NATIONAL ENDOWMENT FOR THE Humanities

DIVISION OF **EDUCATION PROGRAMS**

Narrative Section of a Successful Application

The attached document contains the grant narrative and selected portions of a previously funded grant application. It is not intended to serve as a model, but to give you a sense of how a successful application may be crafted. Every successful application is different, and each applicant is urged to prepare a proposal that reflects its unique project and aspirations. Prospective applicants should consult the Humanities Connections Implementation guidelines at

https://www.neh.gov/grants/education/humanities-connections-implementation-grants

for instructions. Applicants are also strongly encouraged to consult with the NEH Division of Education Programs staff well before a grant deadline.

Note: The attachment only contains the grant narrative and selected portions, not the entire funded application. In addition, certain portions may have been redacted to protect the privacy interests of an individual and/or to protect confidential commercial and financial information and/or to protect copyrighted materials.

Project Title:	Situating Chemical Elements in the Human World to Innovate Undergraduate Education
Institution:	Binghamton University
Project Director:	Pamela Smart and Valerie Imbruce
Grant Program:	Humanities Connections Implementation

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Summary Statement: This proposal is submitted jointly by colleagues in Classical and Near Eastern Studies, Art and Design, Art History, Physics, Materials Science, and Binghamton University's Undergraduate Research Center, along with partners at the Corning Museum of Glass, all collaborating under the auspices of Binghamton University's Material and Visual Worlds Transdisciplinary Area of Excellence. Materials Matter is a curricular initiative designed to teach emerging research in the humanities to science and engineering students and, reciprocally, the latest science to humanities students, to model an approach for repositioning the humanities across the curriculum. The National Endowment for the Humanities Connections Implementation grant would enable us to scale up our interdisciplinary Materials Matter course that will be piloted in Spring 2018 as a small-scale class, to become a large General Education course carrying both an Aesthetics and a Laboratory Science designation. This co-taught, interdisciplinary course will focus on selected materials—glass, ceramics, and pigments—and will address them from the perspective of their elemental composition, the chemical processes of their manufacture, and the social and historical conditions that provoked and sustained experimentation in their substance and form, along with the impact of innovations in materials at specific historical junctures. The grant will also enable us to launch the first of a series of small research-intensive freshman seminars, building on our pilot course, and each focusing on a single material from multiple disciplinary perspectives. The seminars will teach humanities research methodologies alongside quantitative and experimental methods of STEM fields, to offer students insights into the process and modes of research early in their college career. Both the Gen Ed course and the freshman seminar will utilize a consistent, purposely designed visual language, to facilitate integration of approaches across disciplines, to explain scientific principles, and as a coherent navigational tool for students. This integrative language will be used throughout, and especially in an app we are developing that will afford students a digital platform for access to information, as well as a mechanism for experiential learning. The app will present students with data sets that they will be tasked with manipulating and analyzing, and will offer interpretive approaches that they will be called on to evaluate and apply. Both courses will also utilize additional experiential learning techniques, including the use of scientific instruments to analyze paintings and hands on experience in mixing pigments and crafting frescoes. NEH support will facilitate further development of this app that will be beta tested in rudimentary form in our pilot course. Beyond the evaluation of the app, the pilot course will be subject to systematic qualitative and quantitative evaluation, as will subsequent courses implemented under this grant. At the close of the implementation and evaluation process we will jointly mount an exhibition in the University Art Museum with our partner Corning Museum of Glass, that will demonstrate the integrative, interdisciplinary approach to materials that underpins our suite of projects, and will utilize museum objects as well as our visual information design. Finally, the grant will fund an undergraduate Summer Research Fellowship, supporting research with an interdisciplinary materials approach, and will enable summer training of graduate student TAs to teach in our courses. In sum, this project will offer undergraduate and graduate students, as well as junior and senior faculty and staff multiple entries into our approach to integrate the humanities and sciences.

Narrative

• **Intellectual Rationale:** Materials are central to human life. We extract, form, and shape them, experimenting with them to meet our needs and further our ambitions. Reciprocally, materials—their abundance or rarity, their weight, pliability, toxicity, and their allure—act upon us. Social systems and historical events have been shaped in response to a plenitude of hardwood, an abundance of iron ore, or a reliance on trade of salt, pigments, or petrochemicals. Yet, for all of our familiarity with materials, they are opaque to most of us. While students majoring in the humanities might learn of the importance of ceramic vessels in supporting the prehistoric domestication of crops, the significance of raw materials in the history of colonialism and industrialization, or the way that artists have experimented with materials to achieve particular effects, they tend to be ill-equipped to understand the contingencies involved, from a materials perspective, leading to some innovations being pursued, for example, at the expense of others.

Our proposed curricular initiative seeks to redress this, through affording humanities students a working understanding of the elemental nature of materials and insight into the drama of their transformation when fused, heated, and compressed, in a manner that integrates this perspective with the social biographies of materials and the processes of value production and meaning making with which they are enmeshed. Our resolutely integrative approach not only supports an enriched training of humanities students, but also meaningfully introduces students in STEM fields to the humanities. Undergraduate STEM majors tend to learn chemistry as an abstract discipline, divorced from the materials it produces and distant from the historical, economic, and social circumstances or their discovery, manufacture, and use. Interdisciplinary course content, in our view, coupled with active learning techniques can more effectively promote learning and interest in materials at the intersection of the humanities and sciences.

Beyond benefits in relation to substantive knowledge acquisition, interdisciplinary study has been shown to better prepare students for work and citizenship through the development of higher-order cognitive skills of critical thinking, problem solving, and understanding multiple perspectives [3]. Additionally, the synthetic nature of interdisciplinary study extends the possibility for students to independently build upon already held knowledge [5,6,7]. These virtues of interdisciplinary approaches are intensified by the use of active, experiential learning, that moves beyond traditional lecture formats to include problem solving, discussion, peer collaboration, and hands-on, kinesthetic learning. These practices introduce learners to more critical thinking and problem solving, resulting in a deeper understanding of concepts, in addition to the transfer of the knowledge gained [15,16]. We anticipate that students who complete the Materials Matter courses will walk away with a new mindset acclimated to solving problems that cross human and natural systems through a multi-disciplinary toolkit.

With funding from SUNY, we have already completed much of the course development for a small pilot course to be offered to students of Binghamton University's Scholars Program in Spring, 2018. This grant also supported training of a physics graduate student in our approach, for the purpose of instructional support for this course. We plan to scale up, first to an enrollment of 60 students, with 2 TAs (one in the humanities, the other in physics) specifically trained in our integrative model working with 4 discussion/lab sections of 15 students each, with subsequent incremental expansion to become a large Gen Ed course of up to 400 students.

During our planning phase Corning Museum of Glass (CMoG) Curator of Science and Technology, Dr. Marvin Bolt, and Chief Scientist, Dr. Jane Cook, have presented lectures on campus, given feedback to Dr. Ersan's students working on information design for CMoG exhibits, and consulted with the Materials Matter team, with funding from a Material and Visual

Worlds interdisciplinary seed grant [Appendix 2h]. Undergraduate Summer Research Fellows have already been hosted at CMoG under the mentorship of Drs. Bolt and Ersan. CMoG is engaged in adopting a similarly interdisciplinary, integrative approach in the redesign of its exhibits, so this partnership supports genuine cross-fertilization between our institutions.

- **Content and Design:** We are developing a suite of curricular initiatives that will address the disciplinary fragmentation of approaches at Binghamton, as elsewhere, across a range of instructional formats:

1. A freshman seminar course that features interdisciplinary undergraduate research projects: We are piloting such a course in Spring 2018, taught by Dr. Becker with the instructional support of a physics graduate student under Dr. Piper. This first iteration will focus on pigments, with other materials—ceramics, glass, and others—becoming the focus, drawing on the expertise of faculty members we will recruit onto the team, who will take the lead in teaching. Students will examine a single class of materials, from their elemental structure, the technologies of their manufacture, the historical conditions that provoked and sustained experimentation in their substance and form, through to the impact of innovations in materials at specific historical junctures. It will serve two purposes: create active learners by offering research experiences to freshmen to engage them early in the excitement and creativity of knowledge production; and allow us to test new course content and activities that we can scale up in the Gen Ed course [Appendix 2c,d].

2. An interdisciplinary Aesthetics and Laboratory Science Gen Ed course using active learning techniques: This will build on the curriculum tested in the pilot and in subsequent iterations of the freshman seminar, scaling up incrementally. Students will explore artifacts—artworks and more instrumental objects of design—as products of the intersections of chemistry, technology, history, and aesthetics. In so doing, it will be the first course at Binghamton University to fulfill

the requirements of both the Gen Ed Aesthetics (A) and Laboratory Science (L) designations, equipping students with insight into creative practices (A) and experience in the formulation and testing of hypotheses and the collection, analysis and interpretation of data (L). We will focus on case studies of objects held in the collection of the University Art Museum and CMoG, each foregrounding a specific material—in the first instance, glass, ceramics, and pigments—in order to understand not only the historical development of various artistic media, but also the elemental character of their materials, the chemistry of their manufacture, and the interrelationships between artistic and scientific imagination, experimentation, and innovation. To this end, we will use both historical examples as well as contemporary experimental forms, such as Corning Inc.'s flexible Willow® glass, and pigments created by Golden Paints in collaboration with artists to achieve specific painterly effects. Employing active learning, students will be trained in the use of various chemical analytical and manufacture techniques, and in humanities methodologies, and will be introduced to graphic design as both a means of investigation and visual communication, in a scaled up version of our freshman seminar prototype. The course intends to equip students with literacy in both the humanities and sciences, as substantive fields of knowledge, and as methodologies of knowledge production. It will introduce a broad range of students to materials science, crystallizing understandings of abstract scientific principles through their material application, while also developing an appreciation for the broader social, historical, and cultural circumstances in which materials are enmeshed. Graduate student TAs, from the humanities and sciences, will also benefit from training in this integrative interdisciplinary approach.

3. A visual language with supporting teaching materials as integrative navigational tool: We will develop a coherent visual iconography and narrative strategies as a roadmap, orienting students

to the scalar framework of both the large and small courses, and presenting complex interactions and concepts in a legible manner. Smooth navigation will also be served by a visually encoded reference library of empirical, interpretive, and conceptual resources [Appendix 2e].

4. An interactive application to promote active learning in the classroom: Our visual integrative language will be used throughout, and especially in a purpose built cloud-based app, a digital platform affording students access to information while also supporting experiential learning, insofar as it will present students with data sets that they will be tasked with manipulating and analyzing, and it will offer interpretive approaches that they will be called on to evaluate and apply. The app and its informational design will orient students to the scalar framework of both the large and small courses, featuring interactive analytical tools at three scales: the object scale will be supported by interactive mind maps, relational diagrams, and historical timelines that speak to human processes; the materials scale will feature chemical analysis; and the elements scale will utilize an interactive periodic table that will give students dynamic access to multiple configurations, properties, and quantitative operations that involve the elements [Appendix 2f].

5. Summer Scholars and Artists Fellowships for Undergraduates: The Undergraduate Research Center has run a summer research program for five years, supporting students who make significant contributions to their fields, under faculty mentorship, and who often go on to win prestigious internal and external awards. Support from NEH will create an additional summer placement for a student pursuing an integrative research project on materials [Appendix 2g].

6. A curated exhibit between Binghamton University and Corning Museum of Glass: The interdisciplinary principles and approaches developed for the course will be drawn together in the form of an exhibition, curated collaboratively by Dr. Smart and Dr. Bolt of CMoG, and presented in the University Art Museum, and subsequently at CMoG, at the culmination of the

three-year course implementation and evaluation process. It will demonstrate the intersections of chemistry, physics, technology, history, cultural analysis, and aesthetics in relation to a selection of objects—paintings, ceramics, and glass—utilizing the course's design language to communicate complex processes and relationships in a unified, compelling way.

7. An institutional model for sustaining interdisciplinary courses: To succeed, interdisciplinary initiatives must forge links with established curricular and institutional structures and foster sustained commitment at high administrative levels to provide support where it does not already exist. By establishing support from our Provost and Vice Provost, linking our project to the academic programming and priorities of the Undergraduate Research Center, and making this project a signature of the Materials and Visual Worlds TAE, we are taking these courses out of interdepartmental nether-space to live along established avenues that support interdisciplinary research. Throughout this granting period we are committed to establishing institutional means by which collaborative teaching beyond the curricular plans of disciplinary departments can be sustained. We expect that the Joint Task Force on Interdisciplinary and Transdisciplinary Work, on which team members Smart and Poliks serve, will work to resolve the kinds of structural and procedural issues that have tended to compromise these kinds of initiatives.

Course Design

Course content: Glass, ceramics and pigments will together be the materials of focus for our Gen Ed course, and will singly be the focus of freshman seminars, because they are materials with wide geographic and temporal use, and we have considerable expertise in these materials here, in the arts, humanities, sciences, and engineering. Other materials could readily be introduced to accommodate the expertise and interests of a changing roster of faculty. Elementary topics in materials science—an introduction to the periodic table, and essential chemical compounds, their

formulas and simple chemical reactions—will complement humanistic approaches, and the range of perspectives will be applied to the analysis of paintings, glass and ceramic artifacts, and other objects of art and design selected for study during the semester.

Narratives of Glass: Among the attributes of glass that have made it such an important material are chemical properties that render it inert, its transparency, its receptivity to added color, and of course its longevity. We will make use of recent acquisitions of CMoG, including Roman sea glass and glass blown by a contemporary Afghani artist who is the last to use ancient techniques as examples of materials and processes used in the ancient world that will be compared to more recent forms, such as Corning's Pyrex®, Gorilla®, and flexible Willow® glasses.

Students will learn about the aesthetics of Roman glass, and the manifold ways it was used ranging from decorative glass, windows, mosaics, vessels, and beads. They will look at the site of Apollonia-Arsuf (near Caesarea) in Israel that, among other things, is the point of origin for CMoG's sea glass. An archaeological introduction to the site will reveal the multiple glass furnaces (6^{th}-7^{th}c. A.D.) found there, and will serve to introduce students to both classical archaeology and ancient glass-making technology. This exploration will be supplemented by having students look at glass vessels and mosaics excavated from Apollonia. This sea glass was likely part of a bottle or other tableware, but has been weathered, both physically and chemically, by Mediterranean Sea water for up to 2,000 years. Glass from this era typically includes: Silica, from sand (these pieces likely include some quantity of alumina and lime as impurities); Soda, from natron (sodium carbonate and sodium bicarbonate are likely components, as well as chlorine as a contaminant; and 3) lime from sand and possibly shells (i.e. calcium carbonate). Students will learn about the chemical changes that occur during firing and vitrification.

Techniques to quantify and fingerprint chemical characteristics of artifacts will be introduced as a means to explore chemical composition, like Corning's hyperspectral imaging technology that allows the user to develop techniques to "fingerprint" unknown materials against a standard.

Narratives of Pigments: Students will explore the many layers of information that paintings can reveal about the natural world itself, in terms of the pigments used by artists, how they were obtained or created, and the chemical properties that imbued these paintings with color and texture. Students will also investigate how color choices might reflect extant cultural values, conditions of economic exchange, or aesthetic experimentation. The ways in which art and science have been historically bound together, will be a central theme throughout, such as when innovations in technology have impacted artistic choice or technique, while at other times, how artistic imperatives led technological innovation and revisions of scientific knowledge.

In the first half of the pigment module, students will explore a painting of the Roman period from a range of perspectives. Popular pigments used in the Roman period will be introduced through the periodic table, focusing on the elements carbon, calcium, and iron. Such elements will introduce students to certain commonly-used pigments formed from these elements, such as red ochre (Fe_2O_3), as well as calcium carbonate pigments such as Egyptian blue ($CaCuSi_4O_{10}$), azurite ($Cu_3(CO_3)_2(OH)_2$), and malachite ($Cu_2CO_3(OH)_2$). Once they learn the basic components of a few common pigments and their properties, students will experiment with testing paintings using X-ray fluorescence with two goals in mind: to identify the pigments and to tell cheap red ochre from the rare cinnabar (HgS). In addition, students will see that even once a pigment is identified, trace elements may help researchers to determine from what specific source a particular pigment originated. While ancient Romans did not understand chemistry as we do now, rampant adulteration of pigments and fraud provoked Roman scholars such as Pliny the

Elder to develop chemical tests of a sort. Pliny could detect fraud by smell, taste, texture, burning, and by performing chemical tests. Students will conduct some of these ancient tests and learn the chemical reasons why Pliny's tests were successful. Such a foray exposes students not only to the realities of the marketplace and the knowledge that any ancient artist would need to have known, it also helps students to see how applied chemistry has been useful through the ages in the marketplace.

Another part of this module centers around a modern painting created for this course. Since the Industrial Revolution, intentional experimentation (Prussian blue) and accidental discoveries (mauve invented instead of a synthetic quinine) have made more colors available to artists and impacted art in the modern era. This included the idea of putting oil paints (which were time-consuming to set up) in sealable metal tubes, allowing artists to quickly access a variety of colors at one time (19^{th} Century Impressionism is inconceivable without this innovation). Students will learn how the care of art relies on chemistry, in the practice of art conservation and restoration.. To this end, students will partake in a three-part rotating lab in order to learn about the pigments used in modern painting. First, students will utilize UV light in order to see beyond the superficial to discern evidence of earlier drafts or retouchings. They will then identify pigment "samples" drawn from the painting, by using hydrocholoric acid to test for calcium carbonate and also polarized light microscopy, so that they can identify unknown pigments in comparison with known samples. Students will then learn more about the chemistry of modern pigments, utilizing the expertise of chemists at nearby Golden Paints, and will manufacture a modern pigment themselves, to think about chemical processes in relation to the desired properties that such compounds make possible, like texture, colorfastness, luminosity, etc.

Laboratory exercises will provide an opportunity for students to investigate their own questions, within a structured, guided environment. Exercises will involve multiple analytical techniques to acquire information for case study problems involving glass, ceramics, paintings, or such artifacts as a set of toys painted with various pigments having different elemental compositions.

- **Collaborative Team**

Dr. Hilary Becker, Assistant Professor of Classical and Near Eastern Studies, Binghamton University, is an expert in ancient Roman pigment. She plays a significant role in the development of course content and in the integration of humanistic and scientific analytic approaches. She is scheduled to teach our pilot course in Spring, 2018 (with instructional support from a physics graduate student) and, is likely to periodically teach a freshman seminar on pigment. She will also contribute modules to our scaled up Gen Ed course.

Dr. Marvin Bolt, Curator of Science and Technology, Corning Museum of Glass: Bolt contributes his expertise on glass and science communication to course development. He will give guest lectures on glass to the Gen Ed course, and the freshman seminar, and will continue to host undergraduate Summer Research Fellows. He will also collaborate with Smart and Ersan on the proposed exhibition for the Binghamton University Art Museum and for CMoG.

Dr. Gokhan Ersan, Assistant Professor of Art and Design, Binghamton University, will continue to develop and implement the visual language and interactive app for the course, drawing on his expertise in the visual communication of science. He is already collaborating with CMoG on linked projects, and advising Summer Research Fellows. He will play a significant role in the design of the proposed exhibition, and his communicative model will facilitate the sharing of our approach beyond our own initiative.

Dr. Valerie Imbruce, Director, Undergraduate Research Center, Binghamton University, will orchestrate the project, and will systematically conduct course evaluations and lead our scholarly research and publishing on interdisciplinary pedagogy informed by course data. This research will also underpin the promotion of our model, both across this campus and beyond. She will link the course to the activities of the Undergraduate Research Center.

Dr. Louis Piper, Associate Professor of Physics, Binghamton University, will continue to contribute to the development of course modules and mentor his graduate student who will TA. Drs. Piper and Ersan will continue to collaborate on how to best conceptualize and visualize the complex and abstract chemistry concepts presented in this course.

Dr. Mark Poliks, Professor of System Science and Industrial Engineering, Binghamton University, brings his expertise in chemistry and materials science to course development and instruction as well as providing access to equipment and laboratory space in the S3IP-Center for Advanced Microelectronics Manufacturing (CAMM). Contributions will include not only the content design of course modules, but also design of course materials, such as input into the visual language and interactive app. He will also serve as a contributing lecturer in the course.

Dr. Pamela Smart, Associate Professor of Art History and Anthropology, Binghamton University, will continue to participate in the integration of science with the humanities in the process of curriculum development. She will collaborate with Drs. Bolt and Ersan in the conceptualization and design of the proposed exhibition. As chair of the Material and Visual Worlds TAE, and as a member of the Joint Taskforce for Interdisciplinary and Transdisciplinary Work, with Dr. Poliks, she will work to ensure continued structural support for teaching across departments and schools.

- **Institutional Context and Resources**: Binghamton University has a long-standing reputation for academic excellence in undergraduate education. It has evolved from a four-year liberal arts college to a research university offering master's and doctoral programs in the liberal arts, sciences, engineering, nursing, and other professional programs, with 13,465 undergraduates, 3,359 graduate students, and 611 tenure-track faculty. For 17 years, Binghamton has been listed among the top 50 public U.S. universities by the *U.S. News & World Report,* and the school is consistently recognized by *Kiplinger's Personal Finance* and *Forbes* for best value in the nation. The 2017 freshman class has an average SAT of 1360 for math and critical reading and an average incoming GPA of 3.65. Binghamton's freshman retention rate is 91.7%, compared to a national average of 73.3%, and graduates have high earnings [13,14]. Binghamton has been growing more diverse, with 18% underrepresented minority undergraduates in 2015.

This project will join two of Binghamton's colleges, Harpur College of Arts and Sciences and the Watson School of Engineering and Applied Sciences. As of Fall 2016, there were 1,473 declared majors in the Arts and Humanities representing about 15% of the total undergraduate majors in the Harpur College of Arts and Sciences. The humanities division has experienced the national trend in decreased enrollments over the last decade, although majors in the arts have increased due to new investments in studio art and cinema. The top three largest majors in these two divisions are Art Studio, English, and Romance Languages (History is included in the Social Sciences Division). The Watson School has 1,923 enrolled undergraduates, with growth over the last 10 years, particularly in Systems Science and Engineering. Computer Science, Mechanical and Electrical Engineering are the largest majors. [See Appendix 2b for more enrollment data.]

Ongoing collaborations with the University Art Museum will be supported by the mission of its director to draw diverse academic constituencies into an engagement with the museum's

collections. The museum's study room will afford students direct access to selected objects from the collection. We will mount an exhibition in the museum demonstrating our integrative approach at the culmination of the grant period. The expanding resources of Binghamton University's Center for Learning and Teaching will support the instructional and evaluative elements of the course. The Undergraduate Research Center, directed by Dr. Imbruce, provides an institutional home for our freshman research seminar, and the Summer Research Fellowships.

The proposed initiative is consistent with Binghamton University's commitment to collaborative research and teaching across schools. Both Donald Nieman, Provost and Executive Vice President for Academic Affairs, and Vice Provost for Undergraduate Education and Enrollment, Donald Loewen, have lent their enthusiastic support to the project. The Provost has agreed to ensure that Teaching Assistantships will be available beyond departmental allocations to support the various interactive elements of the course delivery. The Joint Taskforce on Interdisciplinary and Transdisciplinary Work, newly convened by the Provost and the Faculty Senate, is expected to address the structural challenges of co-teaching across departments and schools, along with other issues of resource allocation that will ensure the long-term sustainability of Materials Matter. The Material and Visual Worlds TAE, reporting to the Provost, awarded a seed grant to Drs. Poliks, Ersan, and Bolt, from which preliminary ideas and relationships were developed, and it serves as the institutional hearth for the project.

- **Impact and Dissemination:** Beyond its contribution to the university's commitment to undergraduate research experiences, to the provision of high quality Gen Ed courses, and to interdisciplinary teaching and learning, we see this initiative as serving to clear an institutional path for other such interdisciplinary curricular developments. We have a critical mass of colleagues who have the requisite substantive expertise, pedagogical skills, intellectual

convictions, and enthusiasm to sustain the course both within and beyond its initial development and implementation period. We also see the potential for the development of a programmatic initiative, a science communication major or minor, which could build upon the foundations of Materials Matter. The mix of senior and junior faculty on our team is a further strength of our model in terms of ongoing sustainability.

We plan to extend our model to humanities and science colleagues in other institutions. As well as producing the standard academic products of publications and presentations, our course app will be open source and all course materials publically available through the Internet.

Evaluation: Evaluation will encompass on-going formative and summative assessments of student learning gains and achievement of all project goals. Dr. Imbruce will design the assessment of student learning gains and will provide timely formative feedback to guide program improvements. Assessments will use data-driven measures and outcome indicators to examine program activities and student growth, inform faculty teaching, course implementation, and institutional policies concerning interdisciplinary course initiatives. There are two groups of initiatives in education research that we draw on in the study of this project: the transformation from passive to active learning techniques in lecture style courses [1,2] and the engagement of undergraduates in course based research experiences [3-5]. We plan to combine elements of each model (the active lecture and a structured, but open-ended research experience) in an interdisciplinary context, and drawing on the work of others [6] *hypothesize that a combination of interdisciplinary content and intentional pedagogy can promote learning better than either in isolation*. There are three main sets of variables that characterize the learning process: pedagogy, course content, and leaner characteristics. A challenge in the design of educational research is that you cannot assign students to courses randomly. Small sample sizes and small windows of

gain to be made through the course (if students are highly competent at the start of a course) also diminish statistical power. To overcome these limitations, we will use propensity score matching to control student level variables and non-random assignment [7]. We will assign students in the treatment courses (Materials Matter) with a match in learner characteristics (e.g. prerequisites, major, GPA, other demographic factors) in a control course that does not use interdisciplinary, active learning. Pre- and post-tests will use the validated survey instruments, the Student Assessment of Learning Gains, to gauge humanistic and scientific literacy, understanding of key concepts, student motivation and interests. We will also use instructors' direct assessment of student learning and student reflections for contextual analysis to better understand student growth. For deeper investigation in the course experience, we will observe class instruction and will conduct semi-structured interviews to ask students to judge the effectiveness of the course and use of the course app, and faculty to judge the quality of student learning throughout the course as well as their own experience teaching across disciplines, using interactive technology, and pedagogies in the course. Questions that we seek to address with our mixed quantitative and qualitative design are: What are the educational outcomes of interdisciplinary courses? How do these outcomes compare to disciplinary based courses? Are student-learning gains attributable to the interdisciplinary nature of the course? Are student learning gains attributable to the learning techniques used in the classroom? As the projects move forward past NEH funding, we plan to track long-term outcomes beyond the course to be assessed in a longitudinal study that will address students' post-course experiences, interest in humanities or STEM fields, declared majors, and career goals. Faculty will also be asked to evaluate the impact of the intervention and coursework on their students in future courses.

Materials Matter Plan of Work

With existing support		
January 2018	Launch of Materials Matters interactive app	Gokhan Ersan
January – May 2018	Launch of Materials Matter pilot course in the Binghamton Scholars Program	Hilary Becker and Todd Rutkowski Course modules by: Louis Piper, Mark Poliks, Marvin Bolt
January – May 2018	Course assessment, including pre- and post-tests, interviews with faculty and students, and participant observation of course	Valerie Imbruce, with research assistant
Feb 25 – April 25, 2018	Glass Science Exhibition in Binghamton University Art Museum	Gokhan Ersan and students
February 2018	Recruitment of a student for the Summer Scholars Program	All team members
Late Feb/early March	Team Meeting to review course progress, and: • Create Gen Ed course in course registry for Fall 2018 • Get approvals from curriculum committee	All team members
June 2018	Team meeting to debrief on the spring term activities; Preparation of formative course evaluation	All team members; Valerie Imbruce
NEH Award Year 1		
Early July 2018	Team meeting to review course evaluation and plan for upcoming year • Recruit graduate assistants • Identify instructors for Gen Ed and Research Seminar courses • Review upcoming conferences and prepare abstracts for submissions	All team members
July – August 2018	Summer Scholar works with faculty mentor	Undergraduate student and appropriate team member
July – August 2018	Graduate student training for interdisciplinary teaching	Pam Smart, Valerie Imbruce
July – August 2018	Development of ten lab exercises for Gen Ed science lab designation	Mark Poliks, Louis Piper, science graduate assistant

July – August 2018	Revision of syllabi and materials from pilot for the Gen Ed course and for the Freshman Research Seminar • Development of new module on glass • Continued work on app	Gokhan Ersan, Hilary Becker, graduate assistants
Late August 2018	Team Meeting to prepare for fall course launch	All team members
Sept – Dec 2018	Launch of Gen Ed Materials Matters Course	Hilary Becker and Pam Smart Course modules by: Louis Piper, Mark Poliks, Marvin Bolt
Sept – Dec 2018	Course assessment, including pre- and post-tests, interviews with faculty and students, and participant observation of course	Valerie Imbruce, with research assistant
Late Oct/early Nov 2019, or ass needed	Team meeting to review course progress • Register freshman research seminar as University wide course	All team members
January 2019	Preparation of formative evaluation of Gen Ed course	Valerie Imbruce, with research assistant
January 2019	Team meeting to finalize plans and materials for Freshman Research Seminar	All team members
January – May 2019	Launch of Freshman Research Seminar, focus on glass	TBD
January – May 2019	Course assessment, including pre- and post-tests, interviews with faculty and students, and participant observation of course	Valerie Imbruce, with research assistant
February 2019	Recruitment of a student for the Summer Scholars Program	All team members
Late Feb/early May 2019	Team meeting to review course progress	All team members
June 2018	Team meeting to debrief on the spring term activities; Preparation of formative course evaluation Conference travel	Valerie Imbruce, with research assistant Appropriate team members
Late June 2018	Team meeting to debrief on the spring term activities and plan for next year, and	All team members

	• Recruit new grad assistants if necessary • Recruit new faculty into the team to build ceramics module • Review upcoming conferences and prepare abstracts for submissions	
NEH Award Year 2		
July – August 2019	Summer Scholar works with faculty mentor	Undergraduate student and appropriate team member
July – August 2019	Graduate student training for interdisciplinary teaching	Pam Smart, Valerie Imbruce
July – August 2019	Revision of syllabi and materials from pilot for the Gen Ed course and for the Freshman Research Seminar • Development of new module on ceramics • Continued work on app	Gokhan Ersan, Hilary Becker, graduate assistants and other team members as appropriate
Late August 2019	Team Meeting to prepare for fall course launch • Work with NEH on planning for two-day meeting at NEH offices	All team members
Sept – Dec 2019	Second iteration of Gen Ed Materials Matters Course	TBD Course modules by: Louis Piper, Mark Poliks, Marvin Bolt
Sept – Dec 2019	Course assessment, including pre- and post-tests, interviews with faculty and students, and participant observation of course	Valerie Imbruce, with research assistant
Late Oct/early Nov, or ass needed	Team meeting to review course progress	All team members
January 2020	Preparation of formative evaluation of Gen Ed course	Valerie Imbruce, with research assistant
January 2020	Team meeting to finalize plans and materials for Freshman Research Seminar	All team members
January – May 2020	Second iteration of Freshman Research Seminar, focus on ceramics	TBD
January – May 2020	Course assessment, including pre- and post-tests, interviews with faculty and students, and participant observation of course	Valerie Imbruce, with research assistant

February 2020	Recruitment of a student for the Summer Scholars Program	All team members
Late Feb/early May 2020	Team meeting to review course progress	All team members
June 2020	Conference presentations	Appropriate team members
June 2020	Team meeting to debrief on the spring term activities; Preparation of formative course evaluation	Valerie Imbruce, with research assistant
Late June 2020	Team meeting to debrief on the spring term activities and plan for next year, recruit new grad assistants if necessary, consider bringing new faculty into the team to build ceramics module	All team members
NEH Award Year 3		
July – August 2020	Summer Scholar works with faculty mentor	Undergraduate student and appropriate team member
July – August 2020	Graduate student training for interdisciplinary teaching	Pam Smart, Valerie Imbruce
July – August 2020	Revision of syllabi and materials from pilot for the Gen Ed course and for the Freshman Research Seminar • Continued work on app	Gokhan Ersan, Hilary Becker, graduate assistants and other team members as appropriate
Late August 2020	Team Meeting to prepare for fall course launch, upcoming conference opportunities, and • Begin planning for curated museum exhibition in spring	All team members
Sept – Dec 2020	Third iteration of Gen Ed Materials Matters Course	TBD Couese modules by: Louis Piper, Mark Poliks, Marvin Bolt
Sept – Dec 2020	Course assessment, including pre- and post-tests, interviews with faculty and students, and participant observation of course	Valerie Imbruce, with research assistant
Late Oct/early Nov 2020, or as needed	Team meeting to review course and exhibition progress	All team members
January 2021	Preparation of formative evaluation of Gen Ed course	Valerie Imbruce, with research assistant
January 2021	Team meeting to finalize plans and materials for Freshman Research Seminar	All team members

January 2021	Finalize exhibit for University Art Museum	Pam Smart, Gokhan Ersan and Marvin Bolt
January – May 2021	Third iteration of Freshman Research Seminar, focus back to pigments	Hilary Becker
January – May 2021	Course assessment, including pre- and post-tests, interviews with faculty and students, and participant observation of course	Valerie Imbruce, with research assistant
February 2021	Recruitment of a student for the Summer Scholars Program	All team members
Late Feb/early May 2021	Team meeting to review course progress	All team members
Mar – May 2021	University Art Museum Exhibition on Materials Matter	Pam Smart and Marvin Bolt
June 2021	Conference presentations	Appropriate team members
June 2021	Preparation of final project summative evaluation	Valerie Imbruce
June 2021	Team meeting to debrief on the project and plan for sustained rotation of Gen Ed, Freshman Seminar Courses, and Summer Scholar • Prepare publications on the project	All team members

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