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Art History in STEAM:

Integrating Art Historical Content and Pedagogy

into High School Mathematics Curricula

A Thesis in Art History

by

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To my mom and dad, who showed me how wonderfully art and math go together.

And to Professor Keane, without whom none of this would have been possible.

Abstract

My thesis aims to evaluate the integration of art historical content and pedagogy in high school mathematics curricula. I propose a curriculum reform which establishes an inquiry-based learning model in which art history acts as the primary point of inquiry. This model functions as an inversion of the traditional mathematics lesson; it seeks to lead students through concrete regions of thought, before gradually building towards conceptual abstraction. Throughout the course of the following paper, I will attest to both the pedagogical and practical benefits of this integrative model. I begin by examining the current state of art history education in the United States, and categorizing it within the scope of Bloom's Taxonomy. I then conduct a brief overview of mathematics education, before ultimately synthesizing the two. The structure of art history education allows teachers to root each lesson within the concrete elements of the artwork itself, before using those formal qualities to inform an abstract analysis of the work as an operative whole. Similarly, an art historical structure within mathematics would allow teachers to introduce tangible works of art and architecture, before examining how those objects exemplify abstract mathematical principles. The following paper provides three sample lesson plans in which teachers may see this integration represented, as well as other educational resources. Overall, this curriculum reform seeks to facilitate comprehension in mathematics through an art historical framework.

Table of Contents

Chapter 1: Introduction.. 1
Statement of the Problem..1
The Transition from STEM to STEAM...4
Curriculum Reform Proposal...8

Chapter 2: The Current State of Art History Education... 11
Art History Within the Discipline..12
Art History as a Facet of the Arts and Humanities...21

Chapter 3: In Support of the Integration of Math and Art History...................................... 32
Problematizing Mathematics Curriculum..33
The Pedagogical Benefits of Art History..40

Chapter 4: Integration in Action: Lesson Plan Support.. 49
Deconstructing the Art Historical Math Lesson.. 49
Sample Lesson I...53
Sample Lesson II..57
Sample Lesson III.. 62

Chapter 5: Conclusion...68
Summary of Claims... 68
Future Inquiries..70
Concluding Statements.. 74

Bibliography.. 75

Chapter 1: Introduction

Statement of the Problem

Students in the United States have historically struggled with mathematics. According to *The Nation's Report Card,* there have been no significant changes in the overall average mathematics scores from 2015 to 2019. In the report, it was shown that select demographics worsened in performance: "scores decreased for lower-performing students at the 10th and 25th percentiles."[1] Among those whose scores decreased at the 10th and 25th percentiles were students that attended public school. Out of the public school students who were evaluated in this report, higher performing students remained stagnant, while lower performing students actually worsened. This data is especially concerning due to the fact that it was taken *before* the Covid-19 pandemic, when public schools largely converted to remote instruction, and students experienced an incredible loss of learning.[2][3] Moreover, the data reflects an ongoing struggle for high school students, who do not seem to be engaging at a high level in their mathematics courses. According to a survey from 2015, only 43% of 12th grade public school students reported having a positive view of mathematics.[4] So not only is student performance declining, but over half of them don't even *like* math to begin with. They may be disinterested, disengaged, or perhaps just tired. Ultimately, the data cannot tell us this. It can only tell us that high school math students are not

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[1] "NAEP Report Card: 2019 NAEP Mathematics Assessment." *The Nation's Report Card.* https://www.nationsreportcard.gov/highlights/mathematics/2019/g12/.

[2] Dorn, Emma, Bryan Hancock, Jimmy Sarakatsannis, and Ellen Viruleg. "COVID-19 and learning loss—disparities grow and students need help." McKinsey & Company, December 8 (2020): 6-7.

[3] "NAEP Report Card: 2022 Mathematics Assessment." *The Nation's Report Card.* https://www.nationsreportcard.gov/highlights/mathematics/2022/.

[4] "2015 | Survey Questionnaire Results: Students' Views of Mathematics, Reading, and Science." *The Nation's Report Card.* https://www.nationsreportcard.gov/sq_students_views_2015/.

improving academically, and that the majority of them are not enjoying their classes either. And while these two things may not be explicitly causal, they certainly demand a closer look at how we are encouraging students to engage with course material.

Struggles in mathematics have been attributed to a variety of sources over time, whether it be international relations, developmental psychology, curriculum design, or educational inequity. Nevertheless, imparting quantitative literacy upon our students has been an ongoing struggle. STEAM education has thus been proposed in recent years as a tool with which to overcome some of the existing obstacles to student comprehension. “STEAM,” an offshoot of STEM, aims to introduce the visual and performing arts as an integral component of education in the fields of science, technology, engineering, and mathematics.

Proponents of this new model have hailed its educational benefits. One article published by *Art Education* asserts that “like STEM, STEAM education stresses making connections between disciplines that were previously perceived as disparate.”[5] Another article explains that “the arts can broaden and deepen process and meaning for STEM practitioners.”[6] As many researchers have proposed, this deepening of meaning comes from the hands-on nature of the arts, which provides context to otherwise abstracted mathematical concepts; “In conventional curriculum, high-level math is a solo effort. When science and math become entirely quantitative, there’s a disconnect between math and real-world applications.”[7] Ultimately, the arts

[5] Guyotte, Kelly W., Nicki W. Sochacka, Tracie E. Costantino, Jaochim Walther, and Nadia N. Kellam. “STEAM as Social Practice: Cultivating Creativity in Transdisciplinary Spaces.” Art Education 67, no. 6 (2014): 12–19. http://www.jstor.org/stable/24766127.

[6] Wynn, Toni, and Juliette Harris. “Toward a STEM + Arts Curriculum: Creating the Teacher Team.” Art Education 65, no. 5 (2012): 42–47. http://www.jstor.org/stable/23391519.

[7] Wynn, Toni, and Juliette Harris. “Toward a STEM + Arts Curriculum: Creating the Teacher Team.” Art Education 65, no. 5 (2012): 42–47. http://www.jstor.org/stable/23391519.

allow teachers to make STEM course material concrete, thereby substantiating abstract ideas with tangible course material.

Within the realm of STEAM, I aim to address art history as an important facet of the arts, and to propose that the existing curricular structure of mathematics can act as a barrier to student comprehension. By including art history in the conversation surrounding STEAM education, I believe we, as educators, would be presented with an unprecedented opportunity to achieve STEM learning objectives. Throughout this paper, I will specifically evaluate the integration of art history into mathematics education. I believe that the infusion of art history content into high school mathematics curriculum would achieve the interdisciplinary connections that STEAM strives to propagate. Furthermore, the lesson structure of art history facilitates a gradual progression from the concrete to the abstract– something that mathematics lessons typically do not do. In fact, mathematics lessons often begin with abstract, overarching learning objectives before supplementing those concepts with concrete examples. This, as I will expand upon, can significantly impede student learning. By implementing art historical pedagogy in the mathematics classroom, teachers may invert the traditional math lesson, and better substantiate abstract concepts by first building concrete foundations with real-world examples. Overall, I believe that art history education has the capacity to remove barriers to access in the classroom, as well as encourage a more interdisciplinary view of the role that mathematics plays in the world. By successfully implementing art historical content and pedagogy into mathematics curriculum, I believe that teachers can broaden accessibility to comprehension, and facilitate thinking at a higher level.

The Transition from STEM to STEAM

The goals of STEM education date back far earlier than the "STEM" acronym even existed. Concerns regarding science, technology, engineering, and mathematics have been prevalent for decades. Education reforms, particularly those which target student performance in the STEM fields, began gaining traction in the early 1950s, and continue to sit at the forefront of education policy discussions today. This historical comprehension is necessary if we are to understand where the arts situate themselves among STEM learning frameworks, and ultimately how art history may fit into the equation.

Academic performance has been a national concern since the conception of tuition-free public, or "common" schools in the early nineteenth century. However, large-scale national investment in science, technology, and mathematics really took off in the 1950s when other countries, particularly Russia, began to outperform the United States in these disciplines. After the Soviet Union launched the Sputnik satellite in 1957, the United States government saw a significant push for STEM reform in the public education system. As Russia's scholars continued to push the boundaries of scientific achievement, the US government began to equate national security with the quality of education received by the nation's students.[8] And according to President Eisenhower, this quality was insufficient. On January 27, 1958, Eisenhower addressed Congress with the following message: "National security requires that prompt action be taken to improve and expand the teaching of science and mathematics."[9] It was especially important that these actions be taken at the high school level, since it was not guaranteed that students would

[8] Powell, Alvin. "How Sputnik changed US Education." *The Harvard Gazette.* October 11, 2007. https://news.harvard.edu/gazette/story/2007/10/how-sputnik-changed-u-s-education/.

[9] "Special Message to the Congress on Education." *The American Presidency Project.* UC Santa Barbara. https://www.presidency.ucsb.edu/documents/special-message-the-congress-education-2.

pursue post-secondary education. Other education scholars echoed these concerns, particularly those within the National Science Foundation, who were heavily involved in the reformatory action that took place in the ‘50s. According to Britannica, “adherents of the National Science Foundation and others held education professors and schools of education mainly responsible for what they believed was the low-achieving status of American students, particularly in mathematics, science, and modern foreign languages.”[10] As a result of these concerns, STEM education rose to a level of national importance in the following years. Tensions in the Cold War brought about such changes as the *National Defense Education Act* during the Eisenhower Administration, and the *Elementary and Secondary Education Act* during the Johnson Administration. These events spurred a long-term concern with student performance in mathematics, which continues today.

In the decades following, mathematics continued to be of chief concern in the United States. In the 1980s, STEM reform was once again brought to the fore by the Reagan Administration, which sought to combat the “rising tide of mediocrity”[11] in the public education system. In 1983, a report titled *A Nation at Risk* was published, staking the claim that K-12 schools were ultimately failing to educate our nation’s students. The report called for higher academic standards and more rigorous curricula, among other things. They specifically identified the need to improve mathematics curriculum, pointing to a serious decline in performance over the past two decades. Identified under “Indicators of the Risk,” the Reagan Administration stated that “The College Board's Scholastic Aptitude Tests (SAT) demonstrate a virtually unbroken

[10] Hunt, T. C.. "National Defense Education Act." *Encyclopedia Britannica*, March 20, 2023. https://www.britannica.com/topic/National-Defense-Education-Act.
[11] *A Nation at Risk: The Imperative for Educational Reform.* April 1983. https://www.reaganfoundation.org/media/130020/a-nation-at-risk-report.pdf.

decline from 1963 to 1980… Average mathematics scores dropped nearly 40 points."[12] *A Nation at Risk* spurred conversation among educators and policymakers upon its publication, and played a significant role in shaping future reports which addressed similar issues, eventually leading to the conception of STEM.

The term "STEM" was officially coined in 2001 by the National Science Foundation. In the same year, the *No Child Left Behind Act* was enacted by the Bush Administration, which reauthorized the *Elementary and Secondary Education Act;* the law continued to emphasize quality of instruction, and held public schools accountable for improved student performance.[13] STEM gained traction in the following years as a result of NCLB, as well as multiple new publications that echoed similar sentiments to Reagan's *A Nation at Risk.* One report in particular, according to Brittanica, played a fundamental role in the emphasis of STEM in educational settings: "*Rising Above the Gathering Storm* (2005), a report of the U.S. National Academies of Science, Engineering, and Medicine, emphasized the links between prosperity, knowledge-intensive jobs dependent on science and technology, and continued innovation to address societal problems."[14] As a result of this report, the US saw a renewed drive to improve education in the fields of math and science in order to preserve "US prosperity."[15] This renewed drive was exemplified in the 2015 *Every Student Succeeds Act,* enacted during the Obama Administration. ESSA revised the policies of NCLB, with the continued goal of expanding

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[12] *A Nation at Risk: The Imperative for Educational Reform.* April 1983. https://www.reaganfoundation.org/media/130020/a-nation-at-risk-report.pdf.
[13] Nolen, J. L. and Duignan, . Brian. "No Child Left Behind." *Encyclopedia Britannica*, March 20, 2023. https://www.britannica.com/topic/No-Child-Left-Behind-Act.
[14] Hallinen, J.. "STEM." *Encyclopedia Britannica*, September 13, 2022. https://www.britannica.com/topic/STEM-education.
[15] Hallinen, J.. "STEM." *Encyclopedia Britannica*, September 13, 2022. https://www.britannica.com/topic/STEM-education.

accessibility and upholding student success.[16] Science, technology, engineering, and mathematics have thus been secured as pillars of US education, and continue to shape conversations surrounding curriculum and policy.

STEM has now situated itself among other mainstays in the American educational canon. Now, as we arrive to the present day, educators have sought to introduce a new letter to the acronym: A for Art. STEAM is a relatively new term in the realm of teaching discourse which, much like STEM, has brought about important discussions on how best to maximize student learning. And according to many educators and policymakers, Art is a necessary addition to the STEM fields. According to a number of scholars, art provides a unique opportunity to engage in an inquiry-based learning process in which students play an active role in the discovery of their own learning objectives. In the words of education scholars Toni Wynn and Juliette Harris, "STEAM is a response to the question 'How do we encourage teaching that creates stimulating and inspiring classrooms, where students engage in problem solving and use their creativity and imagination to address interesting and important subjects, and where teachers push students to continue learning long after the exam is over?'"[17] In sum, scholars claim that by introducing aspects of active engagement found in the act of creation, the arts have the capacity to deepen student knowledge of STEM concepts, even beyond the scope of course material.

It is evident that education scholars have long been invested in the improvement of mathematics education, particularly in the face of a perceived decline in student performance. As policies and curriculum reforms develop over time, we see an increased interest in how the arts

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[16] "Every Student Succeeds Act (ESSA)." *U.S. Department of Education.* https://www.ed.gov/essa.
[17] Wynn, Toni, and Juliette Harris. "Toward a STEM + Arts Curriculum: Creating the Teacher Team." Art Education 65, no. 5 (2012): 42–47. http://www.jstor.org/stable/23391519.

can serve as a learning tool for students. In the face of these proposals, I aim to consider art history and its pedagogical relationship to mathematics.

Curriculum Reform Proposal

Building upon pre-existing research in STEAM and arts-infused learning, I believe that art history has an intrinsic link with mathematics that would allow teachers to expand upon many of these benefits. Throughout the history of art, civilizations have recorded the use of countless mathematical principles. Ancient Egyptians employed their knowledge of geometry through the construction of the Pyramids of Giza. Islamic monuments such as the Dome of the Rock have exemplified their devotional practices through the use of pattern sequencing. In the Baroque era, Artemisia Gentileschi demonstrated her knowledge of physics by replicating the parabolic curves of blood splatters in *Judith Slaying Holofernes* in Florence. Education scholar Anthula Natsoulas also points to this relationship, elaborating on the mathematical symbolism often integrated within cultural artifacts:

> Throughout history, different cultures have produced designs to be used as ornamentation, as part of ceremonies, and as religious symbols. Many of these designs are mathematical in nature, and their bases are often the transformations of reflection and rotation in the plane…Thus, history and art merge to create a medium through which students can study the concrete operations of reflection and rotation in the plane, as well as the more abstract concept of symmetry groups.[18]

The evidence of practical mathematics is ingrained all throughout the history of art. These historical works of art possess a wealth of pedagogical tools which teachers may use in their classrooms. If we are to achieve what Wynn and Harris refer to as the ability for students to

[18] Natsoulas, Anthula. "Group Symmetries Connect Art and History with Mathematics", *The Mathematics Teacher 93, 5* (2000): 364-370, accessed Apr 16, 2023, https://doi.org/10.5951/MT.93.5.0364.

"engage in problem solving and use their creativity and imagination to address interesting and important subjects,"[19] we must first construct a curriculum which fosters inquiry-based learning. As I aim to show in the following chapters, art historical content and pedagogy have the potential to facilitate this level of inquiry-based learning.

How will this reform proposition work, and why? An art historical learning model would expand and deepen real-world examples in mathematics curriculum, thereby facilitating a more meaningful connection for students. Moreover, the developmental needs of adolescents dictate that abstract concepts need to be scaffolded more heavily in the classroom, particularly in early to mid-adolescence; the integration of art historical course content would substantiate these overarching abstract ideas that students traditionally struggle with. Mathematics courses can thus adopt an interdisciplinary, multimodal approach to teaching that will support student learning long-term.

This proposed learning model, an inverted structure of the traditional math lesson, will also abide by pre-existing mathematics standards. Common Core State Standards, while no longer ubiquitous, were adopted by 41 of the 50 states as well as the District of Columbia as of 2010.[20] The Common Core Initiative marked a significant shift in the history of mathematics education, and continues to play a role in curriculum standards today. Today, educators have largely adopted the standards proposed by The National Council of Teachers of Mathematics, which build upon many of the premises of Common Core. The content standards remain the

[19] Wynn, Toni, and Juliette Harris. "Toward a STEM + Arts Curriculum: Creating the Teacher Team." Art Education 65, no. 5 (2012): 42–47. http://www.jstor.org/stable/23391519.

[20] "Common Core State Standards for Mathematics." *Common Core State Standards Initiative*, Council of Chief State School Officers. Accessed 31 March 2023.

same, with the addition of "Process Standards" and "Principles."[21] Throughout this paper I will use both Common Core and NCTM as reference points for my proposal, acknowledging that the US education system has been largely shaped by these two sets of standards. This is not to suggest that states who do *not* enforce these standards cannot make use of these resources, but simply to make curriculum reform as accessible as possible given the circumstances.

To further expand on the accessibility of this proposal, the remodeled curriculum is free of cost. The following chapters will include lesson plan support and sample lesson plans, which allow for teachers to adapt their lessons accordingly without having to significantly alter their curriculum. They do not necessitate sweeping infrastructural change across the US public school system, which is an obstacle often faced by progressive curriculum reforms. Rather, this plan operates in accordance with our current system of education, so as to remain accessible to public school teachers who may have resource limitations or minimal administrative support. Ultimately, it is my goal to provide free, accessible, realistic methods for teachers to support student learning in mathematics through an art historical framework.

[21] "Executive Summary." *Principles and Standards for School Mathematics.* National Council of Teachers of Mathematics. Accessed 12 April 2023.

Chapter 2: The Current State of Art History Education

In this chapter I will examine the way that art history is currently taught in the United States. Art history education can be largely encapsulated by two main categories: stand-alone art history courses, and art history content infused into other arts and humanities courses. High schools may offer art history courses as electives for their students, but they also address aspects of art history as they relate to other disciplines such as language arts or social studies. The integration of the arts and humanities is significant because it provides a glimpse into the ways that teachers can encourage their students to adopt a more interdisciplinary view of the world by combining course content from a variety of subject areas. Furthermore, it showcases the educational structures of art history, and how teachers can use them in support of their own learning objectives. This evaluation of art history education will feed into the eventual discussion of how art historical pedagogies can be implemented in math classrooms, and why this may be beneficial.

The current state of art history education in the US lacks standardization, and therefore varies widely depending on individual state and district curricula. However, we can look to Advanced Placement courses, as well as other arts and humanities disciplines in order to gain a better grasp on the ways in which art history is taught in public high schools. Within the scope of independent art history courses, content is taught in alignment with Bloom's Taxonomy. This educational framework informs the structure of each lesson, and shapes the thought processes through which students are guided. In addition to art history courses, this content is also integrated throughout other disciplines, particularly in the arts and humanities. In these scenarios, art historical concepts are most often utilized as a supplement for pre-existing learning objectives. Teachers may use an art historical example as a frame of reference for a theme or idea, or may use a particular work of art in conjunction with that day's lesson. In these scenarios, art historical references act as visual or contextual aids for other related themes. Overall, art history education depends largely upon visual and tangible elements, and builds upon them as the lesson approaches more abstract concepts.

Art History Within the Discipline

Art history is currently taught in public high schools through Advanced Placement, or AP, courses. There are few standalone art history courses offered outside of Advanced Placement, and few studies recording the prevalence of such elective courses.[22] And although there has been a lot of scholarly literature published on the inclusion of art history instruction in Studio Art courses, there is little written about teaching art history as its own high school course.[23] As a result, the discussion surrounding art history education in the US will center primarily around the AP curriculum, which is highly prescriptive and has been well-documented by the College Board.

Advanced Placement courses are standardized throughout the United States, and culminate in a final exam which may allow students to earn college credit in exchange for a sufficient score on the exam. The course curriculum is designed collectively by the College Board, a not-for-profit organization whose responsibilities also include distribution and

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[22] Bergh, Amy. "To the Ages Of Ages: Reconceptualizing High School Art History Curriculum." Master's thesis, Virginia Commonwealth University, 2011.

[23] Fitzpatrick, V.L. *Art history: A contextual inquiry course*. Reston, VA: National Art Education Association. 1992.

evaluation of the exams.[24] The intention of these courses is to provide high school students with more challenging, rigorous alternatives to their standard classes. The curriculum is intended to be equivalent to a college-level introductory course, thereby granting them college credit upon successful completion of the course and qualifying exam.

In the case of Art History, an AP class should be comparable in both content and rigor to that of a global survey course. According to the College Board, students will "explore the history of art across the globe from prehistory to the present."[25] Since students are enrolled in AP Art History for the full academic year rather than a single semester, the content covers the typical two-survey pair offered in college course listings (ex. Art History 101 and 102).

According to the AP framework, students are evaluated by two metrics: course content and art historical thinking skills. The entire curriculum comprises ten units, categorized primarily by geographic region. This content is chosen in alignment with introductory surveys as College Board aims to replicate college-level academic expectations:

> The AP Art History course framework contains clear learning objectives that represent the art historical skills valued by art historians and higher education faculty. The framework limits the required course content to 250 works of art, aligning with college and university faculty expectations of the number and types of works students should know… This approach allows students to develop profound understanding of representative works of art from diverse cultures, including fundamental information that places these works in context and illuminates relationships among them.[26]

As students progress through this content, they are intended to develop a set of "art historical thinking skills" which are integrated throughout each of the ten units. These skills include visual

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[24] "Homepage." *College Board.* https://www.collegeboard.org/.

[25] "AP Art History - Course Content." AP Students, College Board. Accessed 11 Dec. 2022. https://apstudents.collegeboard.org/courses/ap-art-history.

[26] "AP Art History Course Exam and Description." AP Students, College Board. Accessed 11 Dec. 2022. https://apcentral.collegeboard.org/media/pdf/ap-art-history-course-and-exam-description.pdf.

analysis, contextual analysis, comparisons of works of art, and an understanding of artistic traditions.[27] As students encounter different works of art in class, teachers equip them with the resources necessary to achieve these curricular goals. As a result, each lesson is ultimately rooted within the artwork itself, and stems gradually outwards towards each of the aforementioned learning metrics.

Course content resides primarily within the works of art taught in class; it relates to the era, culture, and geographic region from which each piece originates. These components of the lesson are not intended to be interpreted by students, but rather are provided to them by their teacher. If a particular artifact originated from China during the Shang Dynasty, this fact is not open for deliberation. It is simply the teacher's job to relay this information, and the student's job to remember it. When students address course content in their lessons, they engage in a process called "formal analysis," in which they identify each formal component that makes up a given work of art. As explained by the University Writing Center at UT Austin, "the purpose… is to analyze the formal elements of an artwork; it is not meant to be an interpretation."[28] Some components of formal analysis include scale, composition, time period, and medium. These are objective qualities which may be assigned to specific objects and artifacts, and are easily communicated to students. When evaluated on exams, most course content is tested via rote memorization. If a student is asked to identify four formal elements of a work of art, and is only

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27 "AP Art History Course Exam and Description." AP Students, College Board. Accessed 11 Dec. 2022. https://apcentral.collegeboard.org/media/pdf/ap-art-history-course-and-exam-description.pdf.

28 "Art & Art History: Formal Analysis & Comparative Analysis." University Writing Center, The University of Texas at Austin. Accessed 11 Dec. 2022. https://uwc.utexas.edu/wp-content/uploads/Art_ArtHist_Edit2020.docx#:~:text=A%20formal%20analysis%20is% 20quite,meant%20to%20be%20an%20interpretation.

given an image to do so, there is no other way to demonstrate proficiency in course content other than from memory.

Art historical thinking skills, on the other hand, are defined by the concepts extracted from course content. Skills like contextual analysis and understanding of artistic tradition are difficult to measure, and far from objective. Even when provided with the same work of art, with the same set of formal qualities, two students may interpret the function of this work in two entirely different ways. Though informed by the same course content, art historical thinking skills ultimately deviate from the objectivity of formal analysis, as it is common for students to employ contextual analysis in a variety of ways. One manner of interpretation is not necessarily more correct than the other, of course. However, these circumstances showcase the subjectivity of "art historical thinking skills," and demonstrate how abstract thinking can be developed through concrete activities like formal analysis. Although these skills do depend heavily on course content, they allow students to develop more abstract thinking skills moving forward. For example, the AP Instructional Model dictates that teachers should "integrate the content with a skill, considering any appropriate scaffolding."[29] Thus, formal analysis (the content of the artwork) acts as a scaffolding activity, which supports students as they begin to develop higher level art historical thinking skills. By using this structure, the AP Art History curriculum facilitates a teaching model in which learning stems from the concrete and moves into the abstract.

This pedagogical structure aligns with Bloom's Taxonomy, as it builds progressively toward more advanced levels of thinking. The University of Central Florida's Faculty Center

[29] "AP Art History Course Exam and Description." AP Students, College Board, p6. Accessed 11 Dec. 2022. https://apcentral.collegeboard.org/media/pdf/ap-art-history-course-and-exam-description.pdf.

explains that “the goal of an educator’s using Bloom’s taxonomy is to encourage higher-order thought in their students by building up from lower-level cognitive skills.”[30] Initially published in 1956, The Taxonomy of Educational Objectives is a framework widely utilized by educators to categorize educational objectives. This framework, colloquially known as Bloom’s Taxonomy, originally consisted of six categories: Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation. The AP curriculum operates in accordance with these categories, which may be shown through a brief overview of the Taxonomy.

Knowledge is defined by the ability to recognize or identify facts, without necessarily knowing what they mean. In this regard, knowledge relies heavily upon memory. For example, if a student were to look at a photo of the Mona Lisa, and recall that it was painted by Leonardo da Vinci in the year 1503, this would demonstrate Knowledge. The student does not need to extrapolate anything from this data, they must simply remember it.

Comprehension, building upon the previous skill, shows that a student is able to categorize or explain learned ideas. Through comprehension, a student may demonstrate a deeper understanding of a fact or concept by restating it in their own words. A student may be asked to demonstrate Comprehension by summarizing the physical characteristics of the Greek Ionic architectural order. By explaining that Ionic columns have fluted shafts, plain bases, and decorated capitals adorned with volutes, a student is thus able to collect data that they’ve learned in class, and categorize it according to a certain set of principles.

Application allows students to, as you might have guessed, apply the knowledge they’ve acquired in new scenarios. Application involves higher level thinking because it encourages

[30] “Bloom’s Taxonomy.” *Faculty Center*. University of Central Florida. https://fctl.ucf.edu/teaching-resources/course-design/blooms-taxonomy/#:~:text=Bloom's%20taxonomy%20was%20developed%20to,a%20variety%20of%20cognitive%20levels.

students to implement facts, rules, or patterns in unfamiliar circumstances. In doing so, students may draw parallels or connections between different types of problems. For example, a student may look at an Islamic manuscript painting that they've never seen before. They may not know the artist, the text from which the painting came, or even the year in which it was produced. However, they may take note of certain visual patterns in the piece such as cloud bands and a flat depiction of pictorial space. By utilizing the knowledge they've acquired throughout the course, they may identify this piece as having been created during the Ilkhanid period. Similarly, a student may look at a painting and take note of its dark background and dramatic lighting. While they may not be familiar with the specific work of art, they may *apply* their contextual knowledge to infer that the painting is Baroque. In this scenario, the student demonstrates Application by translating a specific set of formal qualities into a consistent visual language, and reemploying that language in another work. At this stage, learning becomes more independent as students begin to demonstrate their proficiency outside the confines of the course material. While the act of categorizing a work of art can be included within formal analysis, we begin to see a deviation from the concrete as students are tasked with classifying artifacts. The process of Application employs abstract thinking, as students must take concrete elements from multiple pieces and consider them as byproducts of overarching cultural atmospheres.

Analysis follows Application in Bloom's Taxonomy, in which a student is able to examine a given set of information, and support their conclusions with evidence. Students may make inferences, attribute effects to certain causes, or explain how different ideas relate to one another. Analysis relies heavily upon the connective tissue that students develop as they learn. These processes are evident in a student's ability to extend beyond the bounds of the artwork itself, and take other factors into account such as political and social atmosphere. For example, a student may point out that the Abstract Expressionist movement came about as a result of post-World War II attitudes towards authority and freedom of expression. Throughout the analytical process, students must consider each individual element of the pieces they are examining, as well as the organization of these elements and how they relate to one another.

Synthesis involves the imposition of new structures over pre-existing ideas. A student may synthesize information by drawing together disparate elements and presenting them in a new, cohesive manner. For example, a student may be asked to design their own museum exhibition, and describe how their chosen pieces function together as a whole. In this regard, Synthesis becomes increasingly complex due to the abstract thinking required. They must not only understand each piece's formal elements in conversation with one another, but must also be able to articulate the overarching themes that they've established.

Lastly, Evaluation is defined by a student's ability to articulate and support their own ideas. Argumentative essays are a great example of an educational task that employs Evaluation, as students are asked to present their own opinion, and substantiate their claim with knowledge acquired in class. One popular topic of conversation in art history classes is the controversy of the Elgin Marbles. The Elgin Marbles are a collection of marble sculptures from Ancient Greece which currently reside in the British Museum, despite their origins in the Parthenon in Athens. Some support Britain's acquisition of these artifacts, while others equate the British Museum's actions with looting and thievery. There is much scholarly discourse surrounding the rightful ownership of the Elgin Marbles, so students are often asked to weigh in on the matter, typically in the form of papers or class debates. In doing so, they must also support their claims with evidence. In order for a student to take their own stance on this topic, they must demonstrate Evaluation as they develop a strong thesis and supporting claims.

It is of note that this taxonomy has since been revised. As of 2001, the new taxonomy comprises Remember, Understand, Apply, Analyze, Evaluate, and Create. Each noun from the original taxonomy was modified to its verb form in order to better align with course objectives: Knowledge was changed to Remember, Comprehension to Understand, Application to Apply, and so on. Only one alteration was made to the order of the Taxonomy itself, wherein Evaluation and Synthesis were swapped, and alternatively named Evaluate and Create. In light of these revisions, much of the original premise remains the same.

Overall, Bloom's Taxonomy is largely reflected in the way that AP Art History courses are currently taught in high schools. According to the Vanderbilt University Center for Teaching, "the categories after Knowledge were presented as 'skills and abilities,' with the understanding that knowledge was the necessary precondition for putting these skills and abilities into practice."[31] This premise exists within AP Art History curriculum as well, and can be seen in the differentiation between course content and art historical thinking skills. In the context of art history education, we can understand course content in terms of its relation to Knowledge, and art historical thinking skills in terms of its relation to all other subsequent "skills and abilities."

In order to understand how a work of art functions in relation to its audience, we must first be able to conduct a thorough formal analysis. Formal analysis, though technically a form of analysis, primarily demonstrates Knowledge. In conducting a formal analysis, a student must be able to recall a specific set of information such as composition, scale, and medium, without

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[31] Armstrong, Patricia. "Bloom's Taxonomy." Center for Teaching, Vanderbilt University. Accessed 11 Dec. 2022. https://cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy/.

necessarily understanding the deeper significance of these facts. An interpretation of any piece is informed entirely by its objective qualities, which may only be learned through the presentation of course content. If a student cannot recall or identify these facts, they cannot analyze the piece on a thematic level because there is nothing with which to support their claim. Following this logic, we can operate under the assumption that course content evaluates Knowledge, while art historical thinking skills build upon this Knowledge in all other sectors of Bloom's Taxonomy. By advancing from course content to art historical thinking skills, each lesson navigates upwards through the hierarchical learning structure. By first establishing a foundation of Knowledge, students are later able to achieve higher, more advanced levels of thinking.

In addition to the Taxonomy's categorization of Knowledge and skills and abilities, AP Art History curricula also aligns with its hierarchy of thinking, which "[lies] along a continuum from simple to complex and concrete to abstract."[32] As we have previously outlined, each category in Bloom's Taxonomy becomes increasingly more complex than the one preceding it, thus demonstrating a more advanced learning objective. Likewise, each lesson in art history stems from a tangible physical object (the work itself). The lesson begins with the most concrete learning objective, in which students perform a formal analysis; they list the physical qualities of the artwork, but do not yet branch into abstract discussions about the work as a functioning whole. Rather, the work is broken down into its constituent parts first. Then, students build progressively toward more complex levels of understanding as they utilize this information to analyze the object through a thematic lens. This model parallels Bloom's Taxonomy, and supports student learning by providing a concrete access point through which students may enter.

[32] Armstrong, Patricia. "Bloom's Taxonomy." Center for Teaching, Vanderbilt University. Accessed 11 Dec. 2022. https://cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy/.

Art history education is rooted in the physicality of the art world. As a result, the structure of art history courses revolves around this physicality as well. Each lesson is rooted in the visual or tangible qualities of a given work of art, and as the course progresses, abstract concepts are built upon these foundations. Formal analyses are used to inform thematic interpretations, in much the same way that Knowledge is used to inform Comprehension, Application, Analysis, Synthesis, and Evaluation. In alignment with Bloom's Taxonomy, the framework of art history education moves from course content into art historical thinking skills, and from the concrete into the abstract.

Art History as a Facet of the Arts and Humanities

Aside from the Advanced Placement curriculum, art history is not typically offered as its own entry-level class in high school. Rather, art history content is infused in other arts and humanities courses such as Studio Art, Social Studies, and Language Arts. Students are introduced to art historical concepts through a variety of different lenses, allowing them to develop a more well-rounded understanding of the arts and its role in our society. Through this model, teachers may also encourage a more interdisciplinary view of the world.

Within visual arts courses, art history plays a significant role in introducing and developing course content. In "The Compatibility of Art History and Studio Art Activity in the Junior High School Art Program," author Michael Day asserts that "the study of art history is an essential part of superior art curricula."[33] He further explains that, according to fellow scholar Leon Frankston, "the study of art history [is] a basic prerequisite for the 'ability to appreciate or

[33] Day, Michael D. "The Compatibility of Art History and Studio Art Activity in the Junior High School Art Program." Studies in Art Education 10, no. 2 (1969): 57–65. https://doi.org/10.2307/1319613.

'know' art,' and… art history should be taught at all levels in order to provide students with the basic foundations for visual literacy."[34] In accordance with these observations, many art educators have integrated art historical content into their lesson plans in order to equip students with a stronger conceptual foundation for their practice. And, as standardized education continues to develop in the US, many of these methods have been reinforced in public high schools through the creation of national arts standards.

National standards are intended as a resource for each individual state, which they may choose to incorporate into their own mandated standards. However, these standards are not enforced at the national level. As explained by the National Art Education Association,

> Each State Department of Education creates policy and sets education standards to provide guidelines and expectations for what students should know and be able to do throughout K-12 schooling in their state. While public schools are required to meet local and state standards, national standards are voluntary and used by some states to inform the development of their own state standards; other states adopt the national standards as their state standards."[35]

So while states are not obligated to adopt national arts standards, they do act as an important reference point by which to understand general academic expectations.

The National Core Arts Standards were initially developed in 1994, and have recently been rereleased in 2014. Since 2014, 39 states have adopted revised art standards in response to these policies, thus establishing a consistent narrative among many states as to what education in the arts looks like. In consideration of these statistics and the remaining 11 states, we are not to assume that their arts education system is entirely localized. Even in states whose governments

[34] Day, Michael D. "The Compatibility of Art History and Studio Art Activity in the Junior High School Art Program." Studies in Art Education 10, no. 2 (1969): 57–65. https://doi.org/10.2307/1319613.
[35] "National Visual Arts Standards." National Art Education Association, Art Educators. Accessed 11 Dec. 2022. https://www.arteducators.org/learn-tools/national-visual-arts-standards.

have not adopted national standards, their curriculum is still closely monitored in accordance with similar guidelines. In fact, "all 50 states and the District of Columbia have content or performance standards for art education."[36] This is significant because it demonstrates a level of consistency in education policy across all 50 states, even those who have not implemented the National Core Arts Standards. With this in mind, I will be addressing the framework of the National Standards for the duration of this chapter, as they represent the majority of the United States.

Within their revised framework, the National Core Arts Standards have identified 11 Anchor Standards, each of which offer academic objectives that satisfy High School Proficient, High School Accomplished, and High School Advanced. These Anchor Standards are additionally categorized by four primary goals: Creating, Presenting, Responding, and Connecting. Throughout this framework, many of the key academic objectives connect to art historical themes and ideas, particularly those encapsulated within Presenting, Responding, and Connecting. Anchor Standard 7, for example, aligns with "Responding" and asks students to "perceive and analyze artistic work."[37] In order to demonstrate proficiency at the high school level, students are asked to "analyze how one's understanding of the world is affected by experiencing visual imagery."[38] This core standard, among many others, is heavily rooted in art historical understanding. In order to develop an understanding of how perception is affected by visual imagery in the present tense, one must first examine how human perception has been

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[36] "Art Scan." Arts Education Partnership. Accessed 11 Dec. 2022. https://www.aep-arts.org/artscan/.
[37] "National Visual Arts Standards." National Art Education Association, Art Educators. Accessed 11 Dec. 2022. https://www.arteducators.org/learn-tools/national-visual-arts-standards.
[38] "National Visual Arts Standards." National Art Education Association, Art Educators. Accessed 11 Dec. 2022. https://www.arteducators.org/learn-tools/national-visual-arts-standards. .

historically shaped by visual culture. The achievement of these expectations demands a thorough comprehension of Art History on the part of the teacher, as well as the student.

Furthermore, we can see how lessons in the visual arts may utilize art historical concepts as a means to introduce certain goals. Continuing along the route of Anchor Standard 7, a student may be asked first to “perceive and analyze” a historical work of art, before participating in a class critique with other student work. This historical analysis may serve as a means of familiarizing students with the act of breaking down a work of art, and understanding how it may have been interpreted by contemporaries. By developing these skills in a more controlled environment, it may instill more confidence going forward into a less structured, more independent activity like a class critique.

Art historical concepts can be seen all throughout education in the visual arts. At the national level, these skills have been regarded as quintessential in the process of defining what a successful art student looks like. At the classroom level, art historical content is frequently used as a jumping-off point in class, from which students may learn how to implement certain art skills on their own. Overall, art historical content has been heavily integrated throughout the visual arts by teachers and policymakers alike.

In addition to the visual arts, art historical concepts can be found in classes such as history and social studies. In these scenarios, historical works of art function as primary source material, and are utilized in support of an overall understanding of a given epoch. Much in the same way that letters and journal entries are studied in history, artworks are used as primary documentations of quotidian life. Art, in this way, helps teachers to place historical events in the context of the contemporary human experience, as artists immortalize moments, feelings, and perceptions of public opinion in reaction to greater historical events. Scholar Terrie L. Epstein writes about these pedagogical methods in her article "The Arts of History: An Analysis of Secondary School Students' Interpretations of the Arts in Historical Contexts." She explains that,

> unlike the literal or analytical knowledge students acquire from history textbooks or other discursive texts, the knowledge students construct when working with the historical arts is very human or lifelike in form. These experiences demonstrate that by integrating the historical arts into the history curriculum, secondary history teachers in particular— and perhaps teachers at every level of schooling—can enrich and enliven the historical understandings students come to construct.[39]

In accordance with Epstein's claims, art historical content is employed by teachers in an attempt to supplement overarching historical themes with tangible human experiences. It functions by adding further layers of complexity to a seemingly "objective" sequence of events, often presented through the format of a textbook. By adding art historical content to these lesson structures, teachers may challenge a particular perspective, thereby encouraging their students to employ higher level thinking skills. Overall, these tools allow teachers to characterize periods of history, and to zoom in on a uniquely human perspective which may not be readily available in textbooks.

Many periods of artistic production were defined by the sociopolitical atmospheres from which they arose. The Dada movement, for example, developed in reaction to World War I. European citizens were repulsed by the war, and by the nationalist and capitalist foundations it stood upon. In opposition to this senseless violence, artists founded Dadaism as a means of holding a mirror up to society in the form of unmitigated absurdity and anti-rationalism. And

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[39] Epstein, Terrie L. 1994. "The Arts of History: An Analysis of Secondary School Students' Interpretations of the Arts in.." Journal of Curriculum & Supervision 9 (2): 174–94. https://search.ebscohost.com/login.aspx?direct=true&db=ehh&AN=9407126284&site=eds-live&scope=site.

despite the varying forms taken by Dada art, its message remained the same; "[Dada artists] were united not by a common style but by a rejection of conventions in art and thought, seeking through their unorthodox techniques, performances, and provocations to shock society into self-awareness."[40] A consistent theme can be traced throughout Dada art, speaking to a greater pattern among contemporary thought and emotion. Therefore, the visual language of Dadaism serves as a reflection of public opinion during a time of great social upheaval, even if that opinion did not align with the political events which transpired as a result of World War I.

The same can be said of countless other eras of artistic production, all of which represent a common belief or viewpoint held at a particular point in time. As Epstein summarizes, "the historical arts contain the necessary information to answer a question such as, 'What was life like during a particular historical period for a particular group of people?'"[41] By using art history as a learning tool in high school history classes, teachers may begin to address this question beyond the scope of perceived objectivity. Rather, a constructed visual language allows teachers and students to analyze the perception of history by contemporary populations, not just through a strictly modern textbook-style lens. This also allows students to use a concrete artifact – the artwork – in support of a greater historical understanding. Understanding the perspectives of people other than ourselves depends largely on abstract thinking, as we imagine what life may have been like for a particular group of people. This can be an exceptionally difficult task for adults, let alone high schoolers. However, these abstract concepts can be supported by the use of

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[40] Ades, Dawn, and Matthew Gale. "Dada." Grove Art Online. 2003; Accessed 11 Dec. 2022. https://www.oxfordartonline.com/groveart/view/10.1093/gao/9781884446054.001.0001/oao-9781884446054-e-7000021094.

[41] Epstein, Terrie L. 1994. "The Arts of History: An Analysis of Secondary School Students' Interpretations of the Arts in.." Journal of Curriculum & Supervision 9 (2): 174–94. https://search.ebscohost.com/login.aspx?direct=true&db=ehh&AN=9407126284&site=eds-live&scope=site.

primary sources. Put simply, works of art are concrete and observable, whereas history itself is not. If teachers could time travel, there would be no need for history classes. Instead, we must rely on records of experience which are filtered through the lens of the individual who recorded them. For this reason, art history affords teachers the opportunity to provide a glimpse into the past, and substantiate overarching historical themes with concrete representations of those ideas.

In the context of Dadaism, this allows history teachers to address countercultures/protest movements in conversation with the actions taken by a political party or other governing structure. While many European countries did indeed become involved in World War I, this does not mean that the population was unanimously in support of their decision. However, the broad scope of such nuances are difficult to encapsulate within a singular textbook chapter, so they are often abandoned in favor of a more simplistic overview; while there are no national Common Core standards currently in place for history and social studies, there is an expectation that students develop an understanding of "causal reasoning,"[42] which leads to a greater focus placed on large-scale international relations and political affairs. In the face of such scenarios, teachers may turn to art history in an attempt to provide a more multi-layered view of these topics.

It is easy to see the overlap which exists between history and art history, so it stands to reason that this overlap continues into the realm of education as well. And in US high schools, there is a particular purpose which art historical content often serves in the history classroom: to substantiate greater, abstract characterizations of a particular era with tangible artifacts of the human experience. In support of this conclusion, Epstein articulates that

When the arts are well integrated into the history curriculum, when teachers and students

[42] Stoel, G.L., J.P. van Drie, and C.A.M. van Boxtel. 2015. "Teaching towards Historical Expertise. Developing a Pedagogy for Fostering Causal Reasoning in History." Journal of Curriculum Studies 47 (1): 49–76. doi:10.1080/00220272.2014.968212.

> alike believe historical knowledge can be conceptualized through discourse characterized by qualities other than literal or abstract explanations or assertions and reasoned arguments about primary causes or consequences… groups of students can work together to construct rich and fundamentally human historical understandings.[43]

Regardless of an artwork's original function or intended audience, it ultimately preserves a specific moment in time, as perceived by a specific individual. This is highly valuable as an educational tool because this specificity cannot be achieved by textbooks alone. While it is certainly important to characterize historical periods on a macroscopic level, this may remove students from the more intimate, human facets of history education. In sum, art historical content allows educators to showcase the tangible qualities of human history, and use primary source material in support of students' overall historical comprehension.

Lastly, art history content shows up frequently throughout English and Language Arts courses in high schools. Similarly to its role in history courses, art history serves to contextualize specific lessons and pieces of literature. By providing examples of alternate forms of creative expression, teachers may better supplement lessons in the literary arts.

Common Core State Standards dictate that students grades 9-10 must be able to "analyze the representation of a subject or a key scene in two different artistic mediums, including what is emphasized or absent in each treatment (e.g., Auden's "Musée des Beaux Arts" and Breughel's *Landscape with the Fall of Icarus*)."[44] Categorized under the Anchor Standard "Integration of Knowledge and Ideas," this educational objective conveys the importance of synthesizing the

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[43] Epstein, Terrie L. 1994. "The Arts of History: An Analysis of Secondary School Students' Interpretations of the Arts in.." Journal of Curriculum & Supervision 9 (2): 174–94. https://search.ebscohost.com/login.aspx?direct=true&db=ehh&AN=9407126284&site=eds-live&scope=site.

[44] "Common Core State Standards for English Language Arts." Common Core State Standards Initiative, Council of Chief State School Officers, p38. Accessed 11 Dec. 2022. https://learning.ccsso.org/wp-content/uploads/2022/11/ELA_Standards1.pdf.

visual and literary arts. Furthermore, these standards show that by introducing art history into the classroom, students may develop a stronger understanding of English and Language Arts concepts.

One such example of this synthesis can be found in the 2013 curriculum guide entitled *Cracking the Common Core: Choosing and Using Texts in Grades 6-12.*[45] In adherence with Common Core Standards, the text provides curricular support for Language Arts, Social Studies, and Science, paired with sample lesson plans which educators may incorporate into their own classrooms. For the Language Arts, each lesson plan identifies a "target text," and then constructs the scaffolding necessary for students to analyze the text thematically. This scaffolding depends heavily on building "critical background knowledge needed to comprehend [the] target text,"[46] which is where the visual arts come into play.

The first provided sample lesson revolves around Henrik Ibsen's play *A Doll's House.* In support of student comprehension, the lesson plan identifies three key components which successfully establish "critical background knowledge:" knowledge of the Victorian era, feminist criticism, and societally reinforced gender roles. A variety of sources are provided, one of which being video samples of *Leave It To Beaver* and *I Love Lucy,* which exemplify the reinforcement of traditional gender roles. In addition to providing background knowledge on some of the themes addressed in *A Doll's House*, these sources also demonstrate the inextricable relationship

[45] William E. Lewis, Sharon Walpole, and Michael C. McKenna. *Cracking the Common Core: Choosing and Using Texts in Grades 6-12.* New York: The Guilford Press, 2013. https://search.ebscohost.com/login.aspx?direct=true&db=nlebk&AN=665696&site=eds-live&scope=site.
[46] William E. Lewis, Sharon Walpole, and Michael C. McKenna. *Cracking the Common Core: Choosing and Using Texts in Grades 6-12,* p 192. New York: The Guilford Press, 2013. https://search.ebscohost.com/login.aspx?direct=true&db=nlebk&AN=665696&site=eds-live&scope=site.

between the visual, literary, and performing arts. And while this particular lesson plan employs excerpts from television shows, one can easily see how art historical examples may be used in place of pop culture media. For example, a teacher may decide to select Victorian familial portraits, which would not only provide information on the Victorian era, but may also shed light on contemporary gender roles. Or, in alignment with *Leave It To Beaver* and *I Love Lucy*, a teacher may choose to pursue a more contemporary route. According to the lesson plan, the above excerpts were chosen in order to "make connections between the Victorian Age and the 1950s era depicted in the video texts."[47] With these goals in mind, a teacher may choose instead to analyze the work of Roy Lichenstein and draw similar comparisons. Regardless of how an educator may choose to interpret or adapt these lesson plans in their own classroom, it is easy to see how art historical sources aid in achieving Language Arts learning objectives.

In each of the aforementioned examples, art history functions as a vehicle for "critical background knowledge." As articulated in the Common Core State Standards, it is essential that students are able to analyze the relationships between different artistic media. The given example even specifies the ability to relate writing and painting, further attesting to its value in Language Arts education. When students can successfully orchestrate a conversation between a literary and visual artwork, they may develop a more complex understanding of their thematic and symbolic significance. This in turn allows students to build higher level thinking skills in English Language Arts, such as Analysis and Synthesis. Overall, art history supports Language Arts

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[47] William E. Lewis, Sharon Walpole, and Michael C. McKenna. *Cracking the Common Core: Choosing and Using Texts in Grades 6-12,* p 192. New York: The Guilford Press, 2013. https://search.ebscohost.com/login.aspx?direct=true&db=nlebk&AN=665696&site=eds-live&scope=site.

education by expanding ideas presented in literature, and expounding upon those themes in a more visual format, thereby contextualizing abstract themes and learning objectives.

The integration of art history can be observed all throughout the arts and humanities. Studio Art, Social Studies, and Language Arts all utilize art historical content in support of discipline-specific learning objectives. Across all disciplines, it is common for teachers to employ art historical content as a means of contextualizing or substantiating greater overarching themes. Due to the physicality available via art history, students can see concrete examples of larger, more abstract themes that they may be working with in class. As a result, teachers may use these examples to supplement their own course content. In Studio Art, this could mean providing an example of a particular style or technique. In History, this could mean incorporating primary source material in the form of contemporary artwork. Or in Language Arts, this could mean comparing and contrasting multiple avenues through which an artist may convey their ideas. Regardless of context, teachers integrate art historical content throughout other disciplines with the ultimate goal of supplementing their own learning objectives. In doing so, teachers may provide concrete, tangible examples in order to provide a stronger foundation for student understanding within their own discipline.

Chapter 3: In Support of the Integration of Math and Art History

Now, operating under the assumption that the A in STEAM does indeed account for Art History, what are the implications of this conclusion for math curricula? How can high school students ultimately benefit from the integration of art history concepts, and how can this integration be achieved? In sum, I believe that math lessons may provide broader points of entry for students if they first establish an art historical foundation from which students can build upon as they reach more abstract levels of understanding. Due to the pedagogical framework implemented in math lessons, teachers typically supplement overarching concepts with supporting examples, thus moving from the abstract towards the concrete. This structure can prove to be quite frustrating for students, and often leaves them with more questions than they arrived with. The root of this frustration, as I develop throughout the following chapter, is largely attributed to the psychological development which takes place during adolescence. As students continue to develop their ability to think abstractly, they may encounter obstacles to comprehension when these abstract concepts are not adequately scaffolded in class. I aim to invert this framework, and utilize art historical pedagogy as the means through which to achieve this inversion. By moving from concrete art historical narrative towards its mathematical byproduct, teachers may better support student learning, particularly for those who are still developing their abstract thinking skills. By rooting course content in the realm of art history, students may develop a stronger grasp on the real-world implications and practical origins of mathematical concepts which may otherwise feel ungrounded.

Problematizing Mathematics Curriculum

First and foremost, what comprises high school math curricula? According to the Common Core State Standards, high school students must demonstrate proficiency in a list of "conceptual categories," including Numbers and Quantity, Algebra, Functions, Modeling, Geometry, and Statistics and Probability.[48] These conceptual categories are reflected by NCTM as well, in which they are referred to as "content standards." NCTM content standards include Numbers and Operations, Algebra, Geometry, Measurement, Data Analysis and Probability.[49] These categories are not relegated to their own individual courses, but rather address a set of skills which are expected of high school graduates in preparation for college. They are assessed to varying degrees throughout high school math curricula, and rely largely on conceptual abstraction. Among the typical courses that a high schooler might take are Algebra, Geometry, Algebra II, Pre-Calculus, Trigonometry, and Calculus, all of which employ the aforementioned skills. And while these course offerings may vary between districts and states, the curricular objectives remain largely the same.

According to scholars Robert Berry and Matthew Larson, over 90% of US high schools adhere to the same course pathway, and have done so for the past 130 years: "...for the vast majority of students today the high school mathematics curriculum continues to begin with a year of algebra followed by a year of geometry and a second year of algebra. This sequence was first recommended by the Committee of Ten in 1892."[50] Berry and Larson have problematized

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[48] "Common Core State Standards for Mathematics." Common Core State Standards Initiative, Council of Chief State School Officers. Accessed 30 January 2023. https://learning.ccsso.org/wp-content/uploads/2022/11/ADA-Compliant-Math-Standards.pdf.

[49] "Executive Summary." *Principles and Standards for School Mathematics.* National Council of Teachers of Mathematics. Accessed 12 April 2023.

[50] Berry, Robert Q., and Matthew R. Larson. "The Need to Catalyze Change in High School Mathematics." The Phi Delta Kappan 100, no. 6 (2019): 39–44. https://www.jstor.org/stable/26614902.

this stagnation, pointing out that "high school NAEP scores have remained essentially flat for decades," despite improved performance at the elementary and middle school level.[51] They have identified curriculum structure as a primary causal factor, pointing out that "urgent calls for reform in mathematics education date back at least four decades."[52] Unfortunately, these proposals have been to little avail; even as of 2019, Berry and Larson assert that "it is necessary to identify, confront, and make long overdue changes to the structures, policies, instructional approaches, and focus and relevance of high school mathematics."[53] The National Council of Teachers of Mathematics echoes a similar sentiment, claiming that "all high schools should reevaluate their mathematics programs to determine whether the current sequence of courses is preparing students for the demands of a workplace that will require more than the mastery of isolated mathematics skills."[54] In light of these observations, it is imperative that new and innovative approaches are implemented in public school classrooms, particularly with regard to curriculum design.

Seeing as the curriculum has become relatively stagnant in the past century, one can imagine the limitations associated with course content. As Berry and Larson have asserted, "the status quo in high school mathematics persists in part because the structure of high school mathematics remains the same today as it was decades ago."[55] As a result of this stagnation, the

[51] Berry, Robert Q., and Matthew R. Larson. "The Need to Catalyze Change in High School Mathematics." The Phi Delta Kappan 100, no. 6 (2019): 39–44. https://www.jstor.org/stable/26614902.
[52] Berry, Robert Q., and Matthew R. Larson. "The Need to Catalyze Change in High School Mathematics." The Phi Delta Kappan 100, no. 6 (2019): 39–44. https://www.jstor.org/stable/26614902.
[53] Berry, Robert Q., and Matthew R. Larson. "The Need to Catalyze Change in High School Mathematics." The Phi Delta Kappan 100, no. 6 (2019): 39–44. https://www.jstor.org/stable/26614902.
[54] Daniel Brahier, Steve Leinwand, and DeAnn Huinker. "Principles to Actions: Mathematics Programs as the Core for Student Learning." The Mathematics Teacher 107, no. 9 (2014): 656–58. https://doi.org/10.5951/mathteacher.107.9.0656.
[55] Berry, Robert Q., and Matthew R. Larson. "The Need to Catalyze Change in High School Mathematics." The Phi Delta Kappan 100, no. 6 (2019): 39–44. https://www.jstor.org/stable/26614902.

majority of lesson plans in mathematics follow a similar, if not identical, formula: the learning objective or target skill is introduced at the beginning of class, followed by an example and perhaps some practice problems. In this model, the learning objective leads the lesson. When a lesson begins with the students' intended takeaway, this often results in the teacher explaining a mathematical concept in the theoretical sense *before* grounding those ideas in the context of something tangible and recognizable to students. Furthermore, it causes skills such as Application to rest upon higher level thinking skills such as Analysis and Evaluation in Bloom's Taxonomy, which can be challenging for students to develop. These expectations are reflected in the Common Core Standards, which contend that "mathematically proficient students can apply the mathematics they know to solve problems arising in everyday life, society, and the workplace… By high school, a student might use geometry to solve a design problem or use a function to describe how one quantity of interest depends on another."[56] Abiding by these standards, a student must develop mathematical proficiency *before* they understand how those skills are applied in the real world, not the other way around. These standards are closely paralleled by the NCTM's Process Standards, which maintain that students should "solve problems that arise in mathematics and in other contexts," as well as "apply and adapt a variety of appropriate strategies to solve problems."[57] Once again, skills such as application and adaptation become dependent on pre-existing student comprehension. These are undoubtedly important skills to develop throughout high school, however, they contribute to an educational structure in which the target skill is placed before the supporting course content.

[56] "Common Core State Standards for Mathematics." Common Core State Standards Initiative, Council of Chief State School Officers. Accessed 30 January 2023. https://learning.ccsso.org/wp-content/uploads/2022/11/ADA-Compliant-Math-Standards.pdf.
[57] "Executive Summary." *Principles and Standards for School Mathematics.* National Council of Teachers of Mathematics. Accessed 12 April 2023.

Furthermore, the Common Core Standards name "reason[ing] abstractly and quantitatively"[58] as one of the key Mathematical Practices that students should acquire and strengthen in each conceptual category, but do not articulate how students are expected to develop these skills. This places the above skills at the forefront of each lesson, thereby deprioritizing the foundational activities that these skills build upon. By and large, this creates math lessons which stem from the abstract and build towards the concrete. We are thus presented with a curricular structure which operates inversely to the standard art history lesson.

This lesson structure can have a number of drawbacks. Students are presented with formulas before learning what each variable represents, or given dimensions before being shown a 3D model. Visuals such as graphs, tables, and models are often used to exemplify abstract concepts, but the learning ultimately derives from the data. Once again, this hierarchy of learning is represented in the Common Core Standards: Mathematically proficient students should be able to "identify important quantities in a practical situation and map their relationships using such tools as diagrams, two-way tables, graphs, flowcharts and formulas. They can analyze those relationships mathematically to draw conclusions."[59] A student must possess a strong grasp on a concept abstractly *in order to* map those figures in a concrete manner. In order for a student to first "identify important quantities," they must comprehend the formula as an operative whole before they can even begin to construct a visual diagram. This facilitates an educational model in which real-world examples act as a supplement to the lesson, rather than as the basis for a

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[58] "Common Core State Standards for Mathematics." Common Core State Standards Initiative, Council of Chief State School Officers. Accessed 30 January 2023. https://learning.ccsso.org/wp-content/uploads/2022/11/ADA-Compliant-Math-Standards.pdf.
[59] "Common Core State Standards for Mathematics." Common Core State Standards Initiative, Council of Chief State School Officers. Accessed 30 January 2023. https://learning.ccsso.org/wp-content/uploads/2022/11/ADA-Compliant-Math-Standards.pdf.

mathematical principle. When this happens, teachers must pigeon-hole examples into their lesson, typically in the form of supplemental word problems. And when these word problems come off as awkward or unnatural, it can feel inauthentic to students. If a student has to solve for a problem in which Johnny buys 27 watermelons, they're just not going to take it seriously.

Even when teachers *do* attempt to integrate other disciplines like the arts into their lessons, this learning framework severely limits the depth of comprehension that a teacher can facilitate. Audrey Bennett, a professor of graphic design at Rensselaer Polytechnic Institute, expands upon some of these themes in her own curriculum. She utilizes her acuity for math and the arts to create a graphic design workshop for middle schoolers which aims to combine math and computing principles. She explains, "math teachers might think that if something is not about solving an equation or calculation, it must be a word problem. So you end up with shallow art-math connections like calculating how many crayons or whatnot. But the deeper connections are the ones that can light a student's brain on fire."[60] When a student feels as though a word problem is not relevant in the greater context of the lesson (and the student's life), they are far more likely to disregard their assignments as mere busywork. This can negatively impact a student's engagement with the material, and ultimately hinder their learning.

The perceived relevance of supplemental word problems brings up yet another barrier to student comprehension. As we discuss the accessibility of mathematics curriculum, we would be remiss to leave out discussions of diversity, equity, and inclusion. NCTM emphasizes this facet of accessibility in classroom instruction, defining equity as one of their Six Principles for School Mathematics: "[Equity] demands that reasonable and appropriate accommodations be made and

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[60] Wynn, Toni, and Juliette Harris. "Toward a STEM + Arts Curriculum: Creating the Teacher Team." Art Education 65, no. 5 (2012): 42–47. http://www.jstor.org/stable/23391519.

appropriately challenging content be included to promote access and attainment for all students."[61] I believe that art historical content and pedagogy can achieve these curricular goals, expanding equity and making content relevant to all students.

One byproduct of the current curricular structure is that it lacks cultural relevance. As previously discussed, the supplemental nature of mathematics curriculum forces teachers to pigeon-hole word problems into their lessons as a means of exemplifying the learning objective. Thus, word problems become the only avenue through which teachers can connect course content to their students' lives. The easiest means to achieve this connection is by providing diverse scenarios within the word problems themselves, as well as a diverse variety of names. This is an incredibly important facet to cultural accessibility, but it is also not the *only* one. In addition to these changes, students need to be shown how course content relates to their lives and the world at large. This, as I aim to assert, can be addressed via art historical narrative.

In my view, including a more diverse array of names is a net positive for accessibility in mathematics education. However, it is vital to acknowledge that the conversation surrounding cultural accessibility does not end there. When the diversity of the subjects in a word problem do not match the relevance of the problem itself, this dissonance becomes evident to students. It may come off as a superficial, performative change which ultimately fails to address the root of cultural accessibility. Regardless of *who* ends up buying 27 watermelons at the store, students will still know that it's not realistic. In "A Teacher's Guide to Reasoning and Sense Making," it is acknowledged that this instructional model can seriously stunt student learning: "Often students struggle because they find mathematics meaningless. Instruction that fails to help them

[61] "Executive Summary." *Principles and Standards for School Mathematics.* National Council of Teachers of Mathematics. Accessed 12 April 2023.

find connections through reasoning and sense making may lead to a seemingly endless cycle of reteaching."[62] As the authors explain, high schoolers feel as though this type of coursework is fruitless, and become frustrated because they don't believe this knowledge will benefit them long-term. Furthermore, it deprives students of a far deeper understanding of mathematics, thus establishing more barriers to access. In actuality, all mathematical theorems and principles are derived from some observable property of the natural world. They were recorded, studied, and employed across the entire scope of human history irrespective of time period, geographic region, or culture. The development of mathematics is fundamentally diverse and interdisciplinary, which should be reflected in our classrooms. These principles were discovered by humans because they were useful and relevant in some way, and should be taught as such.

It is easy for students to lose sight of this because all too often they lack the foundational grounding that allows them to see why humans sought to understand the underlying principles of the universe in the first place. In our modern era, we are so far removed from the inner workings of technology, architecture, transportation, and global infrastructure, that we seldom pause to consider a time before those things existed. It may sound silly, or perhaps overly philosophical, but these are the conversations that students wish their teachers had, and which are sorely lacking in the public education system. In "Fires in the Bathroom: Advice for Teachers from High School Students," a series of student co-authors compile a list of advice that they would give to their teachers. One student named Vance explains, "I think one of the only ways people learn something alien is to relate it to their own experience. If a teacher can connect geometry and angles to my interest in art or being an actor, that works. Even though I know I didn't grow up

[62] "A Teacher's Guide to Reasoning and Sense Making." *National Council of Teachers of Mathematics.* https://www.nctm.org/uploadedFiles/Standards_and_Positions/Focus_in_High_School_Mathematics/FHSM_TeacherGuide.pdf.

with math, I know enough because he relates it to me."[63] Another student Lauraliz agrees, asserting that when teachers successfully ground their lessons in concrete terms, "it makes you think, maybe I can relate it to my life."[64] The ability to relate course content to the real world is a cornerstone of mathematics education; in accordance with NCTM learning objectives, "an effective mathematics curriculum focuses on important mathematics that will prepare students for… solving problems in a variety of school, home, and work settings."[65] Historical and cultural context has the capacity to facilitate these connections, and bridge the gap between mathematical skills and their practical applications. The effective teaching of mathematics depends upon an interdisciplinary approach, *especially* one that takes history and culture into account. In order to engage with course content at a higher level of thinking, students must first understand the "why."

The Pedagogical Benefits of Art History

So how can we, as teachers, show students the "why?" Establishing stronger curricular support is a key step in the improvement of mathematics curriculum. As the creators of Common Core explain, "these Standards do not dictate curriculum or teaching methods."[66] While this design was created in an attempt to allow teachers more flexibility, it ultimately limits the amount of scaffolding support that teachers receive in the classroom. This feeds into many of the

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[63] Cushman, Kathleen. *Fires in the Bathroom: Advice for Teachers from High School Students.* New York: New Press, 2003.
[64] Cushman, Kathleen. *Fires in the Bathroom: Advice for Teachers from High School Students.* New York: New Press, 2003.
[65] "Executive Summary." *Principles and Standards for School Mathematics.* National Council of Teachers of Mathematics. Accessed 12 April 2023.
[66] "Common Core State Standards for Mathematics." Common Core State Standards Initiative, Council of Chief State School Officers. Accessed 30 January 2023. https://learning.ccsso.org/wp-content/uploads/2022/11/ADA-Compliant-Math-Standards.pdf.

aforementioned issues, in which overarching learning objectives are lacking in support (or provide inadequate support in the form of superficial word problems). Overall, art history education serves to fill out these areas of math, while simultaneously providing historical and cultural relevance to conceptual frameworks. By applying the pedagogical methods of art history education, I believe that teachers would be better supported in the process of lesson planning, and that students would be more prone to mastering abstract mathematical concepts. I propose to integrate the curricular structure of Art History courses into math lessons so that teachers can move students gradually from concrete towards abstract thinking. Furthermore, I aim to ground lesson plans in art historical content in order to demonstrate the origins of mathematical concepts, and showcase their intended function in society.

Arts-infused learning is a facet of STEAM which has been researched among education scholars in recent decades, and has shown incredibly promising results. The Institute for Arts Integration and STEAM points to a recent collection of studies, claiming that "STEAM is a promising approach to positively impacting student achievement and teacher efficacy."[67] Christopher A. Howard, for example, discusses the infusion of Egyptian art into mathematics courses and how this can increase student engagement. He asserts that this art historical content "can enliven the curriculum while making students aware of mathematics history."[68] A 2014 study in arts-integration also showed that students performed at a significantly higher level in mathematics than their control-group counterparts who did not receive art-integrated

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[67] "Why is STEAM Education Important?" *Institute for Arts Integration and STEAM.* https://artsintegration.com/what-is-steam-education-in-k-12-schools/.

[68] Howard, Christopher A. "Mathematics Problems From Ancient Egyptian Papyri." *The Mathematics Teacher* 103, no. 5 (2009): 332–39. http://www.jstor.org/stable/20876630.

instruction.[69] Throughout these studies, the arts have been integrated through a variety of approaches, and have shown positive trends for student learning across the board.

Another study was conducted by *Journal for Learning through the Arts* at UC Irvine in 2011, and recorded the results of five case studies in middle-level classrooms. Through this study, researchers supported the conclusion that arts-infused learning "is a pedagogical approach that meets the developmental needs of early adolescents and fosters a relevant, challenging, integrative, and exploratory curriculum to all learners."[70] The study revolves around middle-school age students; however, its conclusions can also be applied to the cultural and developmental needs of high schoolers. Across each of the five case studies, student groups demonstrated diversity with regard to race, ethnicity, gender, and socioeconomic status. By the end of the study, students showed significant academic improvement as a result of the implementation of arts-infused learning in their core subjects (Language Arts, Mathematics, Science, and History/Social Studies).

Researchers utilized the visual and performing arts as an integrative approach in their classes, however, art historical content was also present in a variety of lessons. One lesson, for example, allowed students to connect and interface with history by recreating traditional Mexican artifacts, while learning about their cultural significance: "Through the study of 'Retablos' (a Mexican art form using painted tin or wood), Orozco School students created personal retablos. This experience enhanced their understanding of the past and enabled them to

[69] Inoa, R., Weltsek, G., & Tabone, C. "A study on the relationship between theater arts and student literacy and mathematics achievement." *Journal for Learning through the Arts: A Research Journal on Arts Integration in Schools and Communities, 10(1)*, 2014.
[70] Lorimer, Maureen R. *Arts-Infused Learning in Middle Level Classrooms.* UC Irvine Journal for Learning Through the Arts, 2011. https://escholarship.org/uc/item/0hp6g86s

articulate 'transformative moments in their own lives.'"[71] Even when integrating the visual arts into their core curriculum, teachers were able to deepen their students' cultural understanding via art history, and encourage a more interdisciplinary approach to learning.

In addition to the study's integration of art history, they also address a key concern when it comes to math curricula in secondary schools. Researchers at UC Irvine collected data from previous findings, reporting that arts-infused learning can aid in the development of abstract thinking, particularly for adolescents. They explain that "because of the varied rates of development, most youth of middle school age vacillate between concrete and abstract thinking." This extends to early high schoolers as well, particularly those who struggle with higher level math. As students continue to build confidence in their abstract thinking skills, it is imperative that they are provided adequate scaffolding in the classroom, even as they advance throughout high school. Arts-infused learning is thus proposed as a solution to this obstacle, offering a more accessible point of entry for math students. "By providing early adolescents with an opportunity to understand challenging concepts through methods that mesh with their varying levels of physical, psychosocial, and cognitive development… teachers can advance student achievement and self-efficacy."[72] Taking the developmental stages of student learning into account is essential when designing curriculum. When considering the development of abstract thinking in adolescents, arts-infused learning addresses the transitional phase that students must navigate between concrete and abstract thinking.

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[71] Lorimer, Maureen R. *Arts-Infused Learning in Middle Level Classrooms.* UC Irvine Journal for Learning Through the Arts, 2011. https://escholarship.org/uc/item/0hp6g86s

[72] Lorimer, Maureen R. *Arts-Infused Learning in Middle Level Classrooms.* UC Irvine Journal for Learning Through the Arts, 2011. https://escholarship.org/uc/item/0hp6g86s

These needs are further corroborated by educational psychologists. Author Arthur Efland discusses these needs in his article "The Arts and the Creation of Mind: Eisner's Contributions to the Arts in Education." As Efland explains, educational psychology in the early twentieth century was dominated by behaviorism, which led to the arbitrary separation of mathematics and the arts. Due to flawed categorical systems put in place by the behaviorists, educational psychologists must now advocate for the reintegration of art and mathematics, attesting to its value in adolescent development.

Behaviorism was based upon the empirical study of learning and human behavior, eliminating schools of thought such as mind and imagination which eluded objective measurement, as they were deemed "outside the legitimate bounds of science."[73] This demonstrated a number of holes in the reasoning of the behaviorists, who were unable to account for certain categories of thought which could not be measured by stimulus and response:

> Though behaviorists never denied the existence of higher order thinking that is, abstract, sense-free thinking as found in pure mathematics, they were unable to explain how these human capacities emerge through the accumulation of such rudimentary stimulus-response events. Nevertheless, they recognized that humans do have a capacity for thinking that relies heavily upon symbols like words, numbers, and the like. Moreover, certain subjects that require reason and logic, like math and theoretical physics, would be inconceivable without such symbols and the rules by which these are manipulated. By contrast it was assumed that the arts, which relied on sensory images, either did not employ this type of propositional thought, or did so to a far lesser degree.[74]

Following this line of logic, behaviorists ultimately separated educational objectives into three categories: cognitive, affective, and psychomotor. These categories represented skills relating to

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[73] Efland, Arthur. "The Arts and the Creation of Mind: Eisner's Contributions to the Arts in Education." Journal of Aesthetic Education 38, no. 4 (2004): 71–80. https://doi.org/10.2307/3527377.
[74] Efland, Arthur. "The Arts and the Creation of Mind: Eisner's Contributions to the Arts in Education." Journal of Aesthetic Education 38, no. 4 (2004): 71–80. https://doi.org/10.2307/3527377.

abstraction, expression, and movement/action respectively. And while this taxonomy was not harmful in its own regard, it ultimately led to the segregation of mathematical and perceptual thinking in curriculum structures. Efland articulates this separation of learning as follows:

> In their attempt to clarify the nature of educational objectives, [they] had, perhaps unwittingly, given rise to the development of curriculum structures that reified these divisions into structures of consciousness… If cognition involves the use of verbal and mathematical symbols to construct rational or formal propositions, then thought relying on perceptual imagery is taken to be non-propositional and hence non-cognitive.[75]

This arbitrary separation of "thinking" and "perceiving" encouraged educational psychologists to classify mathematics and the arts as two distinct categories of thought. Schools eventually emulated this structure, and adhered to a curricular model in which these two disciplines should be taught, and learned, separately.

Over time, behaviorism saw a decline in popularity as educational psychologists began to evolve their metrics for student learning. However, these curricular structures remain pervasive in schools across the US. Nonetheless, educational psychology saw a gradual move towards cognitivism, which made attempts to rectify some of the issues brought on by behaviorism. Notably, psychologists began to expand their criteria for what types of activities constitute "cognitive behavior." Many pointed out, for example, that the process of creating, analyzing, and evaluating works of art is a complex cognitive process, and should be acknowledged as such. While the experience of viewing art is certainly influenced in part by perception, learning about art in an academic setting aligns far more closely with math and the sciences than one might think. When students evaluate a work of art, they first collect evidence through formal analysis,

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[75] Efland, Arthur. "The Arts and the Creation of Mind: Eisner's Contributions to the Arts in Education." Journal of Aesthetic Education 38, no. 4 (2004): 71–80. https://doi.org/10.2307/3527377.

before synthesizing that evidence in support of an overall conclusion regarding the function of the artwork. This procedure closely parallels that of a scientist, whose practices of observation and hypothesis involve both perceptual and analytical processes. With this in mind, cognitivism slowly advanced scholarly understanding of arts education, and made strides towards reuniting our ideas of cognition and perception.

In more recent history, educational psychologists such as Jean Piaget and Howard Gardner emerged. Jean Piaget famously proposed his four Stages of Cognitive Development, while Howard Gardner is most well known for his Multiple Intelligences Theory. Both men played a large part in establishing the role of the arts in developing other facets of learning.

Piaget's Stages of Cognitive Development, according to Efland, "offered a plausible explanation of the development of higher-order thinking." Each stage addresses a different phase of childhood learning, and explains how children explore their environments. As babies grow out of infancy, they can only perceive that which they can touch and feel. However, as they grow older and become more familiar with their surroundings, children may begin to understand more nuanced categories of thought. They develop the ability to understand categories, numbers, and perspectives outside of their own (for example, older children can understand how their own words might hurt another's feelings- this is not something that we can see or touch, but is a fact which we accept to be true). As the brain develops, it works gradually towards higher levels of abstraction as the child approaches adolescence. Piaget claims that from the age of eleven and onwards, the human mind remains in the Formal Operational Stage, in which it develops the ability to form abstract and hypothetical thoughts. In accordance with Piaget's research, this establishes adolescence as the critical age when students may begin to transition from concrete into more abstract learning.

Howard Gardner expanded upon the psychology of learning in 1983 when he introduced his Multiple Intelligences Theory. His theory contributed to the push for arts integration because rather than defining learning on a single continuum, Gardner identified seven distinct “cognitive forms”: linguistic, musical, logical mathematical, spatial, bodily-kinesthetic, intrapersonal, and interpersonal. By broadening the definition of cognition, Gardner challenged the exclusion of arts proficiency from its previously established parameters. He also explicitly acknowledged the exclusion of the arts from core public school curriculum due to its classification as a “non-cognitive” discipline; “Recognizing that schools favor the cultivation of logical-mathematical and linguistic competence at the expense of other intelligences, Gardner has steadfastly advocated that schools dedicate more time to those intelligences typically neglected in public schools, including the arts.”[76] As Gardner continued to develop and advocate for his theories, he ultimately claimed that in order to adequately educate all students, we must cater in equal parts to all forms of student intelligence.

Overall, the development of education research has slowly made attempts to restore the integration of STEM and the arts; however, policymakers continue to face obstacles due to the stubborn nature of public school curriculum. It is therefore my aim to provide realistic methods for teachers to integrate into high school-level mathematics. These methods and resources will not fundamentally alter the curriculum itself, which is a pitfall of many curriculum reforms. Public schools do not have the same liberties as private and charter schools due to their

[76] Efland, Arthur. “The Arts and the Creation of Mind: Eisner’s Contributions to the Arts in Education.” Journal of Aesthetic Education 38, no. 4 (2004): 71–80. https://doi.org/10.2307/3527377.

adherence to federally regulated policies, as well as individual state and district standards. Consequently, it is more common to see progressive curriculum reform implemented in private, charter, and other alternative schooling systems, leaving public schools to continue stagnating. Public schools are also plagued by funding constraints, further attesting to the need for free, accessible curriculum support.

With these needs in mind, I propose my solution as one which will resolve the aforementioned obstacles to student learning, without the need for sweeping reforms. By inverting the structure of math lessons and infusing art historical content, math teachers can still fulfill the requirements of their curriculum and allow their students to excel in math-based content. I do not propose to change the national standards, or to eradicate the current teaching model for mathematics. Rather, I propose to improve the scaffolding which we provide for our students when a new concept is introduced, and be more mindful of how this scaffolding functions. Teachers do not need to make any alterations to their classroom or request additional funding; they may simply equip themselves with the necessary resources to transform the ways in which they navigate course material. These resources are free and accessible, and support student comprehension through the use of arts-infused learning.

Chapter 4: Integration in Action: Lesson Plan Support

Deconstructing the Art Historical Math Lesson

In the following chapter I will provide three sample lesson plans from which educators may borrow or draw inspiration. These lessons will adhere to the conventional 45 minute class period, and will showcase the intended transition from concrete to abstract thinking. Each lesson will begin with a conceptual introduction to the target skill; each targeted skill in mathematics will be introduced conceptually via a brief art historical narrative. After a short period of verbal instruction from the teacher, students will be prompted to consider how this narrative might pertain to the target skill. After students are given the opportunity to brainstorm and discuss, the teacher will begin to expand upon the initial narrative. By pausing for student participation, the teacher facilitates direct engagement and connection with art historical material, rather than allowing students to listen passively while content is delivered to them. Students are thus encouraged to learn actively: they must build upon a given concrete example, and establish connective tissue between real-world examples and abstract mathematical concepts. These narrative introductions also function as a sort of mnemonic device, so that students have a distinct visual to call back to when they employ the target skill in future courses. In this model, art historical narratives function two-fold: they establish a concrete foundation upon which abstract concepts are built, thus allowing for a more accessible point of entry, and they provide visual (imagery of art historical artifact) and auditory (accompanying narrative) mnemonics for students to use moving forward.

After students have begun to interface with the material, the teacher may gradually progress towards higher order thinking skills. Through the incorporation of various class activities, students may also be asked to consider the most important variables in a given scenario. What measurements, for example, might an architect have taken in order to construct a particular monument? Which of those measurements were the most important? Considering these questions allows teachers to substantiate mathematical formulas, and introduce overarching ideas in the form of tangible objects before converting them into variables. In accordance with Piaget's Stages of Cognitive Development, this model fortifies abstract thinking in adolescents. Despite the Formal Operative Stage beginning at age 11, not all high schoolers are confident in this area of learning. The Formal Operative Stage extends into adulthood, and allots for varying rates of development. As a result, many students continue to flex this muscle well into high school. It is therefore important to provide adequate support in the classroom, particularly when it comes to conceptual abstraction. Incorporating discussion activities such as the one mentioned above builds scaffolding for students, and supports those who may need grounding in concrete learning.

Conceptual discussions also increase levels of student independence in order to imbue long-term mathematical confidence. In this model, target skills are introduced as questions. Rather than opening the lesson with a pre-existing law, rule, or formula, the teacher instead poses a scenario to the class. This scenario may be in need of a solution, or it may simply call for an explanation. In either case, the students are tasked with the role of playing detective (or art historian in this case). As students work towards their own conclusions, they are rewarded when the teacher confirms their hypotheses, even if only in part. And even when they do not reach the "correct" conclusion, they still engage in a critical analysis of real-world mathematics. They've considered the scenario and each of its constituent parts (each individual variable), and how these parts operate together as a whole (the synthesis of variables in a formula), which will equip them with a stronger understanding of the target skill later on. This structure facilitates a classroom model in which math is treated like a puzzle.

In sum, when students feel as though they have cracked the code before the target skill is formally introduced, they feel a sense of accomplishment. And when teachers allow their students to play an active role in "solving" this puzzle, they leave class that day with a sense of accomplishment and independence. Moreover, they will enter class the following day with a stronger conceptual grasp on the content, and higher levels of confidence.

Furthermore, the implementation of this "puzzle" model actually mimics the historical events represented in the introductory narrative. Since art history aims to uncover the origins of mathematical principles, students are also given the opportunity to connect with their history as they replicate these same analytical processes. This builds connective tissue across interdisciplinary boundaries, and reinforces the practical use of abstract concepts.

This class structure also caters to multiple forms of Gardner's Intelligences. Art historical content broadly encompasses many of Gardner's Multiple Intelligences, and provides different access points to understanding. Whether a student benefits from the linguistic aspect of story-telling, or the spatial aspect of working with architecture and artifacts, art historical content is largely interdisciplinary. Especially for students who do not feel confident in their logical-mathematical skills, this is critical for ensuring accessible comprehension. As mentioned previously, it is no secret that students develop at different rates, and need varying levels of support in different circumstances. So even if a student *is* confident in their logical-mathematical intelligence, they may very well still get stumped by a challenging lesson. Learning is not static nor linear, so it's important to provide a curricular model that allows teachers to "meet students where they're at."

After establishing a conceptual foundation in the first portion of the class, the teacher will then tie the art historical content to the target skill in mathematics. In this portion of the lesson, the teacher will introduce any necessary tools or new vocabulary, such as formulas, laws, or theorems. By dedicating time towards building up confidence and comprehension, students will now be better equipped to receive new content. They've already developed a thorough understanding of the mathematical principle itself, all they need now is to learn how those ideas translate into a universal mathematical language, or a consistent formula. Ultimately, this accomplishes a successful inversion of the conventional math lesson model, in which all subsequent course material supplements a principle or formula introduced at the beginning of the class. In my proposed framework, the formula functions as the final piece of the puzzle. The entire class period leads up to the abstract representation of the target skill, so that the formula simply becomes a culmination of the rest of the lesson. As a result, the "real-world example" acts as the foundation of the class, rather than as an addendum to the target skill. I believe that by applying these pedagogical methods, teachers can help their students strengthen learning retention, and build confidence in mathematics over time. It is my hope that by providing the following examples, I can demonstrate the successful integration of math and art history, and give educators free, accessible resources to diversify their own curriculum.

Sample Lesson I

Subject: Geometry
Duration of Class Period: 45 min
Objective: Students will be able to apply dilations in real-world scenarios, and identify similarity among dilated figures.
Assessment/Proving Behavior: By the end of class, students will restate the definition of dilation in their own words, supported by a diagram showcasing an example.
NCTM Standard: Use various representations to help understand the effects of simple transformations and their compositions.[77]

Time	Activity	Procedure & Script
10 min	Do Now: Think Pair Share	[Displayed on the board: image of *The Vitruvian Man* by Leonardo Da Vinci] Do Now Instructions: As you come into class and observe the following image, consider how it may have been produced. How/by what process might the artist have drawn this figure? Why do you think the artist drew this image in the first place? Please jot down your thoughts. After you've brainstormed a few ideas, share with the person sitting next to you. Each pair will be asked to share with the class, so pick one partner who would like to be the announcer. [Allow each student pair to share their answers with the class, allowing additional time for follow-up questions or new ideas] Student responses may include any of the following: - The artist drew the figure from observation - The artist took the man's body measurements in order to copy them into his drawing - He might have made this drawing to help other artists - Maybe the drawing is part of a textbook

[77] "Geometry." *National Council of Teachers of Mathematics.* https://www.nctm.org/Standards-and-Positions/Principles-and-Standards/Geometry/.

5 min	Verbal Instruction: Narrative	This drawing is most commonly known as *The Vitruvian Man*, or *The proportions of the human body according to Vitruvius.* It was drawn by the Italian Renaissance artist Leonardo da Vinci, who some of us might recognize as the painter of *The Mona Lisa*. DaVinci is an especially notable historical figure because in addition to his expertise in the visual arts, he was also highly skilled in mathematics. In this drawing, he used both of these skill sets to represent the "perfect" geometric proportions of the body.
5 min	Discussion Question: Critical Analysis	Now that we know a little bit more about this work of art, we can reconsider some of the Do Now questions. For example, knowing why this piece was created in the first place (for the purposes of recording and replicating anatomical proportions), we can assume that the drawing was likely created using observational studies. As some of you have pointed out in our Do Now discussion, Da Vinci probably had to use a real person as reference for his drawing so that he could accurately represent the human form. However, the drawing itself is only about 13.5 in × 9.6 in- slightly larger than your standard printer paper. Even though DaVinci measured and recorded the proportions of the body, the drawing is not life size. How do you think he may have achieved this? [Call on at least three student volunteers] Student responses may include any of the following: - He scaled the measurements down - He divided each measurement by the same number - He may have stood further away from his reference so it appeared smaller from his perspective
10 min	Verbal Instruction: Target Skill	As you've all observed, Da Vinci must have scaled down his reference in order to maintain the correct proportions and achieve them on paper, or else he would've had to use a six foot tall piece of paper, which was likely not available to him at the time. This process, in geometric terms, is called dilation. Dilation occurs when we enlarge or reduce a shape/figure by a **scale factor.** We've already seen this process take place through Da Vinci's creation of *The Vitruvian Man*, all we have to do now is assign the correct

		vocabulary to each part of the process. Now, using what we've spoken about so far in class, can anyone take a guess as to what a scale factor is? [Allow for students to raise their hands and make predictions] The scale factor is the ratio of the corresponding lengths in two similar figures- in other words, the scale factor is simply the number by which we multiply each measurement in order to get our new figure. Let's say, for the sake of argument, that our Vitruvian Man is six feet tall in real life. Now let's say that in Da Vinci's drawing, he is one foot tall on the piece of paper. What number must I multiply the Vitruvian Man's height by in order to get his height in the drawing? [Allow for students to calculate and raise their hands] 1/6 is our multiplier, therefore it will be our scale factor. It is important to note that since we are *reducing* the measurements of the Vitruvian Man (the output is smaller than the input), our scale factor will be a fraction. If we were to reverse this process and enlarge the figure, then the scale factor would be 6 rather than 1/6. As a general rule, all reduced dilations will have a scale factor smaller than 1, whereas all enlarged dilations will have a scale factor greater than 1.
10 min	Structured Practice	We've now worked through the process of dilation in real life, and introduced some new vocabulary that we'll be using in future classes. We've observed dilations through the work of Da Vinci, and calculated scale factors together as a class. So now that we're a little more familiar with dilation, we're going to try to translate these processes into a more mathematical language so that we can use them in other scenarios as well. If you had to write a formula or equation to solve for a dilated measurement, what would it look like? What variables might this formula include? Thinking back on our calculations for *The Vitruvian Man*, please write out your own dilation formula, being sure to label any unknown variables.

		Sample response: O x SF = N O = original measurement SF = scale factor N = new measurement After completing the activity, consider: Are there any other scenarios in which dilations might be useful? What types of professions might employ these methods? Student responses may include any of the following: - Scientists use dilations to enlarge images of bacteria and other microorganisms - Architects use dilations to create blueprints and floor plans to scale with the actual building - Tools like telescopes and magnifying glasses use dilation to allow small objects to be visible to the human eye - Cartographers use dilations to make maps - Astronomers use dilations to make 3D scale models of the solar system
5 min	Exit Ticket: Comprehension Check	Before you leave class today, please complete the following two tasks on your exit ticket. First, rewrite the definition of a dilation in your own words. Then, next to your written definition, draw one example of a dilation that you might see in the world around you.

Sample Lesson II

Subject: Trigonometry
Duration of Class Period: 45 min
Objective: Students will be able to analyze architectural problems, and propose solutions using the properties of right triangles.
Assessment/Proving Behavior: By the end of class, students will solve for an unknown variable in a tangent equation, and reflect on the practical use of trigonometry.
NCTM Standard: Use trigonometric relationships to determine lengths and angle measures.[78]

Time	Activity	Procedure & Script
5 min	Do Now: Brainstorm	[Challenge is posted on the board as students enter class] Consider the following challenge: You are tasked with measuring the tallest building in the world. How do you do it? Get creative! Brainstorm at least one idea, and write it down. Students will be given the opportunity to share with the class afterwards. [Call on at least four student volunteers] Student responses may include any of the following: - I would tie ropes/strings together, hang them from the top of the building to the bottom, and then measure the rope - I would measure the height of one brick/part of the building, and then count how many there are in total - I would use a really long measuring tape - I would fly to the top in a helicopter and then calculate the altitude using the helicopter
5 min	Follow-Up Question	Why might these methods be challenging? [Call on at least three student volunteers]

78 "Geometry." *National Council of Teachers of Mathematics.* https://www.nctm.org/Standards-and-Positions/Principles-and-Standards/Geometry/.

		Student responses may include any of the following: - There may not be any way to access the top of the building to hang a string from - It would be incredibly difficult to keep track of bricks or panels on such a tall building, and how would you get up the side of the building from the outside to count them all? You might lose track from the ground, or you might not be able to see all the way up to the top. - Measuring tapes typically max out at around 50 feet - Most people do not own a helicopter
5 min	Verbal Instruction: Narrative	[Displayed on the board: image of the exterior of *The Pantheon*] Now consider the Pantheon, which was constructed under the reign of Hadrian in the 2nd century CE in Rome. The architectural accomplishments of the Pantheon represented a culmination of Roman design principles. The peak of the dome towered approximately 142 ft tall (43.3 m); this measurement is precisely equivalent to the diameter of the rotunda, thereby creating a perfect semispherical dome. This “geometric perfection” was intended to honor the Gods and their creation of the perfect universe (pan = all, theo/theon = gods). However, the architects of the Pantheon likely did not have access to helicopters at the time of the building’s construction (which would’ve made the process of building it much easier). Instead, these architects likely had to use their pre-existing knowledge of mathematics to find ways around taking these measurements directly, while still achieving the geometric accuracy needed to honor the Gods (and preferably without having to stand on top of the Pantheon- a bit of a safety hazard, as one can imagine).
5 min	Discussion Question: Critical Analysis	[Displayed on the board: image of the interior/floor plan of *The Pantheon*] Before we jump into the ways that architects could’ve calculated for this height, let’s first think about the information available to us. Put yourself in the place of the architect. From ground level, what measurements can you take inside the Pantheon? Remember

		that since the shape of the rotunda is a semisphere, the floor plan will be circular. [Call on student volunteers, writing answers on the board] Student responses may include any of the following: - The diameter of the room (142 ft) - The radius into the center of the room (71 ft, or half the diameter) - The area of the floor - The angle from the edge of the floor to the top of the dome Now, knowing the measurements that we can take from the ground of the Pantheon, can you think of any shapes we might be able to create by synthesizing these measurements? As you are looking at the image on the board, imagine that you can superimpose a shape on top using the measurements we've taken. Since we ultimately want to calculate for the height of the dome, be sure that your shape accounts for that measurement. [Guide students as necessary as they propose ideas, perhaps ask leading follow-up questions if they struggle to come up with "right triangle"]
10 min	Verbal Instruction: Target Skill	[Displayed on the board: right triangle superimposed over the image of the interior/floor plan of *The Pantheon*] As you've all observed, we can actually create a right triangle within the interior of the Pantheon using the radius and the height as the two legs of the triangle. Since the upper leg extends from the centerpoint of the circular floor up to the central point of the spherical dome (the highest point), this will create a 90 degree angle respective to the floor. Now that we know we are working with a right triangle, we can use something called **Trigonometric Ratios**, which demonstrate the relationships between side lengths and angles in right triangles. The three primary trigonometric ratios are Sine, Cosine, and Tangent. For our purposes today, we will only be discussing Tangent. The tangent of a given angle will

		always be equal to the side length opposite the angle, divided by the side length adjacent (next to) to the angle. This is represented by the following equation: Tanθ = opposite/adjacent Now, if we look at our superimposed right triangle, which of the three angles is located opposite the height, and next to the radius? [Allow for students to raise their hand and identify the correct angle] Correct- if we evaluate this angle in relation to the rest of the triangle, we can see that its opposite side length is the height of the dome, while its adjacent side length is the radius of the floor plan, so it fits the criteria of our equation. Now, as architects, we can measure the angle from the edge of the floor up to the peak of the dome. This measurement will be approximately 63.43º. Additionally, we know that the radius will be 71 ft, because it will be half of the diameter which has already been given to us. Now we have all of our puzzle pieces in order to find a solution.
10 min	Structured Practice	Now that we've identified the relevant information for our formula, can anyone come up to the board and fill out the formula with the appropriate variables? We've compiled all of our puzzle pieces, now all we need to do is put them in the right spots. [Allow student volunteer to rewrite new formula below the original, replacing each variable with the appropriate value] Tan63.43º = height/71 What we have now is completely solvable!- all we're left with is an algebraic equation with a singular unknown variable. Luckily for us, trigonometric functions like tangent can just be plugged into a calculator with the given angle measurement, and the calculator will give us an approximated decimal value. What value do you see on your calculator after you press the "tan" button and

		enter 63.43? [Students should get approximately 1.9996. Check to make sure students' calculators are in degree mode, not radian] If we round this value up to 2, this is what our equation will look like: 2 = height/71 After this step is done, the formula becomes a standard, one-step equation which can be solved with algebra. Who can call out our final answer? [Students should get 143 ft as their final answer] Correct! We can now confirm with mathematical certainty that the height of the Pantheon's dome will be equivalent to its diameter, thus creating the perfect semisphere and pleasing the Gods (without having to climb on top of the Pantheon, purchase a 143-foot long measuring tape, or invent the helicopter 1900 years early).
5 min	Exit Ticket: Conceptual Reflection	Before you leave class today, please write your thoughts on the following prompt: Reflecting on our activity today, do you think you would change your answer from the Do Now? Why or why not? How do you think right triangles can be a tool for measurement?

Sample Lesson III

Subject: Algebra
Duration of Class Period: 45 min
Objective: Students will be able to understand how surface area can be calculated using two-dimensional area formulas, and apply these principles to the Pyramid of Khufu at Giza.
Assessment/Proving Behavior: By the end of class, students will solve for the amount of limestone needed to face the exterior of the Pyramid of Khufu using surface area formulas.
NCTM Standard: Understand and use formulas for the area, surface area, and volume of geometric figures, including cones, spheres, and cylinders.[79]

Time	Activity	Procedure & Script
5 min	Do Now: Think Pair Share	[Displayed on the board: image of *The Pyramid of Khufu*] The Pyramid of Khufu is the largest of the three Pyramids of Giza, and is among the largest surviving Ancient Egyptian monuments. As you observe this image, how might you describe the structure of this monument? Think in geometric terms. (Hint: What two-dimensional shapes comprise a pyramid?) Please jot down your thoughts, and then share and compare with your neighbor. How were your answers similar and/or different? Student responses may include any of the following: - Four triangles, one on each side - A square base - A rectangular base - Flat on the bottom and pointed at the top
5 min	Follow-Up Question	Why might contemporaries have needed to know what shapes make up the Pyramids of Giza? Think about the architectural processes involved in constructing these monuments, and why this information might have been important.

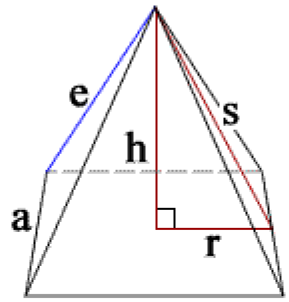
[79] "Algebra." *National Council of Teachers of Mathematics.* https://www.nctm.org/Standards-and-Positions/Principles-and-Standards/Geometry/.

		[Call on at least two student volunteers] Student responses may include any of the following: - It might help architects calculate how much stone was needed to build the pyramids - Maybe surface measurements could help to calculate other measurements like height and volume - It might have helped architects design the blueprint for the building - Architects would know how large the inside would be
5 min	Verbal Instruction: Narrative	While most of it has since been removed, the Pyramid of Khufu was originally encased in a layer of shimmering, polished white limestone.[80] The polished outer facing also would have made it so that the pyramid's exterior was entirely smooth, and would have glistened in the sunlight. This visual effect was symbolically significant to the Ancient Egyptian religion, which relied heavily upon sun imagery and symbolism. Because of its religious importance, architects had white limestone imported from quarries at Tura, which were located approximately 9 miles downriver from Giza.[81] As you can imagine, this was quite the feat. Approximately 5.5 *million* tons of limestone were used in total for constructing the pyramid– this was a highly labor-intensive, and incredibly expensive task. It was important that Egyptians knew *exactly* how much material was needed for the pyramid so that they would not come up short, or waste resources by transporting too much.
5 min	Discussion Question: Critical Analysis	This is where our calculations come into play. In order to calculate how much material was needed to face the exterior of the pyramid with limestone, architects would have needed to know the area of each outer wall of the building.

[80] "Giza 3D." *Digital Giza: The Giza Project at Harvard University.* http://giza.fas.harvard.edu/giza3d/?itemID=bwZfJsv1_.
[81] "Pyramid Casing Stone." *National Museums Scotland.* https://www.nms.ac.uk/explore-our-collections/stories/global-arts-cultures-and-design/ancient-egyptian-and-sudanese-collections/ancient-egyptian-collection/pyramid-casing-stone/.

		Now, let's say the architects had a blueprint of the pyramid for reference. What measurements might they have needed to solve for these areas? Think back on your Do Now responses, and use mathematical language that we've acquired in previous classes– what vocabulary might you use to describe a triangle versus a square? [Call on student volunteers, writing answers on the board] Student responses may include any of the following: - Height of the pyramid - Base of the triangle faces - Hypotenuse of the triangle faces - Length/width of the square base - The areas of the triangular faces - The area of the square base
10 min	Verbal Instruction: Target Skill	As you've all explained already, the **surface area** of a three-dimensional shape can be calculated by adding up the individual areas of each two-dimensional facet that makes up the figure. The definition of the term is **the total area of the surface of a three-dimensional object.** And as we've discussed throughout class today, these are all skills that we've already learned! We're simply taking our knowledge of two-dimensional areas, and applying it in a new scenario. Now, with this in mind, how might you calculate the surface area of the pyramid? What steps might be involved in this process? Write your thoughts down on paper, before sharing and comparing with your tablemates. (Hint: the base of the pyramid is a square) [Call on one to two groups to share their consensus] Student responses should generally encompass the following: - Calculate the two-dimensional area of each face of the pyramid, the four triangular faces plus the square base, and then calculate the sum total of all areas - Calculate the area of one triangular face, multiply the area

		by four, and then add the area of the square base Great! Now that we've thought through the mathematical processes involved in calculating the surface area, let's think about these processes in the context of our problem. We've established that the entire surface area of the pyramid would include each of the four triangular faces of the pyramid, plus the square base. However, we are specifically concerned with the limestone required to face the exterior of the pyramid. How might these calculations differ? [Call on at least two student volunteers] Student responses may include any of the following: - The surface area would cover the entire pyramid structure, whereas the limestone would not have to cover the bottom of the monument - You would not have to account for the square base when calculating the surface area - We would only need to add up the areas of the four triangular faces in order to calculate the amount of limestone needed
10 min	Structured Practice	As you've all observed, the limestone will only have to cover the triangular faces of the pyramid, since the square base will not be visible from the outside. So, for our activity today, I would like you to calculate the *entire* surface area of the pyramid, and then calculate the amount of limestone needed to encase the exterior of the building. Please work independently, and feel free to reference previous class notes if you forget any of the area formulas.

		 a = 756’ h = 481’ e = 719’ Students should solve as follows: Using the Pythagorean Theorem, students can solve for s using measurements h and r. r will be 378’ because it is half of a. $h^2 + r^2 = s^2$ $481^2 + 378^2 = s^2$ $374{,}245 = s^2$ $612 = s$ Square Area = a^2 $756^2 = 571{,}536$ Triangle Area = ½ • sa ½ • 612 • 756 = 231,336 Total Surface Area = 4 (231,336) + 571,536 Total Surface Area = 1,496,880’ Limestone Area = 4 (231,336) Limestone Area = 925,344’
5 min	Exit Ticket: Conceptual Reflection	After you’ve calculated for both answers, please reflect on the following questions in your exit ticket:

		Looking at the total surface area and the quantity of limestone needed for the pyramid's exterior walls, are your answers the same? Is one quantity bigger than the other? Why do you think this is the case?

Chapter 5: Conclusion

Summary of Claims

The integration of art history in mathematics provides innumerable benefits to the teaching of math concepts. An art historical learning model would support a variety of learners, both through the provision of concrete real-world examples, and through the use of multiple intelligences. Varied rates of development in adolescents mean that not all high school students possess the same level of confidence in their abstract thinking skills. As students continue to develop different skill sets throughout high school, it is vital to establish support structures in the classroom so as to facilitate this development. Art history serves to act as this support structure. Furthermore, art historical artifacts and narratives may serve as a mnemonic device associated with specific mathematical concepts, which provides yet another element of scaffolding in the classroom.

In addition to aiding in the development of abstract thinking, art history also attends to a diverse array of intellectual strengths. Not all students enter the classroom equipped with the same levels of quantitative literacy, and it is important to cater to students at all levels of math comprehension. It goes without saying that math teachers are tasked with educating *all* students, not only those who are at a predisposition to doing well. By developing an interdisciplinary, multimodal lesson with which to introduce math concepts, teachers can expand accessibility to student comprehension. In accordance with Gardner's theories, this can be accomplished through the use of art historical narrative. By addressing mathematics in the context of human history and cultural production, these narratives can cater to a variety of different student intelligences. As a result, lessons can provide more points of entry for students depending on their strong suits and levels of comfort.

This proposed curricular model not only provides the pedagogical benefits explained above, but also provides realistic solutions for public school teachers. By implementing an art history-based reform, teachers may expand and diversify their curriculum in order to meet student needs, without the need for infrastructural change across the US education system. Integration of content and pedagogy is free, with relatively low barriers to access. Teachers do not need extensive knowledge in Curriculum Design or Education Policy in order to implement these methods. All a teacher needs to achieve this integration is a point of reference provided by the sample lessons in Chapter 4, and some Art History 101 knowledge, which is readily available across the internet.

Furthermore, this proposal is relatively non-invasive. It adheres to Common Core Standards, and does not demand any additional tools or resources in the classroom that may conflict with public school policies/funding restrictions. Unlike many other propositions for curriculum reform, which are often unrealistic (albeit optimistic), this model does not require a complete renovation of the US public school curriculum. Flipping the lesson plan structure does not actually impact the learning objectives that students achieve– just the order in which they work towards those objectives.

Lastly, art history helps students to understand the real-world implications and origins of mathematical principles. Art history provides tangible artifacts and monuments as a physical manifestation of the concepts learned in class. And while we may not use certain mathematical processes as actively as we did in the past, it sheds light on the historical processes which led us to the society we live in today, in which many of these processes have become automated due to the progression of modern technology. By learning about the history of human development, students can relate different narratives to their own lives and communities. It encourages students to reflect on history more thoughtfully, and consider how math affects different aspects of society, even when they are not explicitly “math-related.”

Future Inquiries

As research continues to develop on this topic, it is my hope that STEAM education continues to expand outwards. Our world is fundamentally interconnected across disciplines, and I do not believe these connections are adequately represented in secondary education. One facet of this disconnect takes place somewhere in the transition from middle school to high school. Throughout elementary and intermediate school, teachers receive multi-subject credentials so that they can teach their students’ “core” subjects– science, mathematics, language arts, and social studies. As a result of this credentialing system, teachers must have sufficient knowledge in a variety of different subject areas. This allows teachers to address common threads across disciplines, and foster a more well-rounded education for their students.

However, secondary teachers must obtain a single-subject credential, in which they are granted qualification to teach courses in their discipline. At this stage, I believe that teachers, and consequently their students, lose some of these important conversations that take place between disciplines. It is my hope that we continue to challenge these boundaries moving forward, and that future inquiries will consider art history in STEAM beyond the scope of mathematics. Art history, in and of itself, is interdisciplinary. It considers the mutual impact which history and the arts have on each other, and takes on the complexities inherent within the arts and humanities. And while this paper primarily deals with the pedagogical relationship between art history and mathematics, there are far more lines of inquiry to pursue within science, technology, and engineering, which ultimately lie beyond the scope of this paper.

Additionally, educators may continue to explore the potential for art history-based mathematics as they expand upon the provided sample lesson plans. This paper offers three fully articulated lessons. There are, of course, countless others to be developed going forward. Listed below are some samples for inquiry, which encapsulate a broader variety of artists and mathematics content.

Art & Additional Resources	**NCTM Standard**
Judith Beheading Holofernes in Florence by Artemisia Gentileschi[82][83]	Algebra - Identify essential quantitative relationships in a situation and determine the class or classes of functions that might model the relationships.
Little Sister by Agnes Martin[84]	Number and Operations - Develop an understanding of properties of, and representations for, the addition and multiplication of vectors and matrices.
Artist's Gridded Sketch of Senenmut at the	Measurement - Use unit analysis to check

[82] Heardman, Adam. "Head of the Curve: Judith and Holofernes Through History." *Mutual Art.* February 1, 2022. https://www.mutualart.com/Article/Head-of-the-Curve--Judith-and-Holofernes/B50D8B4E2644B184.

[83] "Art and Science: Galilean Influences in Artemisia's 'Judith Beheading Holofernes." *Artlark.* February 15, 2022. https://artlark.org/2022/02/15/art-and-science-galilean-influences-in-artemisias-judith-beheading-holofernes/. Artemisia Gentileschi was a contemporary of Galileo Galilei, and the two were also close colleagues. As a result of their long-term friendship, Artemisia Gentileschi was immensely knowledgeable about science and mathematics. She exemplifies Galileo's (unpublished at the time) projectile law of motion in her painting *Judith Beheading Holofernes*, in which the streams of blood create a mathematically accurate parabola. This painting is a testament to Gentileschi's artistic prowess, as well as her scholarly intellect.

[84] "Materials and Process." Guggenheim. https://www.guggenheim.org/teaching-materials/agnes-martin/materials-and-process.

Metropolitan Museum of Art[85]	measurement computations.
Mihrab from Isfahan at the Metropolitan Museum of Art[86][87]	Measurement - Make decisions about units and scales that are appropriate for problem situations involving measurement.
The Rhind Papyrus at the British Museum[88][89]	Geometry - Establish the validity of geometric conjectures using deduction, prove theorems, and critique arguments made by others.
Proun Space by El Lissitzky[90][91]	Geometry - Explore relationships (including congruence and similarity) among classes of two- and three-dimensional geometric objects, make and test conjectures about them, and solve problems involving them.

In consideration of these ideas, I would also like to direct teachers towards other educational institutions such as museums. Museum education deals specifically with historically

[85] "Artist's Gridded Sketch of Senenmut." Metropolitan Museum of Art. https://www.metmuseum.org/art/collection/search/547684?deptids=10&when=2000-1000+B.C.&high=on&ft=*&offset=40&rpp=40&pos=50. This sketch exemplifies the Egyptian square canon of proportions. Other works such as sculptures and relief carvings may be used in conjunction with this piece, and should allow students to compare and contrast how this canon shows up throughout different media. This lesson may facilitate a classroom discussion surrounding the use of geometric shapes in art. Students may also discuss the symbolic significance of geometric proportions in Egyptian art, as well as the practical implications of taking measurements, sculpting, etc.

[86] "Unit 3: Geometric Design in Islamic Art." Metropolitan Museum of Art. https://www.metmuseum.org/learn/educators/curriculum-resources/art-of-the-islamic-world/unit-three. After completing this unit, students will be able to "understand the role of geometric design in the art of the Islamic world, and recognize ways in which featured works of art exhibit repetition, symmetry, two-dimensionality, and an illusion of infinity." The unit emphasizes the symbolic significance of geometric principles, and considers how these principles have facilitated worship in Islamic devotional spaces.

[87] "Islamic Art and Geometric Design: Activities for Learning." Metropolitan Museum of Art. https://www.metmuseum.org/-/media/files/learn/for-educators/publications-for-educators/islamic_art_and_geometric_design.pdf.

[88] Smith, David Eugene. "Historical Survey of the Attempts at the Computation and Construction of π." *The American Mathematical Monthly* 2, no. 12 (1895): 348–51. https://doi.org/10.2307/2970432.

[89] Howard, Christopher A. "Mathematics Problems from Ancient Egyptian Papyri." *The Mathematics Teacher* 103, no. 5 (2009): 332–39. http://www.jstor.org/stable/20876630.

[90] Corrada, Manuel. "On Some Vistas Disclosed by Mathematics to the Russian Avant-Garde: Geometry, El Lissitzky and Gabo." *Leonardo* 25, no. 3/4 (1992): 377–84. https://doi.org/10.2307/1575865.

[91] Levinger, Esther. "Art and Mathematics in the Thought of El Lissitzky: His Relationship to Suprematism and Constructivism." *Leonardo*, Volume 22, Number 2, April 1989, pp. 227-236.

informed learning models, so they are a terrific resource for high school teachers seeking to create a more interdisciplinary classroom. The Guggenheim, for example, provides a variety of educational activities that teachers can implement into their lessons. They dedicate an entire page of their website to teaching materials for educators, in which they provide stand-alone activities and prompts, as well as fully fleshed out lesson plans.[92] One such lesson revolves around Agnes Martin's piece *Little Sister.* The lesson, entitled "Materials and Process," provides one image, one "view and discuss" prompt, and three other classroom activities. Among these activities are mathematical instructions for students to create their own artworks based on Martin's, as well as group discussion questions.

The J. Paul Getty Museum[93] has a similar archive of teaching resources, as well as the Brooklyn Museum[94] and the Metropolitan Museum of Art.[95] All of the aforementioned collections have resources which are specifically targeted toward secondary school teachers, many of which also emphasize interdisciplinary relationships in the classroom. The Met, for example, offers two distinct curricula connecting mathematical principles with Islamic art. These resources can be immensely useful to teachers, especially those who do not have a background in the arts and humanities. Elaborating upon many of the themes addressed throughout this paper, museum education allows teachers to integrate art historical content into their classrooms, while still focusing on their own learning objectives.

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92 "Teaching Materials." *For Educators,* Guggenheim. https://www.guggenheim.org/teaching-materials.
93 "Resources for Teaching." J. Paul Getty Museum. https://www.getty.edu/education/teachers/classroom_resources/index.html.
94 "K-12 Online Learning Resources." Brooklyn Museum. https://www.brooklynmuseum.org/education/k_12/teacher_resources.
95 "Curriculum Resources." Metropolitan Museum of Art. https://www.metmuseum.org/learn/educators/curriculum-resources.

Concluding Statements

Ultimately, it is my hope that future educators will continue to reevaluate the ways in which they introduce other disciplines into mathematics. This model, among many others, fosters a more comprehensive understanding of the role that mathematics plays in the world. My proposed curriculum reform has built upon many of the ideas established by STEAM and arts-infused learning, and seeks to facilitate a more concrete understanding of mathematics which is rooted in historical course content. These goals are met through an inquiry-based learning process, in which art history acts as the primary point of inquiry. I believe that this model would aid student comprehension by supporting mathematics learning objectives, and providing a more accessible, varied curriculum overall.

Bibliography

"2015 | Survey Questionnaire Results: Students' Views of Mathematics, Reading, and Science." *The Nation's Report Card.* https://www.nationsreportcard.gov/sq_students_views_2015/.

A Nation at Risk: The Imperative for Educational Reform. April 1983. https://www.reaganfoundation.org/media/130020/a-nation-at-risk-report.pdf.

"A Teacher's Guide to Reasoning and Sense Making." *National Council of Teachers of Mathematics.* https://www.nctm.org/uploadedFiles/Standards_and_Positions/Focus_in_High_School_Mathematics/FHSM_TeacherGuide.pdf.

Ades, Dawn, and Matthew Gale. "Dada." Grove Art Online. 2003; Accessed 11 Dec. 2022. https://www.oxfordartonline.com/groveart/view/10.1093/gao/9781884446054.001.0001/oao-9781884446054-e-7000021094.

Altay, Mesture Kayhan and Elif Yetkin Özdemir. "The use of museum resources in mathematics education: a study with preservice middle-school mathematics teachers." *Journal of Education for Teaching*, 2022. DOI: 10.1080/02607476.2022.2150534.

"AP Art History - Course Content." AP Students, College Board. Accessed 11 Dec. 2022. https://apstudents.collegeboard.org/courses/ap-art-history.

"AP Art History Course Exam and Description." AP Students, College Board. Accessed 11 Dec. 2022. https://apcentral.collegeboard.org/media/pdf/ap-art-history-course-and-exam-description.pdf.

Armstrong, Patricia. "Bloom's Taxonomy." Center for Teaching, Vanderbilt University. Accessed 11 Dec. 2022. https://cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy/.

"Art & Art History: Formal Analysis & Comparative Analysis." University Writing Center, The University of Texas at Austin. Accessed 11 Dec. 2022. https://uwc.utexas.edu/wp-content/uploads/Art_ArtHist_Edit2020.docx#:~:text=A%20formal%20analysis%20is% 20quite,meant%20to%20be%20an%20interpretation.

"Art and Science: Galilean Influences in Artemisia's 'Judith Beheading Holofernes." *Artlark*. February 15, 2022. https://artlark.org/2022/02/15/art-and-science-galilean-influences-in-artemisias-judith-be heading-holofernes/.

"Art Scan." Arts Education Partnership. Accessed 11 Dec. 2022. https://www.aep-arts.org/artscan/.

"Artist's Gridded Sketch of Senenmut." Metropolitan Museum of Art. https://www.metmuseum.org/art/collection/search/547684?deptids=10&when=2000-1000+B.C.&high=on&ft=*&offset=40&rpp=40&pos=50.

Bergh, Amy. "To the Ages Of Ages: Reconceptualizing High School Art History Curriculum." Master's thesis, Virginia Commonwealth University, 2011.

Berry, Robert Q., and Matthew R. Larson. "The Need to Catalyze Change in High School Mathematics." The Phi Delta Kappan 100, no. 6 (2019): 39–44. https://www.jstor.org/stable/26614902.

"Bloom's Taxonomy." *Faculty Center.* University of Central Florida. https://fctl.ucf.edu/teaching-resources/course-design/blooms-taxonomy/#:~:text=Bloom's%20taxonomy%20was%20developed%20to,a%20variety%20of%20cognitive%20levels.

Britannica, T. Editors of Encyclopaedia. "Pyramids of Giza." *Encyclopedia Britannica*, March 6, 2023. https://www.britannica.com/topic/Pyramids-of-Giza.

"Common Core State Standards for English Language Arts." Common Core State Standards Initiative, Council of Chief State School Officers. Accessed 11 Dec. 2022. https://learning.ccsso.org/wp-content/uploads/2022/11/ELA_Standards1.pdf.

"Common Core State Standards for Mathematics." Common Core State Standards Initiative, Council of Chief State School Officers. Accessed 30 January 2023. https://learning.ccsso.org/wp-content/uploads/2022/11/ADA-Compliant-Math-Standards.pdf.

Corrada, Manuel. "On Some Vistas Disclosed by Mathematics to the Russian Avant-Garde: Geometry, El Lissitzky and Gabo." *Leonardo* 25, no. 3/4 (1992): 377–84. https://doi.org/10.2307/1575865.

"Curriculum Resources." Metropolitan Museum of Art. https://www.metmuseum.org/learn/educators/curriculum-resources.

Cushman, Kathleen. *Fires in the Bathroom: Advice for Teachers from High School Students.* New York: New Press, 2003.

Daniel Brahier, Steve Leinwand, and DeAnn Huinker. "Principles to Actions: Mathematics

Programs as the Core for Student Learning." The Mathematics Teacher 107, no. 9 (2014): 656–58. https://doi.org/10.5951/mathteacher.107.9.0656.

Day, Michael D. "The Compatibility of Art History and Studio Art Activity in the Junior High School Art Program." Studies in Art Education 10, no. 2 (1969): 57–65. https://doi.org/10.2307/1319613.

Delacruz, Elizabeth Manley, and Phillip C. Dunn. "The Evolution of Discipline-Based Art Education." *Journal of Aesthetic Education* 30, no. 3 (1996): 67–82. https://doi.org/10.2307/3333322.

Dorn, Emma, Bryan Hancock, Jimmy Sarakatsannis, and Ellen Viruleg. "COVID-19 and learning loss—disparities grow and students need help." McKinsey & Company, December 8 (2020): 6-7.

Efland, Arthur. "The Arts and the Creation of Mind: Eisner's Contributions to the Arts in Education." Journal of Aesthetic Education 38, no. 4 (2004): 71–80. https://doi.org/10.2307/3527377.

Epstein, Terrie L. 1994. "The Arts of History: An Analysis of Secondary School Students' Interpretations of the Arts in.." *Journal of Curriculum & Supervision* 9 (2): 174–94. https://search.ebscohost.com/login.aspx?direct=true&db=ehh&AN=9407126284&site=eds-live&scope=site.

"Every Student Succeeds Act (ESSA)." *U.S. Department of Education.* https://www.ed.gov/essa.

"Executive Summary." *Principles and Standards for School Mathematics.* National Council of Teachers of Mathematics. Accessed 12 April 2023.

Fitzpatrick, V.L. *Art history: A contextual inquiry course.* Reston, VA: National Art Education Association. 1992.

"Geometry." *National Council of Teachers of Mathematics.* https://www.nctm.org/Standards-and-Positions/Principles-and-Standards/Geometry/.

"Giza 3D." *Digital Giza: The Giza Project at Harvard University.* http://giza.fas.harvard.edu/giza3d/?itemID=bwZfJsv1_.

Guyotte, Kelly W., Nicki W. Sochacka, Tracie E. Costantino, Jaochim Walther, and Nadia N. Kellam. "STEAM as Social Practice: Cultivating Creativity in Transdisciplinary Spaces." *Art Education* 67, no. 6 (2014): 12–19. http://www.jstor.org/stable/24766127.

Hallinen, J.. "STEM." *Encyclopedia Britannica*, September 13, 2022.

https://www.britannica.com/topic/STEM-education.

Heardman, Adam. “Head of the Curve: Judith and Holofernes Through History.” *Mutual Art.* February 1, 2022. https://www.mutualart.com/Article/Head-of-the-Curve--Judith-and-Holofernes/B50D8B4E2644B184.

“Homepage.” *College Board.* https://www.collegeboard.org/.

Howard, Christopher A. “Mathematics Problems from Ancient Egyptian Papyri.” *The Mathematics Teacher* 103, no. 5 (2009): 332–39. http://www.jstor.org/stable/20876630.

Hunt, T. C.. "National Defense Education Act." *Encyclopedia Britannica*, March 20, 2023. https://www.britannica.com/topic/National-Defense-Education-Act.

Inoa, R., Weltsek, G., & Tabone, C. “A study on the relationship between theater arts and student literacy and mathematics achievement.” *Journal for Learning through the Arts: A Research Journal on Arts Integration in Schools and Communities, 10(1)*, 2014.

“Islamic Art and Geometric Design: Activities for Learning.” Metropolitan Museum of Art. https://www.metmuseum.org/-/media/files/learn/for-educators/publications-for-educators/islamic_art_and_geometric_design.pdf.

“K-12 Online Learning Resources.” Brooklyn Museum. https://www.brooklynmuseum.org/education/k_12/teacher_resources.

Levinger, Esther. “Art and Mathematics in the Thought of El Lissitzky: His Relationship to Suprematism and Constructivism.” *Leonardo*, Volume 22, Number 2, April 1989, pp. 227-236.

Lorimer, Maureen R. *Arts-Infused Learning in Middle Level Classrooms.* UC Irvine Journal for Learning Through the Arts, 2011. https://escholarship.org/uc/item/0hp6g86s.

“Materials and Process.” Guggenheim. https://www.guggenheim.org/teaching-materials/agnes-martin/materials-and-process.

“NAEP Report Card: 2019 NAEP Mathematics Assessment.” *The Nation’s Report Card.* https://www.nationsreportcard.gov/highlights/mathematics/2019/g12/.

“NAEP Report Card: 2022 Mathematics Assessment.” *The Nation’s Report Card.* https://www.nationsreportcard.gov/highlights/mathematics/2022/.

“National Visual Arts Standards.” National Art Education Association, Art Educators. Accessed 11 Dec. 2022. https://www.arteducators.org/learn-tools/national-visual-arts-standards.

Natsoulas, Anthula. "Group Symmetries Connect Art and History with Mathematics", *The Mathematics Teacher* 93, 5 (2000): 364-370, accessed Apr 16, 2023, https://doi.org/10.5951/MT.93.5.0364.

Nolen, J. L. and Duignan, . Brian. "No Child Left Behind." *Encyclopedia Britannica*, March 20, 2023. https://www.britannica.com/topic/No-Child-Left-Behind-Act.

Powell, Alvin. "How Sputnik changed US Education." *The Harvard Gazette.* October 11, 2007. https://news.harvard.edu/gazette/story/2007/10/how-sputnik-changed-u-s-education/.

"Pyramid casing stone." *National Museums Scotland.* https://www.nms.ac.uk/explore-our-collections/stories/global-arts-cultures-and-design/ancient-egyptian-and-sudanese-collections/ancient-egyptian-collection/pyramid-casing-stone/.

"Resources for Teaching." J. Paul Getty Museum. https://www.getty.edu/education/teachers/classroom_resources/index.html.

Smith, David Eugene. "Historical Survey of the Attempts at the Computation and Construction of π." *The American Mathematical Monthly* 2, no. 12 (1895): 348–51. https://doi.org/10.2307/2970432.

"Special Message to the Congress on Education." *The American Presidency Project.* UC Santa Barbara. https://www.presidency.ucsb.edu/documents/special-message-the-congress-education-2.

Stoel, G.L., J.P. van Drie, and C.A.M. van Boxtel. 2015. "Teaching towards Historical Expertise. Developing a Pedagogy for Fostering Causal Reasoning in History." Journal of Curriculum Studies 47 (1): 49–76. doi:10.1080/00220272.2014.968212.

"Teaching Materials." *For Educators*, Guggenheim. https://www.guggenheim.org/teaching-materials.

"Unit 3: Geometric Design in Islamic Art." Metropolitan Museum of Art. https://www.metmuseum.org/learn/educators/curriculum-resources/art-of-the-islamic-world/unit-three.

"Why is STEAM Education Important?" *Institute for Arts Integration and STEAM.* https://artsintegration.com/what-is-steam-education-in-k-12-schools/.

William E. Lewis, Sharon Walpole, and Michael C. McKenna. *Cracking the Common Core: Choosing and Using Texts in Grades 6-12*. New York: The Guilford Press, 2013. https://search.ebscohost.com/login.aspx?direct=true&db=nlebk&AN=665696&site=eds-l

ive&scope=site.

Wynn, Toni, and Juliette Harris. "Toward a STEM + Arts Curriculum: Creating the Teacher Team." Art Education 65, no. 5 (2012): 42–47. http://www.jstor.org/stable/23391519.