyond my classroom.

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APPENDICES

APPENDIX A
ART PROJECT RUBRIC

Name:	Project:				Date:
	1	2	3	4	5
Planning	Student showed no consideration of planning when developing their work.	Student is unable to produce evidence of their work and struggles to recount or elaborate on their creative methods.	Student is unable to produce evidence of the planning of their work, though is able to verbally recount their process.	Student has documented the development of their project, though presentation is lacking in quality.	Student thoroughly documents the development of the project from initial ideas to a final product.
Subject	Student showed no consideration of subject when developing their work.	Student was content in copying an image or form, though cannot provide any reasoning for producing their work.	Student is lacking in originality and the subject of their work needs development.	Student has effectively chosen subject for their work, though provides little insight into the significance of their subject.	Student demonstrates a meaningful and purposeful connection with the subject of the work they have created.
Principles of Design	Student showed no consideration of the principles of design when developing their work.	The student's work reflects poor planning when considering the principles of design.	The work may be lacking in several principles that would otherwise enhance the piece.	Student has minor details or errors in craftsmanship that detract from the effect of the composition.	Student has expertly employed the principles of design to create a desired effect or impression in their work.
Audience	Student showed no consideration of their audience when developing their work.	Student is unsatisfied with their work and refused to take on suggestions to improve their product.	Student has developed their work for their personal enjoyment, but has little to no idea how their work might be received by others.	Student understands how their work will be received by others, though the artist acknowledges areas of improvement to be gained in their product.	Student has considered how their work is to be received by an audience outside of their self.
Writing	Student made no effort to effectively describe their work.	Student's writing is confusing and fails to convey a clear narrative surrounding their work.	Student writes about their work, though it is apparent that they have left out key details.	Student has written about their artwork, though has neglected use of writing conventions and/or organization.	Student has clearly and effectively articulated their considerations regarding the subject, process, and materials used in their work.

APPENDIX B
STUDENT PRE ART/SCIENCE SURVEY

Participation in this survey is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

Name _____

Date _____

Class _____

Hour _____

Scientific/Artistic Inquiry

1) Have you ever considered science when creating your art in the past? If yes, please explain how you did this.

2) How would you rate your understanding of the scientific inquiry process?

No Understanding 0 1 2 3 4 Complete Understanding

3) What made you select your answer for question #2?

4) How would you rate your understanding of the artistic inquiry process?

No Understanding 0 1 2 3 4 Complete Understanding

5) What made you select your answer for question #4?

6) How is the scientific inquiry process similar to methods used in artistic inquiry?

7) What ideas do you use when deciding the subject or focus of your artwork?

8) What are the steps of the scientific inquiry process? Please list them.

9) What are the steps of the artistic inquiry process? Please list them.

10) How excited are you about the idea of using science to better understand art?

Not excited at all 0 1 2 3 4 Entirely excited

11) What made you select your answer for question #10?

APPENDIX C
STUDENT POST ART/SCIENCE SURVEY

Participation in this survey is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

Name _____

Date _____

Class _____

Hour _____

Scientific/Artistic Inquiry

1) Would you consider science for subject on an art project in the future? If yes, please explain why.

2) How would you rate your understanding of the scientific inquiry process?

No Understanding 0 1 2 3 4 Complete Understanding

3) What made you select your answer for question #2?

4) How would you rate your understanding of the artistic inquiry process?

No Understanding 0 1 2 3 4 Complete Understanding

5) What made you select your answer for question #4?

6) How is the scientific inquiry process similar to methods used in artistic inquiry?

7) What did you take away or learn from using science as subject in your artwork?

8) What are the steps of the scientific inquiry process? Please list them.

9) What are the steps of the artistic inquiry process? Please list them.

10) How excited are you about the idea of using science to better understand art?

Not excited at all 0 1 2 3 4 Entirely excited

11) What made you select your answer for question #10?

12) Identify one of your biology-based art projects. How did you use your scientific understandings to create an art project?

APPENDIX D
CELL PRE-POST ASSESSMENT

Name _____

Date _____

Class _____

Hour _____

Cells

1) What is cell theory? Can you name its parts?

2) What critical technology has invented that allows scientists to better study cells?

3) Name 5 organelles of the cell.

4) Name one cellular process and what it does for the cell.

5) Describe the process that cells undergo to create more cells.

6) What is the importance of stem cells in an organism?

7) What is your favorite thing that you know about cells?

APPENDIX E
ECOLOGY PRE-POST ASSESSMENT

Name _____

Date _____

Class _____

Hour _____

Ecology

1) What is ecology?

2) How do scientists study ecology?

3) Provide an example of a food chain.

4) Can you show a food web?

5) What natural cycles contribute to ecology systems?

6) What is a niche?

7) What is sustainable development? How is this related to ecology?

8) How does data on populations help scientists study ecology?

APPENDIX F
STUDENT INTERVIEW

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

Name: _____

Class: _____

Date: _____

Student Interview

- 1) On a scale from 0 to 4, 0 being the least understanding and 4 being the most understanding, how would you rate your understanding of high school biology?
- 2) Why did you rate yourself this number for knowledge in biology?
- 3) On a scale from 0 to 4, 0 being the least understanding and 4 being the most understanding, how would you rate your understanding of high school art?
- 4) Why did you rate yourself this number for knowledge in art?
- 5) Describe your experience working in biology. What classes have you taken? Have you done anything outside of school?
- 6) Describe your experience working in art. What classes have you taken? Have you done anything outside of school?
- 7) How do you think that instruction in art might help you better understand biology?
- 8) How do you think that instruction in biology might help you better understand art?

9) What do you enjoy about doing biology in art?

10) What do you not enjoy about doing biology in art?

11) How do you see instruction in biology helping you work towards your personal goals?

12) How do you see instruction in art helping you work towards your personal goals?

APPENDIX G

MONTANA STATE UNIVERSITY IRB EXEMPTION



INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 0000165

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MEMORANDUM

TO: Edmond Walsh and Walter Woolbaugh
FROM: Mark Quinn, Chair *Mark Quinn CJ*
DATE: November 14, 2018
RE: "Biology Investigations in a Visual Arts Classroom" [EW111418-EX]

The above research, described in your submission of November 14, 2018, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

- (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
- (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.
- (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.
- (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.
- (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.
- (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.