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Artistic Presentation of Scientific Research as a Means to Promote Public Awareness

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THE ARTISTIC PRESENTATION OF SCIENTIFIC RESEARCH AS A MEANS TO INCREASE PUBLIC AWARENESS

An Interactive Qualifying Project

Submitted to the Faculty

of the

WORCESTER POLYTECHNIC INSTITUTE

In partial fulfillment of the requirement for the

Degree of Bachelor of Science

By

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Abstract

The goal of this IQP project is to create an artistic exhibit of images and artifacts generated by research being conducted at WPI. The purpose of this exhibit is to generate interest in science and technology, draw attention to research being conducted at WPI, and to attract people to the scientific pursuit of knowledge. The research being highlighted addresses problems of importance to society, and is presented in such a way as to also be of interest as design and art objects. As such, these works are equally at home in the art gallery and the science museum.

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Executive Summary

Public interest in scientific research benefits both the researchers and society alike. Researchers benefit from increased resource opportunities and society benefits through increased knowledge and improved technology. Insufficient numbers of students are pursuing careers in science and technology in the United States. Scientific research is essential to the health and welfare of our society and depends on a continuous supply of new researchers. Scientific information is relatively inaccessible to the general public, accessed mainly through textbooks and academic papers. The artistic presentation of scientific research facilitates an increase in public interest and motivates students to pursue careers in science and engineering.

The goal of this IQP project was to create artistic exhibits of images and artifacts generated by research conducted at WPI. The purpose of these exhibits was to generate interest in science and technology, draw attention to research being conducted at WPI, and to attract people to the scientific pursuit of knowledge. Nano and microscopic images of materials and processes directly related to the research were the central elements in the exhibits. The research highlighted addresed problems of importance to society, and was presented in such a way as to also be of interest as design and art objects. As such, these works are equally at home in the art gallery and the science museum. The exhibits created a context in which the viewer could relate to him or herself and the technology in a way that stimulates thought and inspires. They are informative while elegant, conveying information and displaying harmony of form.

Researchers at WPI were interviewed and images and potential image sources from their research were catalogued. Research addressing larger societal concerns and producing images and artifacts of interest were the focus of the exhibits. Images from scanning electron microscopy (SEM), fluorescence microscopy, differentioal interference cancelation (DIC) and stereomicroscopy from the research was used to create artistic, multimedia displays.

To assess the impact of these studies, we developed a survey that investigated the viewers' response to the exhibit. Preliminary results indicated that both scientist and artist and the general public are excited about the possibility of more collaborative projects. These results also indicated that the viewers reexamined their preconceptions of art and science. From these findings we concluded that the project was successful. Finally, future studies should investigate whether students are more likely to be attracted to careers in science and technology after viewing the exhibit.

Introduction and Background

Art and science create and shape our understanding of the world. Science seeks to model and describe the world and its structures as accurately as possible, while art recontextualizes and reformats information in a way that better allows us to understand and appreciate the world as it is or could be. Science helps us discover the world, and art helps us understand our place in it. The world is transformed and redefined at an ever-increasing rate through science and technology. The need for scientists and artists to show how we fit in and relate to this technological landscape increases exponentially as well.

Since their origins and through the majority of their history, art and technology have been tightly connected, yet recently increasingly separated. The current definition of science includes no reference toward the creativity necessary to develop scientific theories and insights. Science is defined as "the intellectual and practical activity encompassing the systematic study of the structure and behavior of the physical and natural world through observation and experiment" [1]. Technology is defined by Merriam Webster's dictionary as the application of scientific knowledge for practical purpose. This definition of technology mentions the practical, yet technology is also essential in creating virtually all works of art. Artists generally use such old technologies that people forget that they are in fact technologies. To limit artists to old technologies is to limit the power of art itself. It is the exponential rate of modern technological advances that has created a rift between the technologies of the artist, and the technologies of the scientist. The lack of overlap in coursework between science and fine art degrees results in almost a complete segregation between students in either discipline. Reestablishment of a dialogue between the two disciplines could only strengthen advancements in both fields, and increase humanities' understanding of their place in the world.

This project seeks to open a dialogue between the normally segregated disciplines of art and science. By creating artistic exhibits of artifacts generated by scientific research, it is hoped that society will become aware of the benefits of both endeavors. The preconception that science is rigid and fixed can lead many people to not consider pursuing degrees in science and technology. This project aims to educate the public about the creative and exciting aspects of scientific research, and in so doing, attract people to science and technology that perhaps would have otherwise pursued other fields.

The supply and demand for scientists and engineers varies by specialty and region, and through time. The consequences of shortages, however, are far more likely to be serious than the consequences of brief surpluses. The Federal Government enacted legislation entitled the National Defense Education Act (NDEA), to curb the problem of what it perceives as a shortage of home scientists, engineers, and mathematicians. The consequences of shortages of persons skilled in these specialties during a time of war could be unimaginable. One need only look at how the outcome of a world war was determined by the national affiliation of Albert Einstein and the team working on the Manhattan Project to appreciate how science and technology can impact humanity. The National Defense Education Act seeks to foster teaching and scholarship important to the national defense through direct aid, scholarships, and grants. This demonstrates the importance the federal government has placed on creating more scientists and engineers.

There is also a growing need for scientists and engineers to solve the myriad of today's global and societal problems. This need grows as our impact on the environment and the threat of technologically advanced war and terrorism increase as well. Economically, the United States is growing increasingly dependent on a technologically skilled labor force. The prominence of the United States in global affairs is a direct result of its economic strength. The demand for technological goods and services in the United States is increasing. It is imperative that there is a sufficient supply of technologically skilled workers to meet the demand, which ensures a healthy economy by creating more domestic job opportunities.

The benefits to society of scientifically minded individuals run far beyond the strategic and the practical. A survey by the National Science Foundation found that only ten percent of the American public can distinguish astronomy from astrology, that only one third understands what a molecule is, and that nearly half reject the Theory of Evolution [2]. Since 1991 when this study was conducted, numerous studies indicate that these statistics are still accurate. The scientific method by definition requires an open mind, always refining and striving to increase mankind's understanding of the world, based on logic and evidence. Scientific knowledge and understanding fill the vacuum of ignorance and fundamentalism that leave entire societies vulnerable to dangerous ideologies and fascist control. The cost of scientific ignorance in our own country can easily be seen in the politicization of the global warming issue, and the politicization of the teaching of evolution in our public schools.

While science and technology have been used to greatly benefit humanity, they have often been applied toward the pursuit of violence and weaponry as well. Scientific knowledge can both protect us strategically; by increasing the effectiveness of our national defense, and more importantly, it can enlighten humanity towards the end that we can perhaps avoid the misunderstandings and hatred that fuel violence and war in the first place.

Methods of Conveying Science

There exists in modern society, a general need for new and continued scientific research. The findings from scientific studies have become influential in shaping people's day-to-day habits, from their dietary choices to decisions surrounding child raising. Additionally, the findings of past research have become the cornerstones of future research. It is therefore imperative that the findings from scientific research be effectively communicated.

One of the main difficulties in completely communicating scientific research is the high degree of technical information that accompanies each scientific topic. The use of highly technical language in reporting results is the required standard in the scientific community. Scientists communicate their experimentation processes and findings primarily to those involved in their specialized fields of study. Conversely, many scientists do not receive significant formal instruction regarding the relevancy of science to society and culture at large [32]. Scientific findings are passed amongst scientist and are not easily assimilated into society. As a result, the scientific community maintains its status as a tightly knit group and to some may appear to be professionally elitist. Members of the scientific community have the time and technical knowledge needed to assimilate the research, while members of the nonscientific community have a difficult time comprehending the published research. The mechanisms underlying scientific research often are not necessarily intuitive nor are they easily observable by the public, as in the case of quantum mechanics. The inherent consequence is a large communication gap between the scientific and nonscientific communities.

Public perception of science also affects the communication of ideas between the two communities. The public has viewed science as the infallible mechanism to achieve truth and to uncover the laws of the physical universe. While it is true that scientists are searching for reductive theories, such as string theory, to describe a wide range of phenomena, some "have been partly responsible for conveying this omnipotent view of science" [32].

To guard against significant content loss in conveying scientific research, it is important to understand what promotes the successful and continued communication of findings in each of the two communities. Members of the scientific community know that the findings of one particular study are most likely not going to provide the final word. This mentality fuels the deliberate and methodic scrutiny of the scientific conclusions and methods for their, "accuracy, validity, reliability, and applicability," [8] hence generating further investigations and subsequent peer-reviewed manuscripts. Outside the scientific community, news and other media forms are responsible for presenting the findings. The successful communication of research to the non-scientific community is linked to the "instant appeal – the impact of a headline or the allure of a sound bite" [8]. The success of communicating scientific results to the nonscientific community therefore rests upon the ability of the news headline to generate the instantaneous appeal required to captivate the intended audience.

The general public utilizes a wide range of sources to obtain the necessary scientific information, but the majority of these sources are media-based. A trends survey conducted by the American Dietetic Association (ADA) in 2000 revealed the heavy reliance upon media-based sources for health and nutrition information within the general public [9]. Regarding health news, nearly equal percentages of the people polled said that they receive the majority of their information from TV and magazines. A summary of the findings from the ADA survey has been reproduced in Table 1.

Table 1- ADA Trends Summary 2000 [9]

Info. Source	**Media**	**% Surveyed**
Health		
	Television	48%
	Magazines	47%
	Newspapers	18%
Nutrition		
	MD/Dietician/Nutritionist	90%
	Magazines	87%
	Nurses	85%
	Newspapers	82%
	Television	79%

As discussed previously, the members of the nonscientific community rely heavily upon the media as their source of scientific information. To be more accurate, members of this community seek out several media sources to formulate a common consensus on the scientific findings. The media reports available to the public often can be confusing and contradictory. A 1997 survey by The National Health Council indicated that 68% of the survey participants would agree with the statement, “When reporting medical and health news, the media often contradict themselves, so I don’t know what to believe” [10]. Furthermore, the results from the 1997 Food Marketing Institute indicate that eight out of ten consumers think that “it is very or somewhat likely that the experts will have a completely different idea about which foods are healthy within the next 5 years" [11]. The distrust between both communities in this sense is crippling to the communication process. Without a network of trusting social relationships within which claims about nature are to be judged, valid claims about nature cannot be made at all [13].

Clearly, the latter findings from the NHC and FMI investigations demonstrate a significant malady in the successful communication of scientific research. Most people value the results from scientific research, but if only thirty-two out of every one hundred people believe that the specific findings from the science they hear or read about are true, then the overall majority of the scientific research fails to be effectively communicated to the public. The remedy to the situation requires that the writers from both communities work together [25,26] to translate the science into a form that makes it meaningful to the public. The major obstacle facing the media is, according to Rowe, "the lack of understanding of the scientific process itself, especially among non-science writers" [8]. The journalist, for example, views the findings from a scientific study as something that carries headline potential, whereas the researcher views their results as something that is a part of the larger process of "discovery and debate" [8]. Journalists can also misinform the public if they do not possess an understanding of the statistically significant findings reported by the researcher. The scientist is not without obstacles to overcome. Within the scientific community, there is a strong tendency for researchers to become so engaged in their work that they forget their obligation to explain their research to the broader society [24]. Similarly, the scientific community must be able to reduce the technical components of the findings into a form that is more suitable for the media. According to Deborah Blum, a Pulitzer-

Prize winning science journalist, many scientists know very little about “the culture of journalism, what makes a story, and how to talk to reporters.”

It is important to devise methods of effectively and accurately communicating scientific research to the public. It is important that this communication chain between the researcher and the public maintain the integrity of the findings. The Harvard-International Food Information Council Foundation advisory group came to this realization and devised a set of guidelines to regulate the communication of diet and health information at each step of the communication chain [12]. Table 2reproduces the Harvard-IFIC Foundation advisory group’s set of guiding questions, which can be applied to communicate other forms of information with little modification to the first question.

Table 2- Harvard-IFIC Communication Question Set [12]

Number	Question
1	Will your communication enhance public understanding of diet and health?
2	Have you put the study findings into context?
3	Have the findings been peer-reviewed?
4	Have you disclosed the important facts about the study?
5	Have you disclosed all key information about the study's findings?

The Harvard-IFIC list represents a generalized set of guiding questions for scientists and journalists alike. However, scientists will require additional guidelines to better communicate with the journalist. Any important information that the scientist leaves out will not appear in the final translation step that will be available for the public. Furthermore, the scientist must be reminded of the differences between the scientific and non-scientific communities.

and **Error! Reference source not found.**summarize tips given to researchers for communicating science to the general public. The advice in

is from a colleague, while the advice in **Error! Reference source not found.** is from a policy maker.

Table 3- Notes to a Researcher From a Researcher[24]

Number	**Suggestion**
1	*Get your message down to 3 main points,* using nontechnical language
2	*Describe the implications of your work, rather than the clever science*
3	*Learn about the world of the journalist*
4	*Prepare a simple document with the important details*
5	*Understand the importance of pictures*
6	*Let the journalist know you are willing to engage in a dialogue*

Table 4- Notes to a Researcher From a Policy Maker[24]

Number	**Note**
1	*Research is often inaccessible or limited*
2	*Most research findings are equivocal, with marginal or uncertain impact on the overall state of knowledge*
3	*The presentation of research findings seldom takes into account the decision cycles and calendars of executive or legislative policy makers*
4	*Research findings are not often reported in a manner that directly takes into account the resource limitations faced by policy makes*
5	*Research is not often undertaken, or reported in a manner that addresses the most pressing questions facing policy makers*
6	*Researchers do little effort to distinguish themselves from other, self-interested parties*

Collins and Pinch [14,15] offer the “golem metaphor” as a means to correctly relate science and technology to the public. The golem, from Jewish mythology, is a “bumbling giant, powerful but unruly made of natural materials, clay, by human hands” [14]. Mythology holds that the golem is strong and will protect society, provided that society understands it. Collins and Pinch assert that science “has neither the character of a knight, nor Frankenstein – instead like a golem.” The golem metaphor helps to bring back science to the human realm as the golem itself was fabricated not by some divine blacksmith, but instead by very expert and human hands. Scientists, who are considered experts of the natural world, sometimes arrive at their conclusions in a “messy way,” which demonstrates the human side of science. Scientists were not, as Collins and Pinch say in their construction of the golem metaphor, “immaculately conceived.” If the latter had been the case, then science would have to be a process totally void of uncertainty since it would have been heaven sent. According to Garrett and Bird, “a more useful strategy [of communicating scientific facts] is to increase public understanding of the limits of scientific certainty” [27]. Science is a “body of expertise carried out by human practitioners” and to regard science “as a craft skill, as having a human side to it,” makes science less intimidating, especially to school age children.

Science communication and science education, though two separate disciplines, both seek to convey scientific findings and knowledge. While much research has been conducted over the centuries on science education, research on science communication is greatly needed. Negrete and Lartigue [16] assert that due to the similarities between the two disciplines, it is possible to use the findings from science education to improve science communication. The first introductions of science to students in grade school will “largely determine an individual’s view of the subject in adult life” [17]. It is imperative that the science and the manner in which it is taught, do not intimidate the student. Many education systems present science as a series of facts and most “neglect exploration, understanding, and reflection,” [18] which omits “the fundamental phase of generalization” [19] in science. To counter the dryness associated with traditional methods of teaching science, Negrete and Lartigue strongly advocate the use of the narrative to educate and to communicate science.

The power of the narrative rests in its ability to connect with the individual through “imaginative engagement” [20] as a means of “amplifying emotions” [21]. Stimulation of the senses at this level helps students to learn the underlying science more effectively [22]. The effectiveness of the narrative is linked to how the brain processes information. Facts and information presented through narrative evoke imagery that can be more easily recalled than facts alone [16]. Recent research has explored the use of the narrative as an effective means to communicate scientific ideas to the general public. The results from this study conclude that both textual and narrative based forms of conveying science to the public are equally effective; however, the participants noted “that narratives are a more attractive and enjoyable way of learning such information” [23].

Television is also a viable mechanism to deliver science information to the general public. A television channel such as the Cable-Satellite Public Affairs Network (C-SPAN) delivers information on policy, politics and airs unedited coverage of speeches and proceedings twenty-four hours a day to eighty million U.S. households [29]. In a 2003 article appearing in *Science*, Terrence Sejnowski, of the Salk Institute for Biological studies, called for the need of "a C-SPAN for science: a cable science network (CSN)" [29]. The proposed CSN would feature live lectures from respected and knowledgeable scientists on a wide range of topics and in times of crisis would provide "accurate, timely scientific information" at all hours of the day. The majority of policy makers and other public officials do not have the scientific training needed to fully understand scientific findings and therefore rely mainly upon information and advice from lobbyists. A CSN would serve as a source of easily accessible and unbiased scientific information for both the policy makers and the public. Since 2003, Sejnowski, Roger Bingham, and other prominent scientists have worked to develop The Science Network (TSN). The TSN is an active Internet based version of the proposed CSN and represents a significant step towards a television based science network.

Science centers and museums of science have served as very effective mechanisms for delivering scientific information to the public. Science centers in the United States amount to a billion dollar industry and already hundreds of millions of pounds have been spent on similar centers in Britain. Science centers are becoming a global trend with various kinds appearing in nearly all of the European countries, Australia, Canada, India, and Singapore. Science centers, as Gregory supports, "are not museums", as they do not protect and display precious objects; instead they offer active experiments and demonstrations of phenomena of nature, and discoveries and inventions, together with something of how science works" [31]. Science centers reveal the underlying principles that govern the world in a creative and concise manner. The philosophy of the science center contains many of the same themes as this project. Hilda Hein touches upon many of these themes in her cataloging of the philosophy governing the Exploratorium in San Francisco. The following is a passage from the Introduction, written in the spirit of founder Frank Oppenheimer:

> “Museums usually house static displays to be admired from a distance. Even natural history collections, the primary contents of science museums, tend to require only a passive and reverential appreciation of the odd and various specimens someone has painstakingly assembled. Such exhibits can strike wonder at the right diversity of the universe, but they tend also to encourage awe for the brilliance of the few adults who have been able to unravel its complexity. Science museums often glorify scientists more than they teach museum goers the practice of science. Visitors are invited to admire the accomplishments of others, but not always to think that they might go and do likewise.
>
> The proposal that Oppenheimer brought [to San Francisco] was for a museum in which people would directly experience and manipulate things, instead of being told about them. The public was to interact with objects as an experimental scientist does in the natural world or in the laboratory. The museum was to teach that the subject matter of science is all around us and its comprehension is available to all. It was to remove science from the exclusive domain of the experts, to demystify it, and to restore it to the common sphere. It was to convince people that doing science can be interesting and fun for everyone.” [30]

The success of science centers in communicating science is attributed to the hands-on interaction the public has with the various exhibits. To justify the inclusion of hands-on interaction into an exhibit, Gregory offers an argument based upon his philosophy of perception and illusion [31]. Table 5summarizes the logical development of his argument.

Table 5- A Brief Justification for Hands-On Science Centers

Number	**Description**
1	*Perception of objects depends on knowledge.*
2	*Individual learning from experience is stored neurally, and not transferred to the genetic code.*
3	*Eyes are useful, when their brains can read non-optical*

	properties from optical images.
4	*Meaning is projected into the world of objects, from knowledge or assumptions. Without inherited or individually learned knowledge, organisms are effectively blind.*
5	*The hands-on thesis is that non-optical knowledge for seeing comes from the proximal senses and especially from interactive touch.*
6	*This leads to the idea that hands-on Science Centers should help children to see and understand more richly.*

Insufficient experimental data prevents validation of each point in Gregory's argument, however exhibits with interactive components have been shown to clearly compel attention, and also evoke genuine excitement in nearly all children and many of the adult viewers. With the high level of engagement that is achieved with the children and adults who visit, science centers remain a very effective mechanism to convey science to the public, provided that the centers constantly add and modify exhibits to reflect cutting edge science.

The Interaction of Art and Science

Art and science, "The Two Cultures" [37] of human endeavor, remain by definition and public perception, as two unique fields. The dissimilarities between art and science often obscure the similarities between the two fields. Science, governed by rationality and reproducibility, aims to uncover the underlying facts and phenomena of nature. Rationality and adherence to the Scientific Method maintain objectivity, precision and impartiality within science [35]. Reproducibility ensures that the results and observations obtained from experimental investigations are consistent with a generalized trend in nature. Experiments that cannot be reproduced are not acceptable. One common view of science held by the public follows the explanation of Aldous Huxley:

> "For science in its totality, the ultimate goal is the creation of a monistic system in which – on the symbolic level and in terms of the inferred components of invisibly and intangibly fine structure – the world's enormous multiplicity is reduced to something like unity, and the endless succession of unique events of a great many different kinds gets tidied up and simplified into a single rational order …" [34]

The public does not perceive science in the literal reductive sense as hinted by the tone in Huxley's explanation of science. The public perceives science on the symbolic level as being the field capable of simplifying nature's enormous complexity down to a very compact form using rational mechanisms. Science is governed primarily by "cool, detached, objective procedures," whereas art is governed by "hot, subjective intuition" [36]. Subjectivity is the cornerstone of art. Art integrates the desires and personalities of the artist into the final product. The artist's inspired vision, manifested in the final form of the piece, is attained through the "passionate use of artistic media" [35]. The problems that art attempt to solve have "only ad hoc solutions" [38] and do not require the absolute reproducibility that science does. Artistic quality is not measured by some generalized formula, which is unsettling from the scientific point of view. At the core of art lies paradox and duality. Works of art often attempt to show how we are to live with the contradictions that exist in our lives [38]. Art does not seek to provide all the solutions to the dualities that exist because it cannot. Duality in science however, is fundamentality contrary to the concept of "unity" within the field. The dual nature of light as both a wave and a particle is a classical example of the conflict that exists in science when a naturally observable phenomenon fails to be categorized as a single entity. Science rigorously assaults dualities until the evidence forces a change in the generally accepted theory or disproves them completely, but very rarely does science accept the duality without modification. Duality and paradox create inconsistencies within science and weaken the reassuring aspect of the field, while increasing the content depth and according to French painter George Braques, the "disturbing" intent of art.

The Two Cultures are not completely disjoint entities. It is possible to view art and science as part of the same unified culture. Cognitive monists view that both science and art are rational and see art as a part of science. Aesthetic monists hold that science is a part of art and that both art and science are irrational. Common views hold that science is rational or cognitive and art is irrational or non cognitive. There is another theory proposed by Richmond that asserts the "functionally interdependent relationship" of art and science [35]. Richmond corrects the aforementioned views on science and art by qualifying that "art is mainly irrational and science mainly rational." Karl Popper argues that new scientific theories are discovered through creative acts of intuition[42].Logic and rationality do not exist in discovery, but do exist in testing and criticism. Creative insight therefore provides new theories for testing in which case the logic and rationality of science can be applied to determine if the creative insight is actually grounded in reality. Rationality enters the realm of art when discussing how well a work of art "performs the function of art" [35]. Works of art must meet standards of art and often the more irrational a piece appears, the better the piece functions as an object of art. Richmond summarizes the interdependent system of art and science in the following:

> "Imagination, rationality, and works of art thus form an interdependent system. Imagination forms the matrix of inarticulate ideas and problems that works of art

> delineate. By delineating these problems and ideas, works of art stretch and transform the matrix of imagination. Science is an abstraction of the role of rationality in art, and art is an abstraction of the role of imagination in science. Consequently, art and science form an interdependent system." [35]

The personal attributes of artist and scientists help to unify the two cultures further. Common to both artists and scientists are the senses of innovation, intuition, precision, and intense attention to detail. Intuition is commonplace in art and viewed as a viable source of inspiration. Intuition in science leads an "underground existence," [38] even though many famous scientists have testified to the importance of intuition and inspiration in making their greatest of discoveries. Dibbets emphasizes that the artist is not motivated to create works that satisfy aesthetics or pay homage to beauty as many incorrectly believe. Instead, the artist is motivated in exactly the same way as the scientist, namely "to be astonished and to discover" [38]. Dibbets also argues that the problems for both the scientist and artist overlap in the following way:

> "For artists and scientists the problem is not so much *what* to do, but *how* to do it. But the outsider only wants to know: 'what is the practical utility', 'what is it'?" [38].

A bridge serves as a good example to illustrate the latter point. From the engineer's point of view, the obvious solution to connect neighboring points separated by some void or body of water is the bridge. The challenge for the engineer is to design the bridge that is specific for the given situation. The engineer then has to determine which design elements, from the vast multitude of options, will work. The poet, for example, who is inspired by the unique bridge that the engineers designed, must select the right arrangement of words to accurately express the subject. The poet must decide on which words to use, the overall form of the poem, and the ordering of words and phrases within lines. In the end, both the engineer and poet create a unique bridge with its own subtleties and intricacies.

History also reveals certain connections between art and science. When discussing the interactions of art and science, several authors [35,43-44] discuss The Renaissance, The Scientific Revolution, and Leonardo da Vinci. From history it can be argued that the scientific and artistic revolutions turned about the same discoveries of optics and of the importance of the linear perspective. Da Vinci is often included to represent the epitome of the early artist and scientist. In order to expand his artistic skills, da Vinci dissected cadavers in order to understand more completely and methodically the anatomy he was trying to recreate in his drawings and other works of art. Effectively, da Vinci was able to further his art through the direct use of scientific procedures. Additionally many of the artists of da Vinci's era also were highly skilled geometricians. The Einsteinian revolution and the Impressionist-Cubist revolutions also demonstrate similar concomitant changes in both art and science with the development of a nonlinear, multidimensional perspective of the universe. Einstein's theories of relativity demanded the overturn of Galilean-Newtonian space and time [45], while the Impressionist-Cubist revolutions demanded the recognition of "the pluralities of visual fields" [35]. At each of the major junctions of the art and science revolutions lies the dialogue assessing the fundamental question, "Where are we," and the same stretch of the imagination [35] required to formulate the response in both the art and science fields.

Creativity and the use of the imagination are not found in the typical objective definition of science, yet science history and testimony from prominent scientists indicate that the personal element plays an important role in scientific discovery. Michael Polanyi , a well known physical chemist who turned philosopher, argued that knowledge in general and scientific discoveries in particular do have personal elements [46]. Rene Dubos, a French-American microbiologist, expressed a similar view in his book on Pasteur:

> "… like its literary and artistic counterparts, the process of scientific creation is a completely personal experience for which no technique of observation has yet been devised" [47].

The importance of the personal element in scientific discovery is contained in the biographies of some of the Nobel-prize winners. Richard Feynmen's motivation for learning to draw was contained in his want "to convey an emotion about the beauty of the world" [48]. Barbara McClintock's biographer catalogues McClintock's belief that "good science cannot proceed without a deep emotional investment on the part of the scientist" [49]. Such testimony from scientists is highly contradictory to the stereotypical view of the "objective analytical scientist and the subjective intuitive artist" [43]. A modern view on both art and science therefore must include provisions for a mixture of both the objectivity and subjectivity in each field to be accurate and to also dispel the "notion of a battleground between art and science" [50].

Perceptions of Art and Science

Art and science are closely related fields. A unifying basis exists between the two human activities with regard to the creative act [50]. The uniqueness of man is attributed to the equal practice of both art and science. As the British mathematician Jacob Bronowski made evident:

> “Man is unique not because he does science, and he is unique not because he does art, but because science and art equally are expressions of his marvelous plasticity of mind” [51].

Many artists have been inspired by the scientific study of nature. Similarly, scientists have been inspired by art. The spectrum ranges from artists who create art influenced by the forms of nature, to those who use science to create art that references the wonder and mystery of scientific discovery and the world. The importance of illuminating the revelations offered through scientific discovery is emphasized in the following quote by Timothy Ferris:

> “The delights of science and mathematics, their revelations of natural beauty and harmony, their visions of things to come, and the joy of discovery in itself, the light and shadow it casts on the mystery dance of mind and nature, are too profound, and too important, to be left to scientists and mathematicians alone” [2].

Many artists have created works that have been heavily influenced by science. Artist Ned Kahn has been producing such pieces since 1982. His works are inspired by nature and instill a feeling of the wonder and awe of the natural world. In one of his most famous pieces, Kahn creates a small tornado-like, whirling column of fog. The exhibit is open, allowing viewers to move their bodies through the column to observe the effect of a change in the system. His work has been influenced by scientists such as meteorologist Edward Lorenze, the creator of the butterfly effect. Another one of Kahn’s pieces entitled “Wind Veil” allows a visualization of the normally unseen wind patterns. This work is composed of 80,000 aluminum discs connected in a grid which spans the face of a parking garage 260 feet wide and 6 stories tall. As the wind moves across the artwork, the plates move, showing the patterns of the wind, while simultaneously making interesting reflections inside the building. “Part of my philosophy", Kahn says, "is that in our culture, with its increased interest in computers and television and media, with the bombardment of mediated experiences, people have fewer and fewer opportunities to nurture their ability to observe and look closely. So my underlying goal is to create objects or places designed to encourage and nurture observation." Systematic observation is the essence of scientific research. Likewise, art is often based upon insightful observations [39].

Makrolab is an ambitious project combining art and science, while emphasizing the scientific method. Conceived by the Slovenian artist Marko Peljhan, Makrolab places artists and scientists in a remote geographic location together in a small self-sustainable structure that is a combination of a scientific laboratory and an artist’s studio. The team lives together for a period of several months, observing, studying and recording the natural phenomena occurring around them. The reason for the isolation of the team is to remove the distractions of everyday life, allowing for the pure observation of nature. This project is unique due to the simultaneous collaboration between artists and scientists. The Makrolab project breaks down the perceived barriers between the two disciplines [40].

Another artist whom art is heavily influenced by science is sculptor Kendall Buster. Buster’s works are based on observations of organisms viewed through a microscope. Her most recent sculpture, “Garden Snare”, creates the feeling of being inside a living, dividing cell. The sculpture is composed of a translucent skin stretched over a delicate structure. She hopes that it will let people travel to an ordinarily inaccessible space. Buster’s influence comes from her studies of microbiology in college and her work as a lab technician at a hospital. She spent much of her time studying medical slides under a microscope. As a professor of sculpture at Virginia Commonwealth University, Buster teaches her classes as if it were a science class, pushing her students to create art as if they were conducting research. Each sculpture should be an experiment to test a hypothesis. She encourages her students to think of their studios as labs[41].

Scanning Electron Microscopy as an Analytical Tool

The human being attributes a high degree of reliance upon the visual world. As a consequence, humankind is driven to find means to better view this world. In that pursuit, an even greater fascination, as well as frustration, exists when the observed is on a scale that is beyond the limitations of the unaided eye. Traditionally, humans have had an easier time comprehending scales smaller than what the unaided eye can perceive. Scales that approach the infinite tend to prove more elusive in their complete understanding. The world revealed through microscopy remains largely unexplored by the general population. The microscopic world remains a great source of mystery and excitement, which can be used to promote scientific advancement and appreciation among a diverse audience.

A common theme in the history of microscopy is the pursuit of increased magnification. The origins of this field have been argued to date as far back as the first century A.D. when Seneca came to the following realization upon observation through a clear spherical flask of water. He said, “letters however small and dim are comparatively large and distinct” [54]. Such an observation marks the origin of magnification tools and their utility. Little progress in the dozen centuries thereafter was made in lens crafting, except for the trial and error pursuit of making eyeglasses for the elderly from clear minerals. The fabrication of clear silicate glass was not successful until the process was refined in Italy in 1300 A.D. By the sixteenth century, both concave and convex lenses became readily available and as a result the Dutch were able to construct a crude microscope utilizing a linear combination of the two types of lenses to achieve magnification. In the early 1600’s, the fundamental Dutch microscope received the attentions of Johann Kepler and Galileo, who in turn explained how the microscope worked and further refined the lens design. At this particular time, history identifies the two main figures in experimental microscopy as being Robert Hooke and the Dutch draper, Antony van Leeuwenhoek. Between the two, a large volume of drawings from observed specimens was created, as well as a fairly extensive collection of custom microscopes. The general trend over the next two centuries was the further refinement and arrangement of the lenses to achieve a greater magnification. The eyepieces of Huygens (10x) and Ramsden (12x or greater) emerged during this time period and to a large extent are still used today [55].

The general trend to improve the optical lens continued into the early nineteenth century, until the limitations of light microscopy were demonstrated. In 1834 George Airy, an astronomer, demonstrated that light from a star could never be focused at a single point, but instead was limited to a disk. In 1873 Ernest Abbe, who was working with periodic structures, came to a similar conclusion as Airy, henceforth supporting the concept of numerical aperture, or the notion of a limiting angular distance. From the latter discoveries, it was apparent that light, even polarized or near field, was not going to allow higher forms of magnification. Only after de Broglie theory was established in 1924 and the demonstration took place by Busch in 1926 that a suitable magnetic field could be used as a lens, did the possibility of an electron microscope become evident. By the 1940’s, the transmission electron microscope had become commercially available. In the latter part of the century, interest in the scanning electron microscope was raised first by C.W. Oatley. Improvements to the SEM continue to this very day. However, the resolving power of the microscope was pushed beyond the limits of the SEM with the development of the scanning tunneling microscope (STM) in the 1970's [56].

Since the instrument's origin, the electron microscope has found merit in virtually all of the fields of the natural sciences. Clearly the utility of the instrument to the scientific community lies within its ability to image objects beyond the resolution limitations imposed by the wavelengths of light in optical microscopes and some professionals would extend the utility of the electron microscope to that of an irreplaceable tool [1]. The evolution of the electron microscope has led to the development of the scanning electron microscope (SEM) with additional tools such as energy dispersive X-ray microanalysis (EDX).

Briefly, EDX is an additional technology attached to the electron microscope that detects, analyzes, and records the energies of the various X-rays produced by the material. The distribution of the energies of the X-rays can be used to determine the elemental surface composition of the material. Other forms of detectors present in the EDX component are also included in order to account for lighter elements, such as carbon, nitrogen, and oxygen. The overall combination of the recording of the surface morphology obtained from electron mapping, the recording of X-ray spectra, and the presence of other lighter elements has allowed for the analysis of micro domains of major and minor compounds [1]. SEM/EDX technologies are nevertheless a satisfactory response to the call of Hornblower [2,3] in 1962 for the need of a technology that could gather significant information "as to the distribution of elements on a fine scale," regarding problems in archeology. Since Hornblower's time, SEM/EDX technologies have been widely used for a large spectrum of material analysis, including art- and archeology-related investigations of degradation and preservation processes [4-7].

The Use of SEM as a Source of Artistic Inspiration

Microscopy is defined as the “interpretive use of microscopes.” The definition involves a primary observer, a microscope, and a specimen. In essence, a primary observer uses a microscope to view a particular specimen and then is required by definition to interpret the findings. The definition does not restrict microscopy solely to the rational applications of science. Artists can also use microscopy in the creation of their work.

The use of microscopy to create a viable art form extends far beyond the suggestion proposed by the definition. The constant motivation for new inspiration is what fuels the artists’ search for their next new and unique image. With the ability to visualize features as small as forty angstroms, the scanning electron microscope allows artists to “see” into a new, vastly uncharted world. The current appeal to artists lies in the ability to traverse vast differences in scale with the SEM. The purpose of SEM-produced art is not that of deception, attributed to the concealment of the true scale of the piece, but moreover to decontextualize what cannot be observed by the unaided eye.

The use of SEM images as art forms is not as rare as one may assume. One of the leading artists specializing in SEM images is David Scharf. Scharf, a photographer since the age of nine, is known for providing high quality colorized SEM images of specimens mostly from the biological world, but also includes found objects related to science and technology such as accelerometers and computer chips. Scharf's images are well known for their artistic content and technical perfection, being worthy of entry into such esteemed, popular magazines as Life, Time, National Geographic, and Scientific American. Scharf is in essence both an artist and a scientist. His knowledge of electronics engineering has enabled him to improve upon the SEM image acquisition process. Scharf's innovations include the intelligent colorization of the SEM image through the use of multiple detectors, the use of video to record specimens under the SEM and innovative preparation techniques to observe biological systems in their native state. These innovations benefit both scientific and artistic endeavors.[57]

Scientific illustrator, Dee Breger is well known for her work at the Lamont Geological Observatory at Columbia University in New York. Breger has served as the Manager of Lamont's SEM/EDX facility since 1982. Breger derives much joy and satisfaction in bringing the "microworld to the general public." She accomplishes this through her use of SEM images obtained from cutting edge research around the globe as well as with her own SEM images. Breger holds a degree in art from the University of Wisconsin and possesses an exceptional eye for providing "extraordinary perspective on some ordinary things." Breger's images reflect "the astonishment, respect and aesthetic pleasure we get as we marvel at the variety of forms existence itself takes and its enormous range of scales." Breger communicates the essence of artistic perceptions through the use of cutting edge technology [58].

Liz Douglas is another artist who utilizes SEM images in her artwork. Douglas holds a Masters of Fine Art in Painting from Edinburgh College of Art. Douglas's work focuses primarily on the natural forms created by tectonic plates and glacial action. Her work also references graptolite fossils and alpine plants. The forms she observes with the SEM inspire her art. Douglas also works with younger students, exposing them to the natural beauty of plant and geological materials observed in SEM photographs. The work of Douglas serves as a prime example of the use of SEM images as inspiration for artistic creation. [59]

Light microscopy as an Analytical Tool

Living cells and other unstained biological samples can be difficult to visualize using standard light microscopy techniques. In 1955, Francis Smith developed a method to view these difficult specimens [52]. Smith modified a polarized light microscope by adding two Wollaston prisms into the optical path. The prisms, when combined with the polarized light, convert gradients in the optical path thickness of the specimen into amplitude differences. This increases the contrast of the specimen being viewed, giving it a pseudo three-dimensional appearance. Unfortunately this often gives the viewer a false impression that the appearance of shadows in the image shows the topography of the specimen.

Differential Interference Contrast Microscopy as an Analytic Tool

DIC microscopy has many benefits over standard light microscopy. It allows excellent visualization of transparent specimens. With previous systems, specimens had to be very thin and the images suffered from halo effects and limited aperture. With DIC microscopy, the optical path is free from restrictions, allowing full aperture viewing and increased resolution. In addition, it has the ability to read thick specimens. DIC Microscopy also allows for the incorporation of other analytical techniques such as fluorescence microscopy.

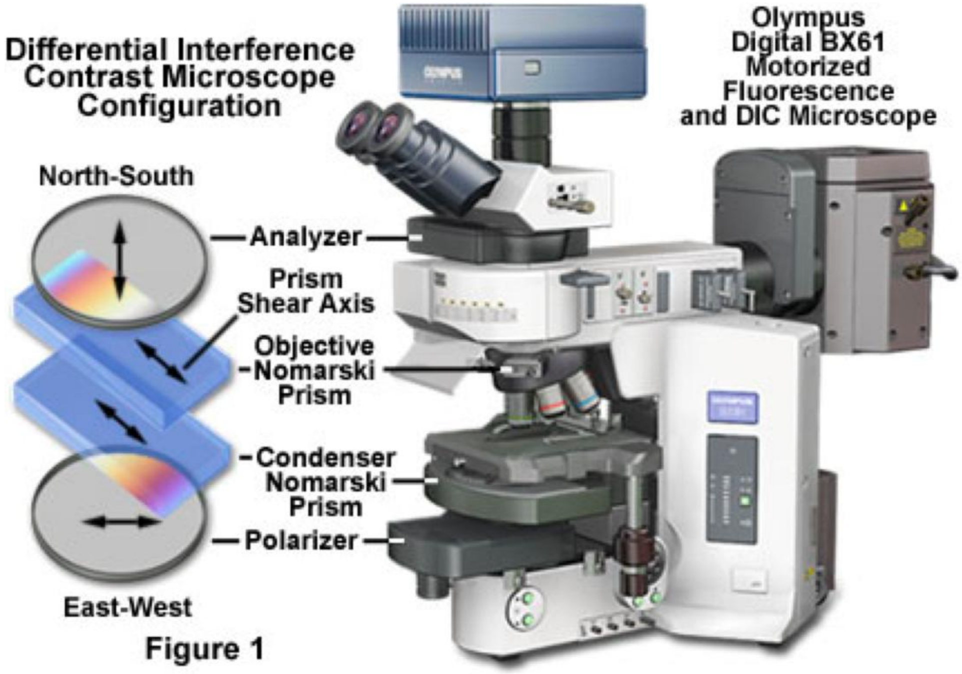


Figure 1- DIC microscope courtesy of Olympus [52]

Fluorescence Imaging as an Analytical Tool

Fluorescence is defined as the ability for a substance to absorb light and subsequently re-radiate it. The British scientist Sir George G. Stokes first described fluorescence in 1852 [53]. He noticed that many materials would emit a light with a longer wavelength than of the excitation source. Many materials were noted to fluoresce after this discovery, but it was not until the

1930’s that this characteristic of certain materials was applied to the field of microscopy. Since then, fluorochromes have been used extensively to stain tissues, bacteria and other pathogens to aid scientist in their research. Fluorescence microscopy is used to identify cells and sub-microscopic cellular structures by staining certain parts of the specimen with flourochromes.

Objectives

The main objective of this project is to create an artistic exhibit of images and artifacts inspired by research being conducted at WPI. The purpose of this exhibit is to generate interest in science and technology, as well as scientific and engineering processes. The exhibit will draw attention to research being conducted at WPI, and attempt to attract people to the scientific pursuit of knowledge. We hope to inspire students to pursue degrees and careers in science and technology by demonstrating the inherent beauty and creativity involved in scientific research. The highlighted research will address problems of importance to society and the practical applications and global impact of the research will be presented. The works will be presented in such a way as to also be of interest and successful as design and art objects. This exhibit will be designed so as to be equally at home in either an art gallery or a science museum, thus bridging the worlds of science and art. We hope to open a dialogue between artists, scientists and the community by exhibiting in both art and science venues. The exhibit will also make the research more accessible to a diverse audience, with emphasis on the elementary- to high school-aged children so that they may be attracted to pursuing careers and degrees in science and technology.

Methodology

Project Design: Origins

Originally, the goal of this project was to create a coffee table-style book of SEM images from various research groups at WPI. Each research group would have had two pages, the first being an SEM image representing their respective research, and the second being a description of the research and the SEM image. Each image selected was to appear as if it were a common figure at the macroscopic level. This requirement was the integral provision for the original SEM image selection. Each selected image was to be given a nonscientific title in order to make the viewer believe that what they were seeing was actually the common macroscopic item as indicated by the title. In a sense, the "art of deception," was to be employed in order to bring about an awakening or a sense of new discovery and excitement within the viewer.

The viewer would initially see the image and the deceptive title on one page before reading the description of the research and accompanying image. It was the assumption that the majority of viewers would not have had experience with the microscopic world or the research being represented, especially since the research was to be current and cutting-edge. By titling the images with common and non-technical terms, it was anticipated that the viewer would feel more comfortable studying the image. Eventually, the viewer would examine the adjacent page, where the true description would be written. It was hoped that the viewer would then be compelled to reexamine the image for the subtleties that distinguish the common item from the scientific item. It was theorized that such a revelation would be an effective means to communicate the highly technical research to the general population.

The original project was intended to be created by a single student and carried with it provisions to be expanded over future academic years. The initial methodology included a process of interviewing representatives from various research groups, from which some would be selected to be included in the booklet. Also, the student would learn how to use the SEM to acquire micrographs of pertinent processes from the selected research groups. The project was revised due to the time requirements associated with working through a full course in SEM operation and sample preparation. The revised provisions called for the inclusion of research into the project with pre-existing SEM or other microscopic images, but did not demand the inclusion of SEM images taken by the project team. Finally, the images would be assembled into a book along with descriptions of the associated research.

The group was subsequently expanded to include a total of three students. The first meeting of the entire group was focused on evaluating the original project design and discussing how it could be altered or modified to better achieve the projects goals and objectives. These were reevaluated and modified in response to the input of the entire team.

The goals and objectives remained focused on presenting these products of scientific research (SEM images) in a creative and artistic context so as to widen the circle of peopleable to benefit from the insights and inspirations that they offer. The idea of using an exhibit in order to open a dialogue within the community, by bringing together populations that normally have little contact with each other, was established as a common goal of the team. By linking the artistic and scientific members of the community, both through the exhibit's creation and its implications, we hoped to instill in all viewers a wider appreciation for the links between scientific research and the creative endeavors of the artist. Achieving this goal necessitated securing venues of exhibition, which would facilitate access to the exhibit by the entire community.

The content of the exhibit itself was one of the main focuses of these first team meetings. The diversity of the backgrounds and interests of the team members resulted in the expansion of the original plan to utilize only SEM images. The idea of using 3 dimensional objects, video, text and quotes, and other forms of imaging besides SEM was seen by the team as a way to better achieve our goals and objectives. By making the exhibit more dynamic and engaging we hoped to more successfully communicate with the viewers.

Venues identified for possible exhibition included Arts Worcester, the EcoTarium, Clark University, and the Gordon Library at WPI. Team members Andres Lopez and Ian Anderson had previously exhibited at Arts Worcester and the Gordon Library. The director of Arts Worcester, Janice Seymour, directs the exhibitions at 8 local galleries and was a valuable resource to the team. She was kept informed of the team's intentions and progress throughout the project. Team member Ian Anderson maintained contacts at Clark University as well and was enlisted to investigate exhibition venues at that University. Professors Pins and Wilcox were chosen to make contact with the EcoTarium and investigate possible exhibition there.

Support and Funding

Funding became one of the main focuses of our team’s initial efforts, as resources available would dictate the scope, appearance, and content of the final exhibit. A grant application was submitted to the Worcester Cultural Commission with the help of the Research Administration office at WPI. The objective of the grant application was to be able to raise enough funding to be able to create a professional exhibit. A copy of the grant application is provided in **Appendix (1.1)**. Fredric Russo was invaluable to the preparation of the grant application and in the securing of matching funds from WPI. A benefit of the grant application process was the need to obtain letters of support for the project and the team members from a wide range of prominent figures within the community. This provided an avenue to spread word of the project and generate interest and support within the community.

A letter of support was obtained for the project from June Eressy, the principle of The University Park Campus School, a Worcester public school designed with the help of Clark University. A copy of the letter is provided in **Appendix (1.1)**The progressive and innovate nature of the school has made it a national model and one of Worcester’s greatest educational success stories. The school draws from some of the poorest neighborhoods in the city, perhaps representing the population the team most wants to reach with this exhibition. The number of children from these socioeconomic and racial groups going to college at all, let alone for science and technology, are far below the national averages. By exciting and attracting some of these students to the sciences, we provide society with more scientifically literate and skilled individuals, and we help the students rise out of cycles of poverty that are so difficult to escape.

A letter of support was also obtained from Janice Seymour of Arts Worcester **Appendix (1.1)**. Her enthusiasm and support for the project provided the team with multiple benefits. Her direction of multiple art galleries in Worcester, both public and private, provided the team with several possible venues for exhibition. She is also involved with a myriad of comities and projects within the community at any given time. Her discussions with this diverse cross section of civically-minded persons informed the community about our project, provided publicity and community awareness of the project and its exhibition before it had even been completed.

Unfortunately the Worcester Cultural Commission rejected the grant application due to a late submission. The application process did however generate interest in the project as letters of support were obtained from Arts Worcester, and the principal of a Worcester public school, June Eressy. Funding was subsequently procured through Professor Wilcox' professional development fund and the IGSD office at WPI. A working budget of 1,400.00 dollars was established.

Researcher Interviews

Professors at WPI were interviewed by the team and asked questions pertaining to the nature of their research. An interview form was developed to aid the team in gathering and organizing information from the interviews and is provided in **Appendix (1.2)**. The goal of the interview was to determine the nature of their research and it's suitability for the project. Researchers were asked if they utilized SEM or other forms of microscopy in their research as a means to quickly establish the likelihood of their ability to provide us with images. The relevance and significance of their research was then discussed to determine the overall relevance of their work to society. They were next asked about equipment and processes involved in their research to determine whether there were artifacts or lab processes that would be of visual interest involved in their research. We asked the researchers for images that they would be willing to let us exhibit and then created a library of images from which we could create the works. A summary of each interview is provided in **Appendix (1.2).**

Mid way through the interviewing phase, the research team under Lauren Matthews expressed the need for SEM images of the unknown fine structure of the reproductive systems of crayfish. Due to the time requirements of sample preparation for the SEM, it was decided to attempt to obtain an SEM micrograph of the crayfish, time permitting.

Imaging

There are several points that had to be taken into account when selecting images for the exhibit. First and foremost was visual interest. The images had to be interesting to look at. Without dynamic, eye-catching images, the observer would pass over them and dismiss the exhibit as a whole. In addition to having dynamic images, we required that the topics presented be interesting and relevant to society. Relevancy was determined by evaluating the researches potential impact and benefit to society, human health, and the environment.

The next most important criterion in selecting the images for the exhibit was image quality. The ideal resolution of a file being printed for a gallery is 300 pixels per inch(ppi) at the desired dimensions. For example, to print an 8 by 10 inch photo, the digital file would require a resolution of at least 2400 by 3000 pixels, which is the equivalent of a picture being taken with a 7.2 mega-pixel camera. For our purposes, 175ppi was enough resolution to give us an acceptable print. The majority of the images obtained are 512 by 512 pixels, which allowed us to make prints 3 by 3 inches without any loss in image quality. As the resolution of a file decreases, the image looses detail, has less contrast, and becomes less dynamic. At the extreme range, the individual pixels become visible leading to a pixilated or blocky image.

There are ways to increase the resolution of an image. When an image is enlarged in Adobe Photoshop©, the program interpolates the data. The program inserts pixels, choosing their colors based on information from the surrounding pixels. The amount that an image can be enlarged is limited however, since the pixels quickly become apparent as the size is increased. The quality can be improved slightly by enlarging the image by no more than ten percent at a time and between each enlargement, a filter can be used to help smooth the edges of the pixels. This creates an image that is larger and does not look pixilated, but its clarity will suffer as the image is enlarged.

The quality of our prints was also based on the file format. The most common file type used is the JPEG format, which is the name for a compression algorithm that shrinks the size of the file while maintaining its resolution. The new JPEG format can reduce the size of a file by up to twenty percent. Unfortunately, this compression does not come without a cost. The compression works by breaking an image into 8 by 8 pixel blocks, and characterizes them. While this process does create manageable file sizes, it leaves the image looking blocky and pixilated. Many of the images that we received were in the JPEG format because of the ease of storing and transferring the files. Two other common file formats that were encountered were bitmap (BMP) and (TIFF). Both of these are uncompressed file formats that do not have the degradation associated with the JEPG format.

Black and White Wet Process

Traditional black and white photographs are typically printed on silver-gelatin paper. The paper is coated with a gelatin film impregnated with silver halide crystals. The silver halide reacts with exposure to light and the developing chemicals to create a permanent image. Unlike a flat-looking inkjet print where the pigment is laid onto the surface of the paper, silver-gelatin prints appear to have more depth to them. The chemicals are suspended all throughout the gelatin coating on the paper instead of sitting on the surface like an inkjet print. Where there are highlights, very few silver halide crystals remain and the white base of the paper is visible. The shadows of the image are composed of layers of silver halide crystals stacked on top of each other, completely obscuring the white base. This layering of silver gives the print a three-dimensional quality and a luminescence that cannot currently be matched by an inkjet print.

To print on silver-gelatin paper, a transparent negative image is needed. Light is shone through the film, and projected onto the photo paper. Some of the older SEM images were recorded using Polaroid 4 by 5 film. This film produces an instant positive image and a negative transparency used to create enlargements. With a 4 by 5 inch sheet of film, it is possible to make quality prints up to several feet across on silver-gelatin paper. If a negative is not available, an inter-negative can be created from a digital file using a laser film recorder (LFR), which will project a digital image onto a piece of film. This makes it possible to print a digital image on traditional wet-process paper. The problem is that they must be contact printed, which means the negative cannot be enlarged.

Test Prints

To test the print quality of an image, a local printing service, LB Wheatons, was employed to produce three different sized prints from several files. A file 512x512 pixels was printed at 4"x6", 5"x7" and 8"x10". Following the standard of 300 ppi, a 521 pixel file could only be printed at 1.7"x1.7". Within the quality tests, the 4x6 prints had sharp borders, the pixels were not visible, and the images seemed to pop out of the page. The 5x7 inch prints however started to lose some contrast and clarity around the edges, but were still acceptable. The 8x10 inch prints lost considerable clarity and contrast and the individual pixels became evident. This may still be acceptable for our purposes because the benefits of having a large image outweigh the benefits of clarity and crispness.

Frame Design

Once all of the images were obtained from the researchers, samples were printed to check image quality. Many of the files were only suitable to make small prints without loss of quality. The images of the electrospun fibers and the black and white oocytes were very small files and could only be printed at two by two inches. Fortunately, due to the high volume of these images, we were able to create successful compositions. Both pieces benefited from having large numbers of images. Showing many similar images from the same research helped relate the art back to science. Scientists often search through similar samples looking for slight variations which can reveal valuable information.

Some of the larger files, such as the florescent microscopy images of smooth muscle cells captured by Marsha Rolle, could be arranged in such a way that by using only five images the piece could still be very dynamic and intriguing. The intense color in these images allowed the piece to be successful while having fewer images.

Once image sizes and preliminary composition ideas were decided, the best images were sized to the proper dimensions and resolution for printing, as well as basic color, level and contrast corrections. The images were then sent to White House Custom Color to be printed. The team settled on metallic glossy paper for the final prints, which made the images look slightly luminescent and therefore more engaging. For each piece, more images than were necessary to fit in the frames were printed so that there were more to work with for the final composition of the piece.

Next, the team designed the frames to hold the images. We did not want this to simply look like an exhibition of some pictures in frames. The frames needed to be part of the art, not just a means to display it. We settled on using steel as our medium because it allowed us to create unique and engaging frame designs. It was also possible to finish the steel so that it had a clean and simple look that did not compete with the images. Pro Engineer solid modeling software was used to visualize the frame designs. Proper aesthetic appearance was achieved by independently modifying parameters including image layout, border size, frame thickness and overall size. It was important to make sure that all of these parameters were optimized so that the frame complimented the images without interfering with them. Figure 2 shows several iterations of the design of the frame in which images from Satya Shikumar's work were displayed. In each design alternative, only the border size was changed until balance was achieved. Pro Engineer allowed us to easily visualize and communicate small changes in design to the group before manufacturing the frame.

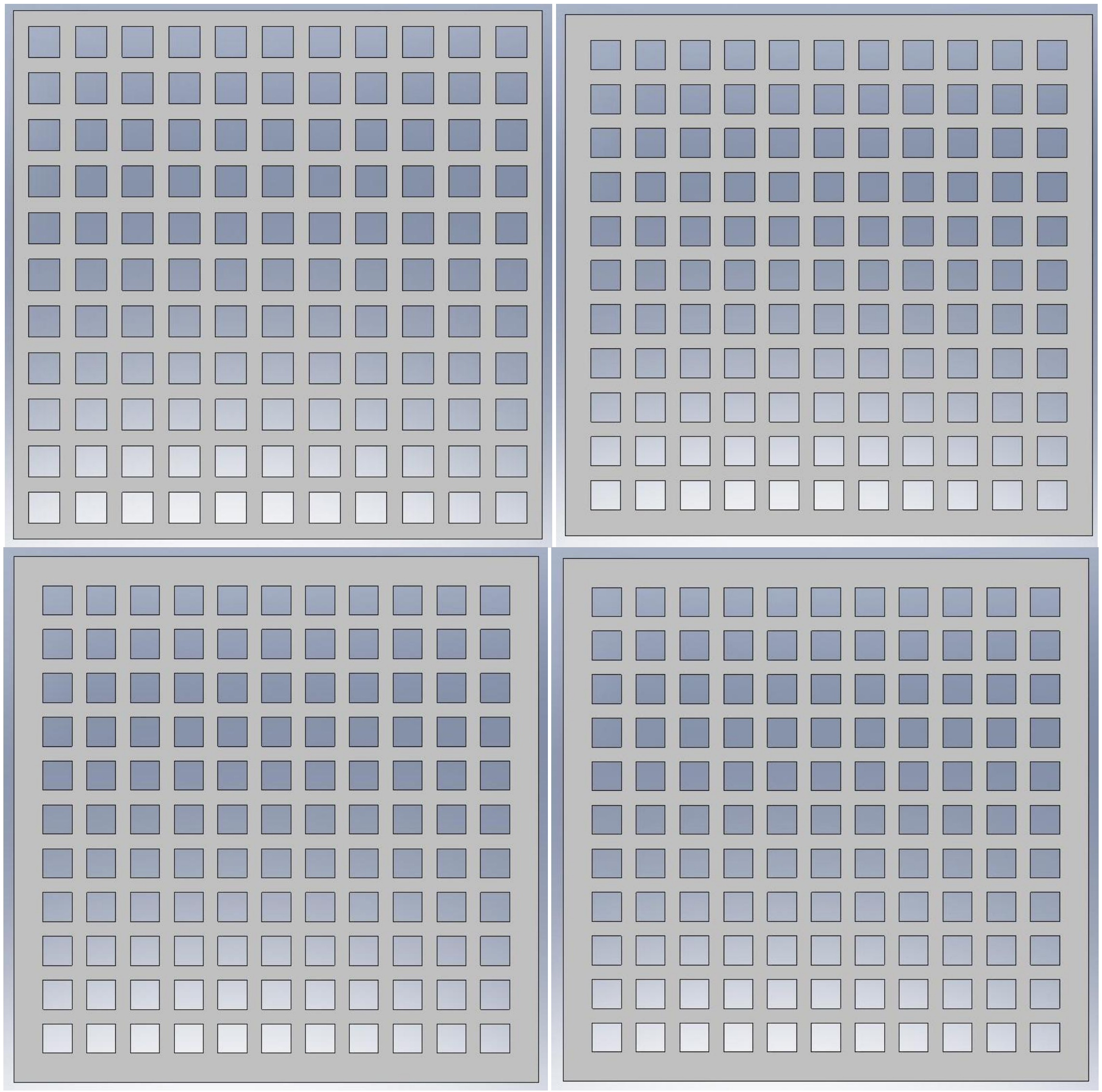


Figure 2- Frame design choices

After the design was complete, the pattern was made which would be used to cut the sheet metal. This was exported to a DXF file, which was to be sent to the company to be cut. The DXF file format is the last step before the individual machine level code is created in Computer Numerical Controlled (CNC) machining. Figure 3 shows two CAD images of the frame, as it would look on a wall and as the flat sheet metal pattern before bending.

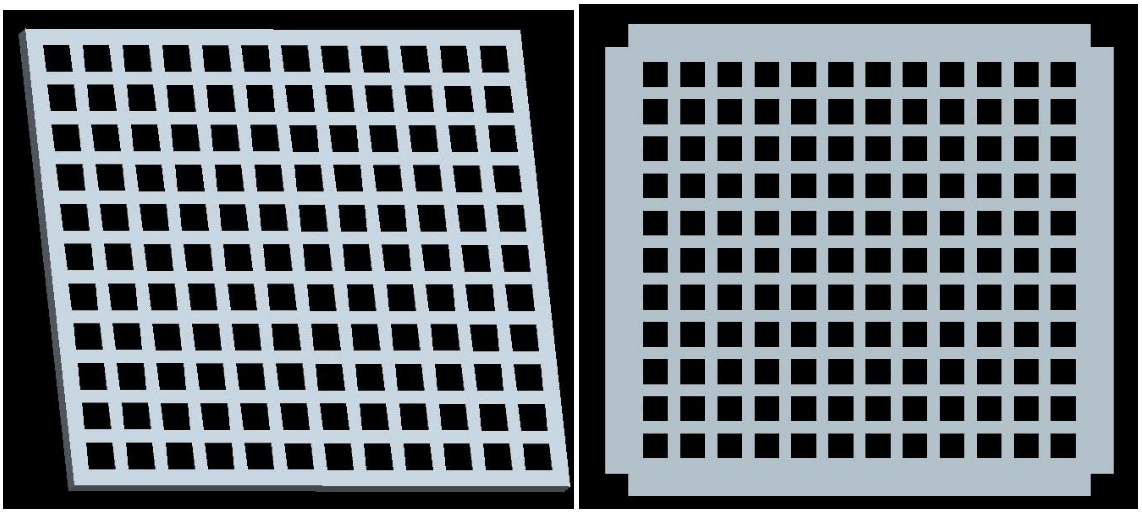


Figure 3- Frame and sheet metal pattern

The CAD files were sent to Vangy Tool Company in Worcester, Massachusetts who cut out the designs from 16-gauge and 14-gauge mild steel sheet. The water jet was chosen over plasma and gas torch based machines because it provides the most accurate and reliable results cutting thinner sheet metal. The pieces were then brought to D B Cotton in Putnam, Connecticut to have the sides bent on an industrial metal brake. Seems or bends were also added at the wall edge of the pieces so that there were no sharp edges against the wall.

The pieces were then brought to Blind Sight Sculpture in Thompson, Connecticut where the team finished the fabrication themselves. The corners of each piece were TIG welded and then sanded smoothed so that the pieces appeared to be seamless as shown in figure 3. Brackets were then welded onto the backs to align the Plexiglas and the foam core onto which the photographic prints were attached. Threaded studs were then welded onto the backs in the corners so that welded steel frames could be used to secure the Plexiglas and foam core from behind as seen in

Figures 4 and 5. The welds showing through onto the front, from welding the tabs and threaded studs onto the back, were then sanded smooth to maintain a seamless and clean aesthetic. Steel washers were then welded onto the inner back edges to provide a location to attach picture wire for hanging. In order to space the bottom of each piece to maintain parallel with the wall in various installation situations, holes were tapped for small machine screws in the back bottom of each piece so that the spacing from the wall could be adjusted upon installation if needed. The entire assemblies were then blasted with glass beads in order to achieve a uniform satin finish of clean bare steel as shown in Figure 7.

Figure 4- Welded corners ground smooth

Figure 5- Detail of threaded stud

Figure 6- Frame securing matte and Plexiglas

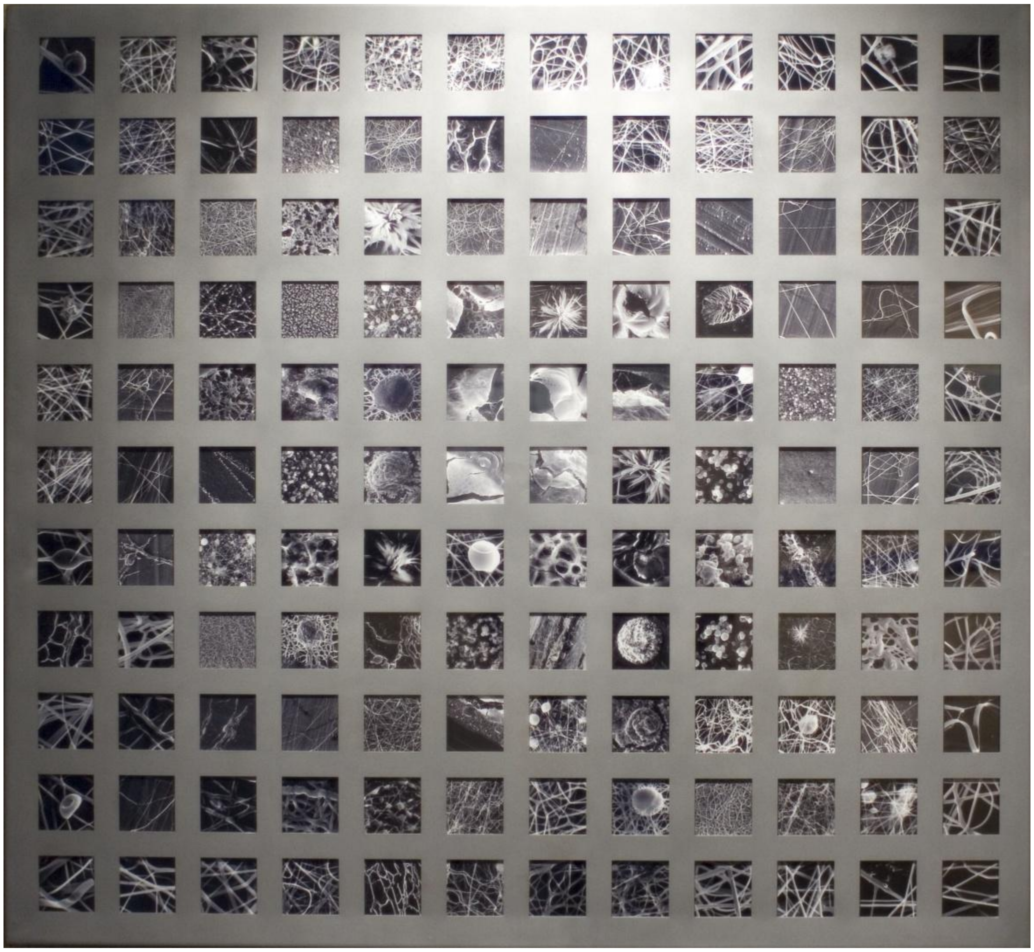
Figure 7- Glass beading a frame

The openings for the prints were traced onto the foam core by installing it without the Plexiglas and tracing the openings with a pencil. The foam core was then removed and the images for each piece were arranged and selected. Aesthetic considerations were balanced with the need to convey a sense of the original purpose of the images. The scientific origins of the images were acknowledged by maintaining images in groups that suggested that there was information being gathered and a methodology was involved in there capture. Once the images were arranged and selected they were glued onto the foam core using the tracings as a guide. The pieces were then clear coated with an acrylic clear coat before final assembly with the Plexiglas and images.

Design of Individual Works

Electrospun Fibers

Scanning Electron Microscopy
Research conducted by:
Satya Shivkumar – WPI Professor Mechanical Engineering Dept.
Goki Eda, WPI Graduate Student, Alumni
Xiaoshu Dai, WPI Graduate Student, Alumni



The pictures shown here are of various polymer fibers created by a technique called Electrospinning. In this technique, a polymer is dissolved in a solvent and the resulting solution is spun under the action of a high voltage to produce fibrous meshes. Polymer meshes are frequently used in many biomedical applications such as drug delivery devices and tissue engineering scaffolds. The applications of this research are of tremendous importance to human health care.

The organization of this piece was one of the most difficult due to the sheer number and variety of images. Many incarnations were tried before the final layout was decided upon. The team started by laying out the images on the matte in a random order. Next the images were arranged by tonality, with the darkest ones towards the edges, and the lighter images in the center. The piece was not aesthetically balanced with this arrangement, so we reorganized it so that the most strongly composed images were at the center, and the more uniform fibrous pictures were at the edge. This overall pattern worked well, but more adjustments were necessary. Next we rearranged any images that seemed out of place to reach the final layout that seemed natural and aesthetically pleasing. Even without text, this piece is able to hint at the scientific method. Scientists change parameters of a process to create variations in the outcome of the experiment. This piece shows the record of such changes, which a scientist would then study to determine the results of modifying these parameters. By viewing the results of such an experiment, the observer can start to get an understanding of how the scientific method works.

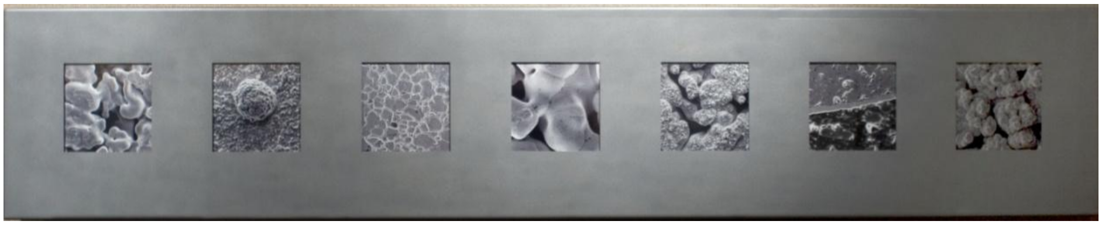
Vascular Smooth Muscle Cells

Fluorescence Microscopy
Research Conducted by:
Marsha Rolle
Assistant Professor WPI, Biomedical Engineering

The images are all vascular smooth muscle cells isolated from rat tissue, cultured on glass coverslips and stained using fluorescently-tagged molecules. The purpose of her experiments was to characterize cell shape, and the quantity and organization of the "scaffold" proteins the cells produce. Marsha Rolle's research is focused on coaxing cells to make and assemble their own scaffolds, rather than relying on exogenous scaffold materials for tissue engineering. The red stain is rhodamine (red fluorescent molecule)-conjugated phalloidin, which binds tightly to actin, which makes up the cellular "skeleton". The green staining is a fluorescein (green fluorescent molecule)-conjugated antibody that binds to fibronectin, a cellular "scaffold" protein. Finally, the blue staining (Hoechst dye) is a DNA-binding molecule and is used to stain nuclei. Showing all three colors in the piece revealed to the viewer how each color allowed the visualization of very different components of the cell and tissue. The process of the actual research was thus portrayed by the piece. The research has important implications to human health care. Tissue engineering and regenerative medicine are two areas with the potential to realize significant advances from this research.

Inorganic Hydrogen Separation Membranes

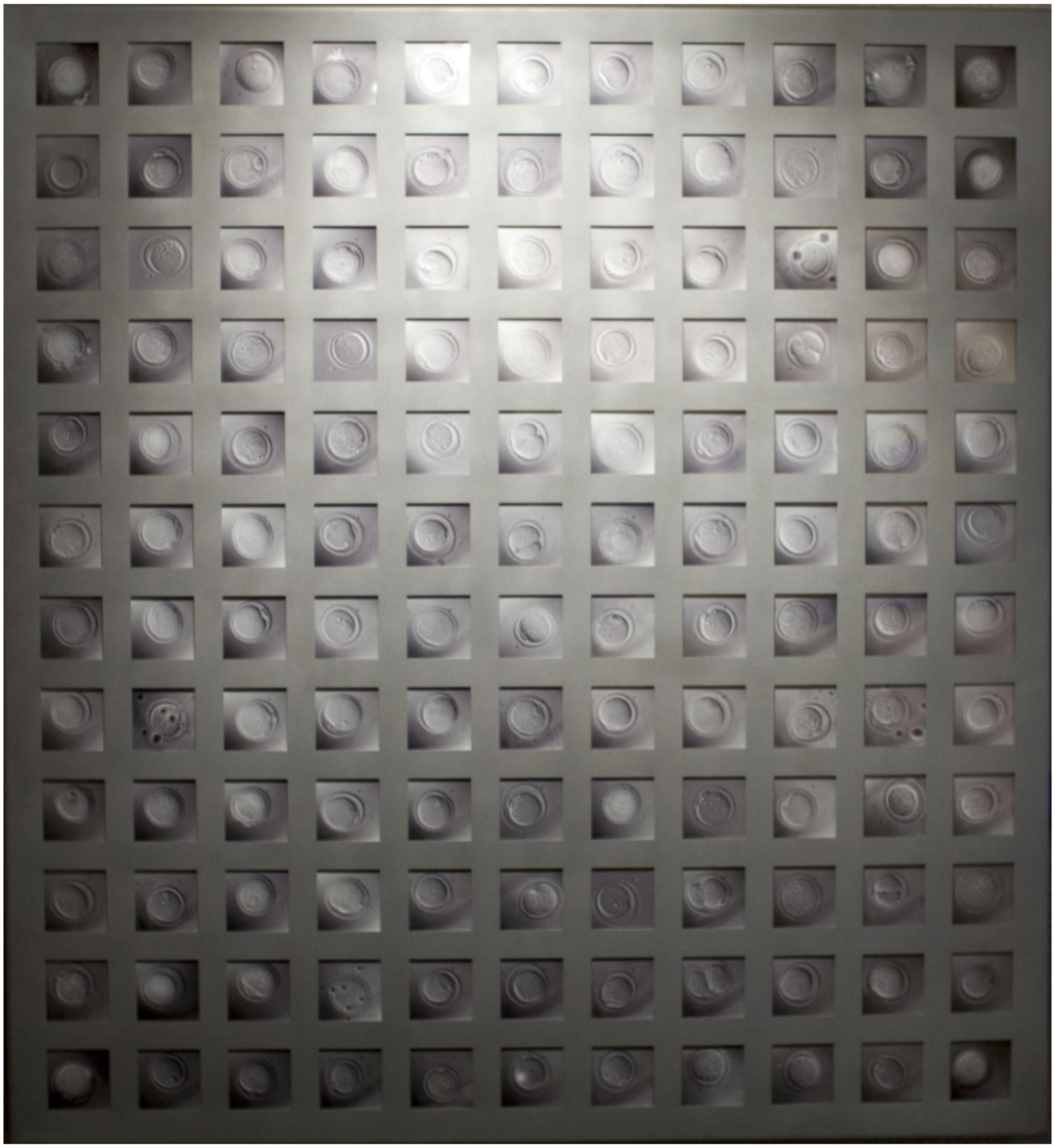
SEM Micrograph
Research conducted by:
    Yi Hua (Ed) Ma
        WPI Professor, Chemical Engineering
    M. Engin Ayturk
        WPI Research Assistant Professor, Chemical Engineering
    Images courtesy of Center for Inorganic Membrane Studies



Images show the top surface of cross-sectional SEI micrographs of oxidized, activated, and palladium (Pd) and/or silver (Ag) deposited porous (or non-porous) sintered metal supports. The Center for Inorganic Membrane Studies at WPI is led by Professor Yi Hua Ma (Frances B. Manning Professor of Chemical Engineering). The goals of the Center are to develop industry and university collaboration for inorganic membrane research and to promote and expand the science of inorganic membranes as a technological base for industrial applications through fundamental research. Hydrogen separation is one of the most significant potential applications of this research and has tremendous potential for changing humanities energy options. Different magnifications of the surface as well as cross sections were shown in order to create a narrative referencing the investigation done by the researchers.

Mouse Oocytes

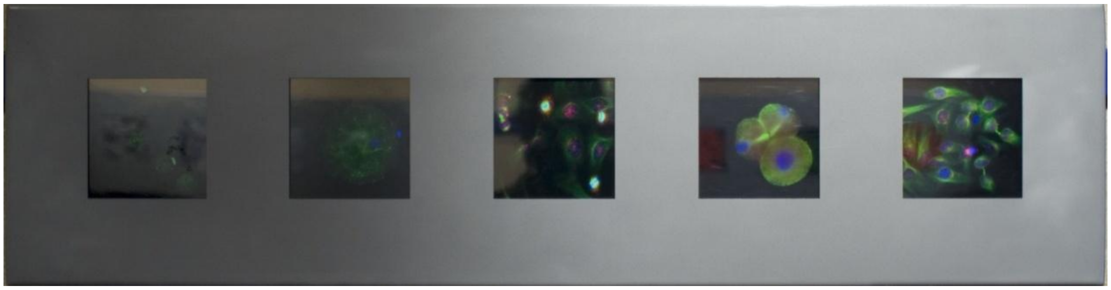
Differential Interference Contrast Microscopy
Research conducted by:
Eric Overstrom,
WPI Professor, Biology and Biotechnology
Christine Lima,
Biology and Biotechnology Graduate Student



Research focuses on developmental biology. Eggs and sperm are studied with a focus on gene expression in both, as well as the fertilization process timing and intricacies. Relevance to human fertility and industrial agriculture are some of the main implications. Methods to expel DNA from eggs chemically are being examined in order to set the stage for effective cloning. The vast amount of images of such similar yet different cells highlights the repetitive nature of the observations conducted in the research and nature of life itself.

Oocytes, HeLa Cells and Fibroblasts

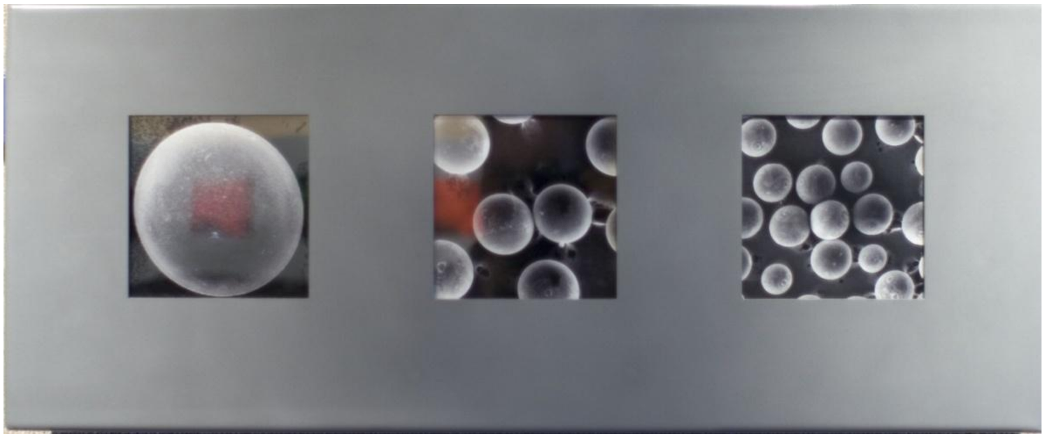
Fluorescence Microcopy
Research conducted by:
Eric Overstrom,
WPI Professor, Biology and Biotechnology
Christine Lima,
Biology and Biotechnology Graduate Student



Research utilizes fluorescent microscopy to study cell growth and division. The fluorescent tags reveal the locations of molecules of interest so that researchers can accurately describe the cell processes underlying fertility, cell growth, and disease. The applications to human health and medicine are significant. The pieces reveal the importance of the fluorescent tags to identifying structures in the cells and demonstrate the processes of the researchers.

Zeolites

Scanning Electron Microscopy
Research conducted by:
Prasad S. Sarangapani, Nathan T.H. Neal, Matthew R. Knott, Proffessor Robert W. Thompson, and Antony S.T. Chiang



Images show silicate-1 microspheres, using a Dowex® ion-exchange resin as macrotemplate. Each sphere is a hollow particle composed primarily from the ion-exchange polymer. The grainy surface of the sphere consists of a zeolite film. The hollow microspheres are shown mounted on a copper specimen holder. The Thompson Research Group at WPI investigates the methods of synthesis for various zeolite molecules. Zeolites are composed primarily of silicon, oxygen, and aluminum. Zeolites form solid open structures with specific sized interior cavities and can be compared to a molecular version of a sieve or sponge in their ability to trap specific cations. There has been recent interest in using zeolites for environmental remediation, especially in wastewater applications. The Thompson Group examines the assembly of zeolite nanocrystals into various morphologies in order to increase the external surface area.

Analysis of a Steel Beam from the World Trade Center

Scanning Electron Microscopy
Research conducted by:
Ronald R. Biederman, Professor, Mechanical Eng. WPI
R.D. Sisson, Jr. Professor, WPI
George F. Vander Voort, Buehler Inc.

These images show a metallographic cross section of steel beams from the World Trade Center building 7. They show the results of high temperature attack of the steel by a slag. These images are from a study done for FEMA in May 2002 which overviews how and why the steel failed. Research like this is useful for public safety. By analyzing the steel, the causes of its failure can be identified and in the future changes can be made to buildings to help reduce the chance of such failures. For this piece, we had to choose between seven excellent images. We decided to use three different types to show the different methods of coloring images for analysis that researchers utilize to reveal information.

Video Console and Text

Information about the nature of the images and research represented in each piece, as well as the researchers responsible for the images was provided in two ways. First, there was a small tag created to display next to each piece providing some basic information, secondly, a video display was created to provide more detailed information. The video display was created by editing together images into a slide show, with transitions, and by zooming in and out of the images to create interest and motion. Text providing information about the researchers and the images was superimposed over the relevant images. Quotes by famous scientists were also include and displayed over images and video clips obtained of researchers in their labs at WPI. The video screen was incorporated into a floor standing steel display designed and fabricated by the team.

A video console was included in the exhibit so that information related to the research could be made available in an engaging and professional manner. This gave the team the ability to link the images on the wall with the research being conducted and thus link the art to the science in a creative and interesting way. Content presented in the video display would thus help achieve the team’s objectives of inspiring and informing the public about scientific research. The potential global impact of the research could also be shown so that the viewer would be made aware of the potential practical applications of the research.

The video console allowed for the presentation of relatively large amounts of information in a single engaging display, rather than walls covered with printed text that would interfere with the art works on the wall. Avoiding the use of printed text allowed the exhibit to remain suitable for exhibit in art galleries where the text would have precluded the exhibits acceptance. The video console revealed to the viewers that these images are in fact the artifacts of scientific research, connecting the science with the beauty and quality of the art works on the wall. In order to fully integrate the video console into the exhibit, it was designed so as to complement the works on the wall and as such maintained the same visual language of sleek minimal design and a satin finished, mild steel construction. The video screen used was a wide screen 16:9 aspect ratio flat panel LCD measuring seven inches diagonally with an integrated DVD player. The seven-inch screen was chosen because it was small enough to not distract the viewers as they looked at the works on the wall, yet large enough to allow text to be read easily.

The base of the video console was a circle cut out of three quarter inch mild steel. To this base, a four foot piece of one and three quarter inch square steel tube was welded Figure 8. The square tube was roll bent into a mild radius for aesthetic appeal, and to the top of this tube a box constructed to contain the video screen was attached. The box was constructed of steel as well, and was bolted to a plate welded to the top of the steel tube. . Steel armored electrical cable with a grounded plug was used to bring power from an electrical outlet to the console. An opening the size of the screen was machined from the front of the box, so that the viewer would see only the screen. The rest of the DVD player and internal wiring were hidden from view and protected by a sheet of laminated safety glass. The video content presented would thus appear to be framed entirely in steel, just as the images on the wall were.

Figure 8- Construction of Video Console

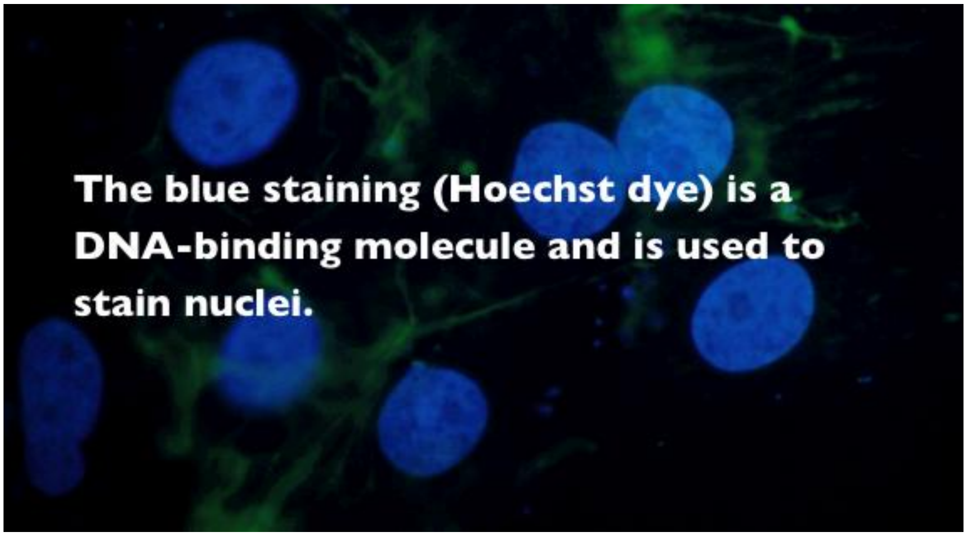
Video content was produced on an Apple Mac Book Pro using iMovie software. Some of the images from the exhibit were presented in a slide show format with zooming and panning to create a dynamic presentation that created a sense of traveling through the images. The names of the researchers, as well as descriptions of their research, were presented over the associated images Figure 9 and Figure 10. The global implications and practical applications of the research were also presented as text over the corresponding images Figure 11.

Eric Overstrom

Christine Lima

Biology Biotechnology Department

Figure 9- Researchers Credited for Images



The blue staining (Hoechst dye) is a DNA-binding molecule and is used to stain nuclei.

Figure 10- Description of Research

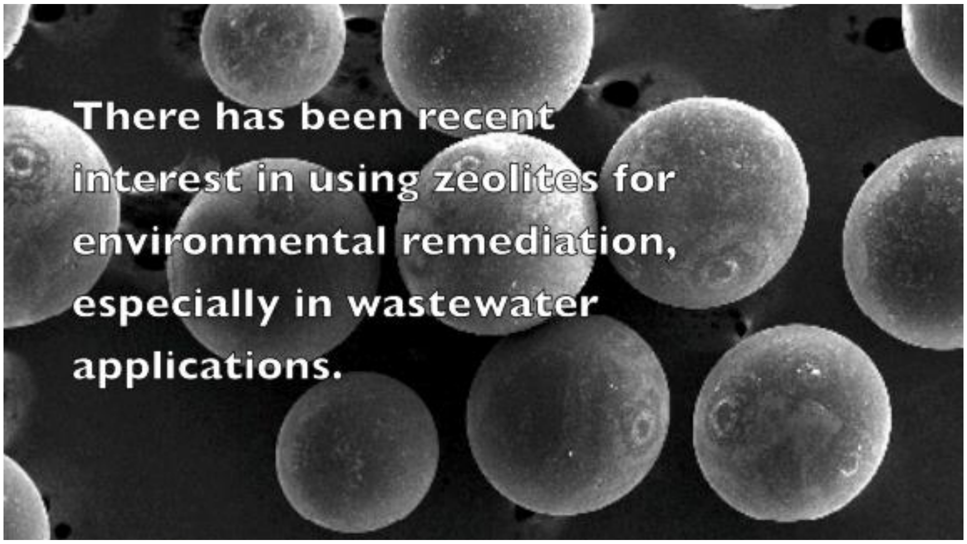
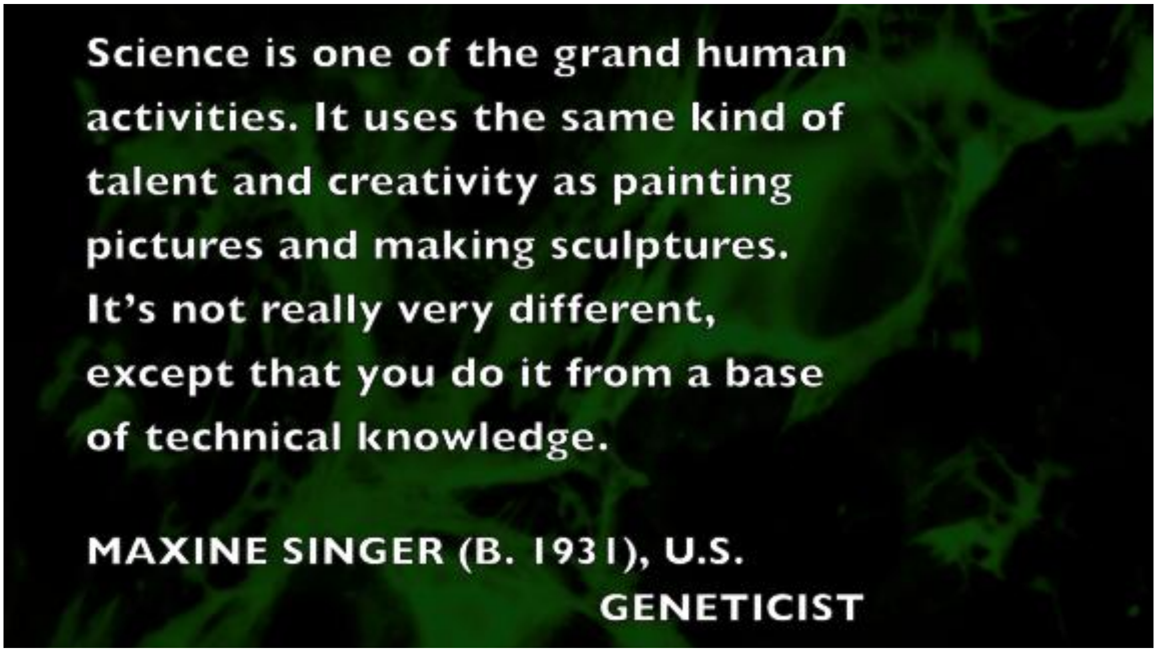


Figure 11- Applications of Research

Video footage from laboratories at WPI was also included so that a true sense of the laboratory environment could be conveyed to the viewer Figure 12. This connection to the researcher in a real lab reminds the viewer that they to could be working in a lab with the proper education and effort. We hoped to create a sense of accessibility to these careers in scientific research by showing this footage in the context of an artistic exhibit.

Figure 12- Lab Footage

Quotes from famous scientists were presented in the video display between each research group's information and images Figure 13. The quotes chosen articulated the concept that art and science are indeed connected, and that science involves creativity and is truly inspirational. The video content was burned to a DVD programmed to play automatically upon insertion and to loop continuously.



Science is one of the grand human activities. It uses the same kind of talent and creativity as painting pictures and making sculptures. It's not really very different, except that you do it from a base of technical knowledge.

MAXINE SINGER (B. 1931), U.S. GENETICIST

Figure 13- Quotes by Scientists

The inclusion of text in the exhibit provides a powerful means of communicating with the viewer. The majority of the images and artifacts in the exhibit are abstract or enigmatic on their own. Accompanying the pieces with descriptions provides the viewer with information with which they can better relate to the work. The careful crafting of descriptions can accentuate the intrinsic beauty and sense of discovery present in scientific research as evidenced by these images. By creatively explaining these images with the judicious use of facts, we hope to instill an appreciation in the viewer for our world as revealed by scientific inquiry. The images are evidence of an unseen world and they present us with a glimpse into the world of which our day-to-day experiences tell us little to nothing. We hope that viewing these images will return some of the curiosity and wonder we all shared in childhood.

Descriptions of the images and the research accompanying each piece were designed to clearly explain the subjects in the images and the relevance of the research, while remaining concise and accessible. It was important that the presence of the text next to the pieces not interfere or compete with the works themselves; therefore, limiting the size and amount of the accompanying text was of great importance to the team. Credit was given to the creators and owners of the images as well.

In contrast to the subtlety of the text accompanying each piece, quotes and definitions will be important components of the video. These quotes and definitions provide perhaps the most powerful means of communicating to the viewers a true sense of what it is we are hoping to accomplish. By including the definitions of science, art, creativity, and technology, and manipulating their presentation and display, we present the viewer with an opportunity to reexamine the relationships between these words and themselves. The presentation of quotes by famous scientists that address a wide range of topics will communicate to the viewer a sense of their humanity and provide insight into the creative mind of the scientist. A list of relevant quotes by scientists collected by the team is provided in **Appendix (A1.3)**.

Survey Design

In order to test the effectiveness of our project, a survey had to be developed to measure the responses from the viewers. We needed to know if our goals had been met. Did we change the perspective of the viewer? Did they become excited about scientific research? The team initially struggled to create a comprehensive quantitative survey to get answers to these questions. After a meeting with Professor Chrys Demetry, who has experience in survey design, the quantitative method was soon abandoned in favor of a qualitative method.

The choice to utilize a qualitative approach to assess the design and effectiveness of the exhibit stems from the nature of the project itself. Time is an issue in the museum setting. Lengthy surveys become more of a hassle for the responder to answer. Negative bias may enter into the response simple due to agitation or frustration caused by completing such a long survey. Science museums also tend to be very popular among children. Most children visiting the museum are too young to complete a survey without the permission and guidance of their legal guardian. For families with many children at the museum, it becomes difficult for the guardian to help the child complete the survey and to also watch out for the other children. Lengthy surveys do not fit into the "mild chaos" of the museum setting, and therefore the survey was required to be very brief. Additionally, one of the goals of this project was to excite people about scientific research. Quantifying excitement and enthusiasm is possible through the use of various systems of scales or ratings. Given the nature of the topics being juxtaposed in the exhibit, it was determined that the means of assessing responses to the exhibit should be able to permit various forms of expression. Science and art are generally not unified in the same venue and by intentionally combining the two fields in the same exhibit, it was theorized that the responses would be varied and personal. A qualitative method was adopted in order to permit and capture the variety in the anticipated responses.

With the help of Chrys Demetry, we developed the survey shown in **Appendix (A7).** The first question was meant to be open ended and engaging to the respondent. This question was designed to bring out the unguided reactions to the exhibit. The next question was more focused, designed to bring out the viewers perspectives of art and science and how they might have been effected from the exhibit. The third question was designed to get an indication of the most successful element of the exhibit. The final question was broader, allowing the respondent to voice any opinions that might be relevant to the project.

Once survey results were obtained, Grounded Theory was used to classify the data. First the results were transcribed into table form, grouping responses in a way that facilitated coding. Coding is a process where short descriptive codes are created for each response to a survey question. This is ideally done by several different people, independently of each other. Once the coding had been done, the researchers came together to reduce the codes until a sufficient number of categories were obtained. By the end of this process, the qualitative answers had been broken down into useful categories which can be further analyzed for the specific purposes of the research.

Results and Discussion

The final exhibit consists of eight wall mounted pieces and a floor standing video display. The eight wall mounted pieces present the prints of the microscopy images in arrays of from three to one hundred and thirty two images. The clean simplicity of the metal frames prevents them from competing with the images, yet the frames novelty and creativity attract the viewer, and add a dimension not possible using conventional mattes and frames. The pieces are able to stand on their own as works of art due in part to their success as design objects and their harmony of form. They also create a sense of a narrative while remaining somewhat enigmatic as well.

The video console provided the ability to inform the viewer about the nature of the images and the researchers responsible for capturing them, as well as displaying the quotes by famous scientists. This resulted in the ability to orient the viewers as to the scientific nature of the images without distracting them from the works themselves. The quotes, text, and images in the video console, combined with the wall-mounted pieces, create a sense of unity between art and scientific research. This sense of unity between the disciplines of art and science allows the viewers to reexamine their preconceptions about the nature of each, and to see both as a celebration of being, were as before perhaps they saw scientific research as mainly rigid and academic.

The initial exhibit was held at the EcoTarium in Worcester and was enthusiastically received by the museum. The exhibit can be seen in Figure 14 and Figure 15. The museum staff was impressed and very appreciative of the quality of the work. The opening reception, held on April 24th, was a huge success. See **Appendix (A6)** for the invitation. The diversity, excitement and number of guests far exceeded our expectations. Approximately 70 people attended the opening. Those in attendance included students and professors from WPI and Clark University as well as artists and other residents of Worcester. It was interesting to see the artists of the community interact with the scientists, sharing thoughts and ideas. The exhibit successfully opened a dialogue between artists and scientists. Furthermore, everyone seemed to be very excited by the exhibit, both the artists and scientists seemed to see something new. Our most important goals of this project were to open a dialogue between artists and scientist and to excite people about science. As one WPI professor commented about the exhibit, “It reminds me of why I originally got interested in materials science and why I enjoyed spending so much time taking that perfect photomicrograph.”

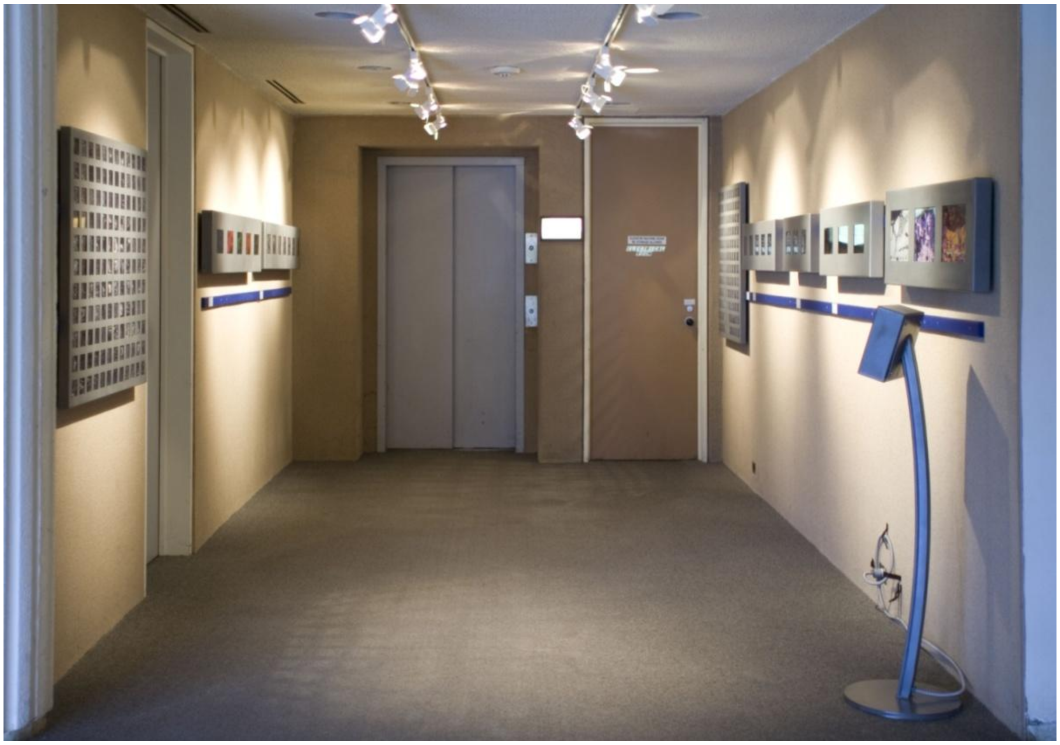


Figure 14- EcoTarium installation

Figure 15- Detail of Installation

Surveys were handed out to help record and categorize viewers' opinions the exhibit. During the opening, 42 surveys were filled out. The surveys represented a broad spectrum of visitors to the gallery. The answers to the surveys and the demographics can be seen in **Appendix (A9).** In order to analyze the results, the team used Grounded Theory. First, they typed up the responses to the questionnaire and then grouped the responses together for each of the four questions. Next, two researchers each simplified the responses into key words. The team worked together to further classify the responses into a few categories. The results of the Ground Theory grouping can be seen in **Appendix (A8).**

Responses to the first question, "How would you describe this exhibit to a friend?" were placed into one of seven groups. Responses that described the exhibit as both an art and science exhibit, but focused on the art were labeled as "art dominant". Responses that also described it as both an art and science exhibit but focused on the science were labeled “science dominant”. The ones that only mentioned art were labeled “art”, while those that only mentioned science were labeled “science”. The remaining were labeled “equal” if they talked about art and science without preference, or “non-descriptive, positive ” or “non-descriptive, neutral” if it did not mention science or art at all. As shown in Figure 16, 44% of the people surveyed would describe the exhibit favorably, but did not mention the connection between art and science. 5% talked about the connection, but emphasized art. 12% also described the connection between art and science but emphasized science. Finally, 20% of the viewers implied that it was an equal combination of art and science. Most people would describe the exhibit with enthusiasm, and slightly over half of these would describe it in terms of art and science. One of the objectives of this project was to create an exhibit that is suitable for both an art gallery and a science museum. For those who described the exhibit as art and science, the majority felt that they were presented equally, demonstrating the exhibits suitability for both a science museum and an art gallery.

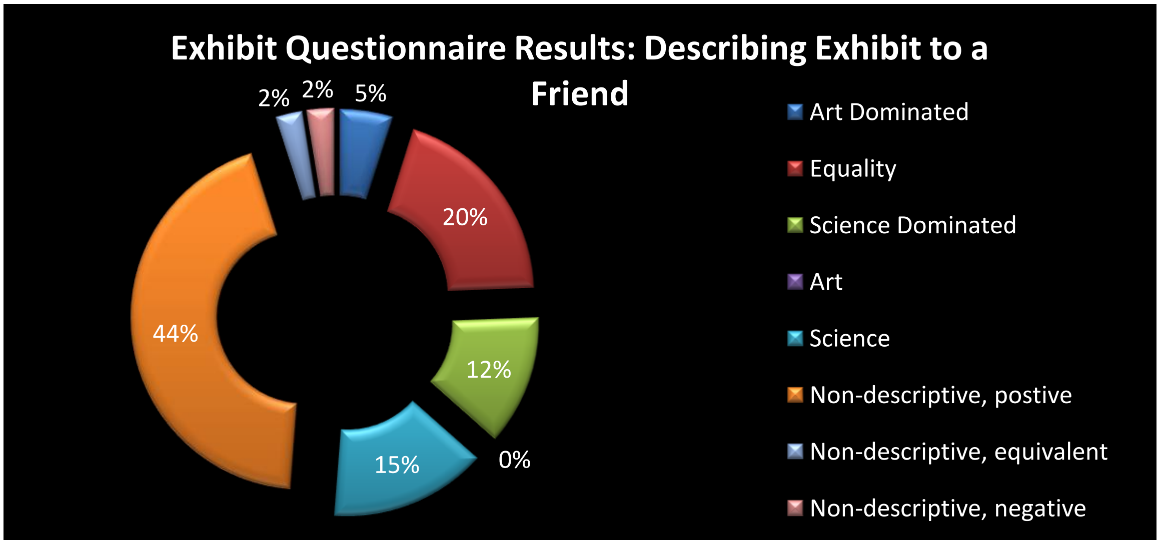


Figure 16- Question One

The second question asked, “How has this exhibit changed your perceptions or definitions of art and science, if at all?” The responses were labeled “affirmative, related” if perspectives were changed toward a union or art and science. If no change was noted and the viewer already saw science and art as a single entity, it was labeled “negative, related”. If the viewer didn’t mention the relationship between science and art, and their opinion was not changed, it was labeled “negative”. The results are shown in Figure 17. 78% percent of the people who filled out surveys left the opening with the opinion that science and art are related. Of these people, 59% had changed their viewpoints because of the exhibit. 5% of the people did not mention a connection between art and science after seeing the exhibit. Changing people’s preconceptions about art and science is important if we are to dispel the notion that science is not a creative endeavor.

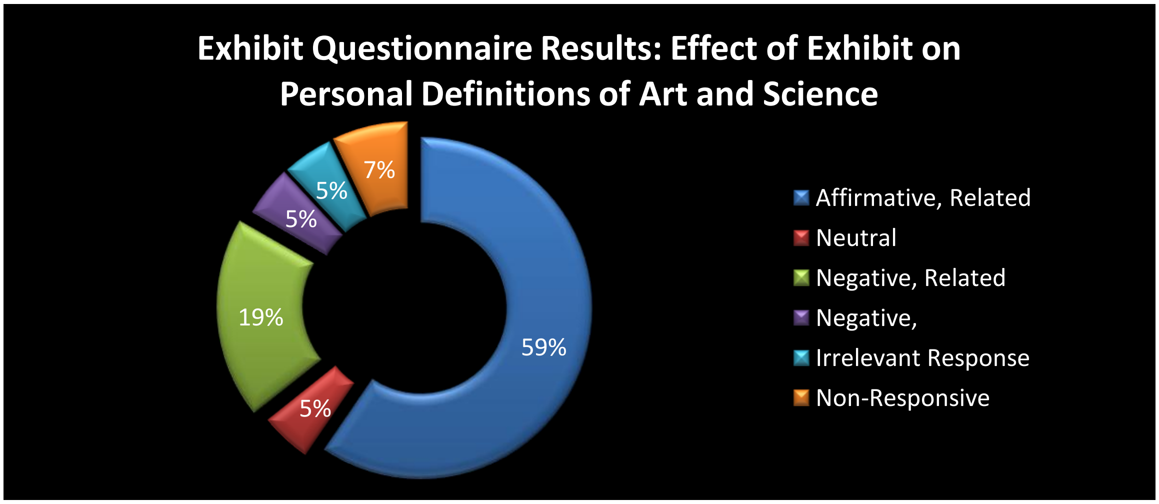


Figure 17- Question Two

The third question asked, “Which aspect of this exhibit will you remember most?” The results from this are shown in Figure 18. People seemed to like the piece showing electrospun fibers the most, which is a testament to the power of having multiple images.

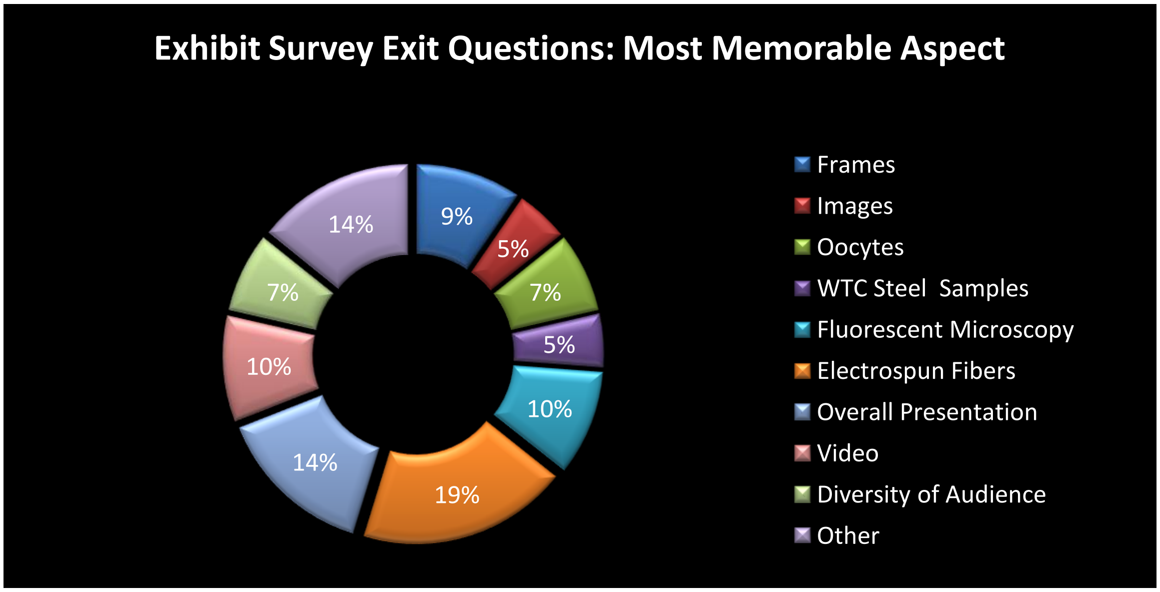


Figure 18- Question Three

The final question simply asked for any additional responses to the exhibit. The majority of the comments were congratulatory remarks for putting together an exciting, interesting and unique exhibit. Out of the 37 responses, four wanted to know more about the images and the science behind them. Other important comments noted that exhibit was “refreshing” and “a nice change of pace” from typical art or science exhibits.

The exhibit will remain at the EcoTarium until the end of May. Next, it will be moved to another venue in Worcester where it can reach a different segment of the community. Jan Seymour of Arts Worcester is planning on displaying the exhibit at one of the many galleries for which she coordinates exhibits such as a gallery at Quinsigamond Community College or the new Hannover Gallery. Eric Overstrom, department head and director of life sciences at WPI is interested in acquiring some of the pieces for permanent display in the LSBC lobby at WPI, which attests to the quality of the work. The Gordon library at WPI will also likely be a venue of exhibition before the pieces find a permanent home.

Interest in the exhibit itself will only increase as more people see it and news and reviews spread through the community. The original objective of increasing public awareness of scientific research through artistic presentation was achieved through the creation of a quality exhibit, which is being enthusiastically displayed in various public venues. The works attest to the wonder and beauty that is revealed through both scientific research and artistic explorations.

Conclusion

From its inception as a plan to create a coffee table book of beautiful SEM images, to its final incarnation as the multimedia exhibit which was installed at the EcoTarium, this IQP was designed to excite people about science. Scientific research can be incredibly interesting; the forms that it studies are beautiful and the process creative. The scientific process should be understood and made accessible to anyone, not just the scientists conducting the research. Through the artistic display of scientific research, this project has successfully created an avenue through which the excitement of scientific discovery can be experienced by society. If this exhibit inspires even just one student to pursue a career in science, the project will have been a success. It has created interest and excitement from which future projects that combine scientific research and the arts can be developed.

Further Recommendations

This project created a good foundation for a continued collaborative art and science IQP at WPI. Communication and excitement has been established with organizations and galleries across Worcester. Our project only scratched the surface of what is possible. Future projects could benefit from incorporating more equipment, supplies and artifacts from the research into an exhibit. The work needs to also move away from the wall and into 3-dimensions so that the viewers can interact more freely with the art. This would create an even more engaging exhibit and further the original objectives of the project.

With the recent addition of two full time art professors, a project like this could metamorphose into a class that deals entirely with the union of art and science. It would lend itself easily to a sculpture class, which is one of the most obvious unions of art and science. In the future, the class could expand into its own program, especially with collaboration from the consortium schools. WPI and Clark University could team up to offer a fine arts program connected with the sciences. Clark already has all of the basic art classes and fine arts resources. WPI has all of the technical classes necessary ranging from electronic music to metal fabrication. With some organization and a few specialized classes, a comprehensive program could easily be developed. Many tech schools already have such programs. Rochester Institute of Technology offers BFAs and MFAs in topics ranging from master printmaking and casting to art therapy. Rensselear Polytechnic Institute offers a BFA in electronic arts. Clarkson University offers collaborative art and science programs. In addition, such a program would help creating a more diverse student body and enrich the WPI experience.

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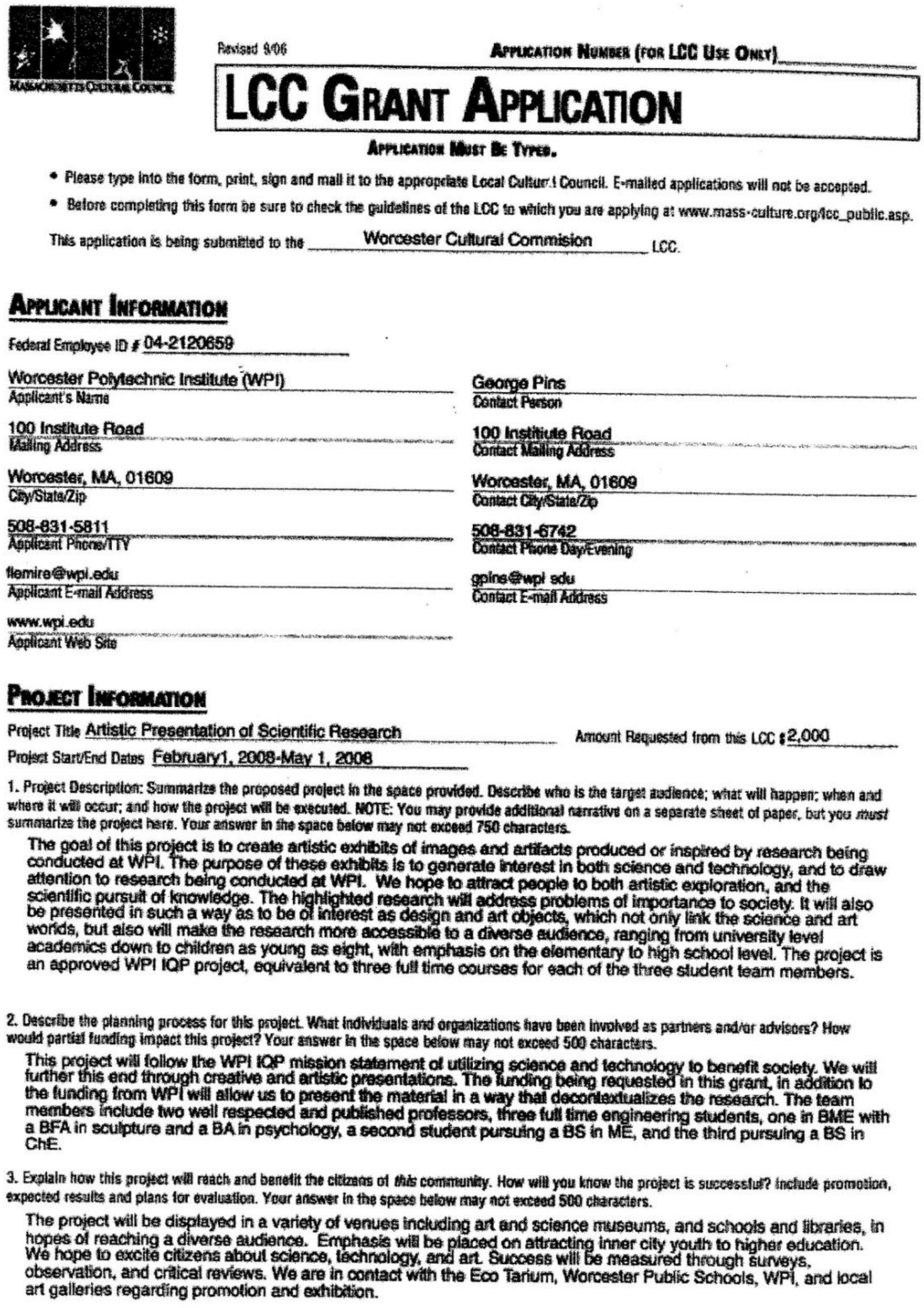
Appendices

A1 Worcester Local Cultural Commission Grant Particulars

A1.1 LCC Grant Application



MASSACHUSETTS CULTURAL COUNCIL

Revised 9/06

APPLICATION NUMBER (FOR LCC USE ONLY)__________

LCC GRANT APPLICATION

APPLICATION MUST BE TYPED.

- Please type into the form, print, sign and mail it to the appropriate Local Cultural Council. E-mailed applications will not be accepted.
- Before completing this form be sure to check the guidelines of the LCC to which you are applying at www.mass-culture.org/lcc_public.asp.

This application is being submitted to the Worcester Cultural Commision LCC.

APPLICANT INFORMATION

Federal Employee ID # 04-2120659

Worcester Polytechnic Institute (WPI) Applicant's Name	George Pins Contact Person
100 Institute Road Mailing Address	100 Institute Road Contact Mailing Address
Worcester, MA, 01609 City/State/Zip	Worcester, MA, 01609 Contact City/State/Zip
508-831-5811 Applicant Phone/TTY	508-831-6742 Contact Phone Day/Evening
flemire@wpi.edu Applicant E-mail Address	gpins@wpi edu Contact E-mail Address
www.wpi.edu Applicant Web Site	

PROJECT INFORMATION

Project Title Artistic Presentation of Scientific Research

Amount Requested from this LCC $2,000

Project Start/End Dates February1, 2008-May 1, 2008

1. Project Description: Summarize the proposed project in the space provided. Describe who is the target audience; what will happen; when and where it will occur; and how the project will be executed. NOTE: You may provide additional narrative on a separate sheet of paper, but you *must* summarize the project here. Your answer in the space below may not exceed 750 characters.

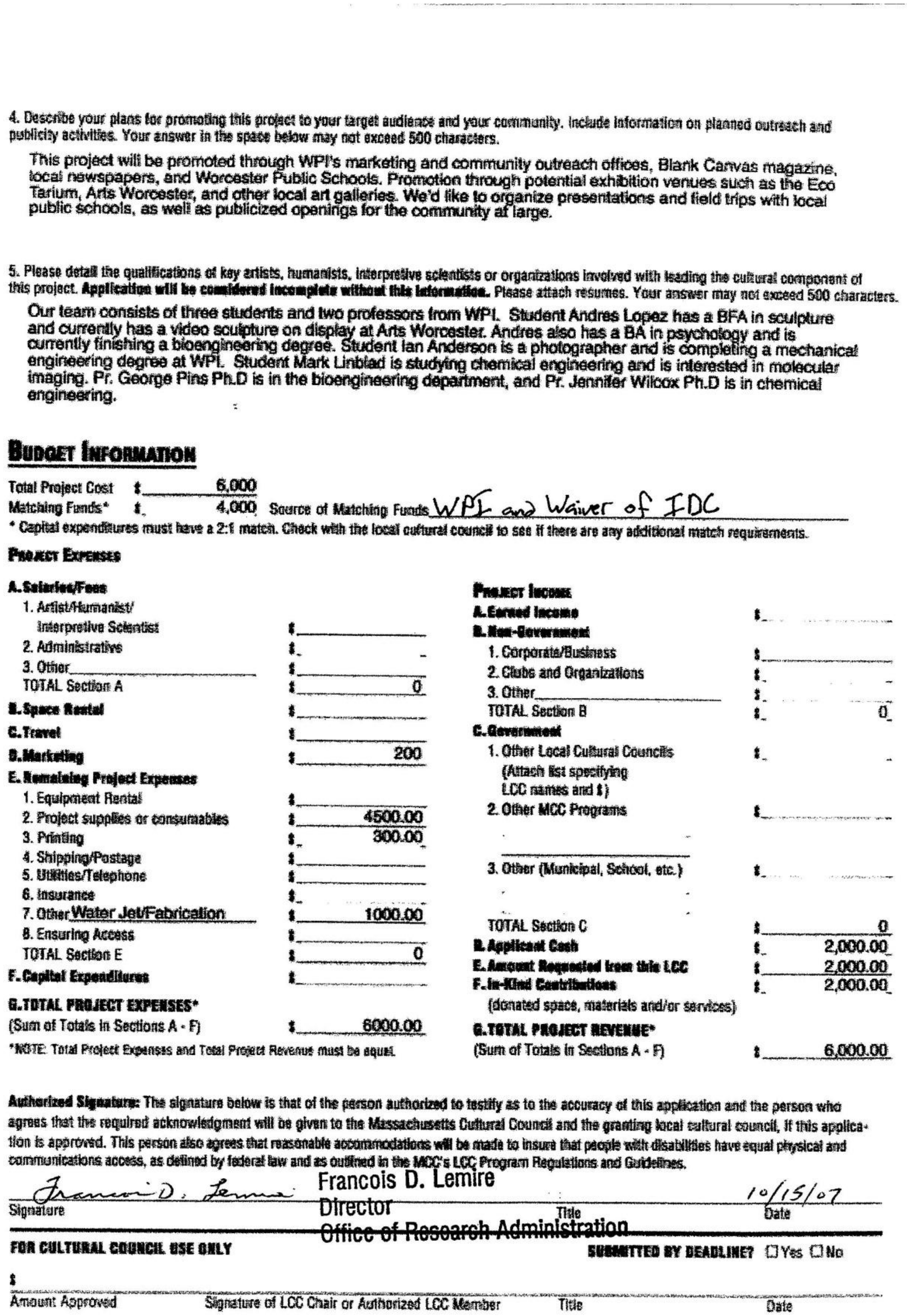
The goal of this project is to create artistic exhibits of images and artifacts produced or inspired by research being conducted at WPI. The purpose of these exhibits is to generate interest in both science and technology, and to draw attention to research being conducted at WPI. We hope to attract people to both artistic exploration, and the scientific pursuit of knowledge. The highlighted research will address problems of importance to society. It will also be presented in such a way as to be of interest as design and art objects, which not only link the science and art worlds, but also will make the research more accessible to a diverse audience, ranging from university level academics down to children as young as eight, with emphasis on the elementary to high school level. The project is an approved WPI IQP project, equivalent to three full time courses for each of the three student team members.

2. Describe the planning process for this project. What individuals and organizations have been involved as partners and/or advisors? How would partial funding impact this project? Your answer in the space below may not exceed 500 characters.

This project will follow the WPI IQP mission statement of utilizing science and technology to benefit society. We will further this end through creative and artistic presentations. The funding being requested in this grant, in addition to the funding from WPI will allow us to present the material in a way that decontextualizes the research. The team members include two well respected and published professors, three full time engineering students, one in BME with a BFA in sculpture and a BA in psychology, a second student pursuing a BS in ME, and the third pursuing a BS in ChE.

3. Explain how this project will reach and benefit the citizens of *this* community. How will you know the project is successful? Include promotion, expected results and plans for evaluation. Your answer in the space below may not exceed 500 characters.

The project will be displayed in a variety of venues including art and science museums, and schools and libraries, in hopes of reaching a diverse audience. Emphasis will be placed on attracting inner city youth to higher education. We hope to excite citizens about science, technology, and art. Success will be measured through surveys, observation, and critical reviews. We are in contact with the Eco Tarium, Worcester Public Schools, WPI, and local art galleries regarding promotion and exhibition.



4. Describe your plans for promoting this project to your target audience and your community. Include information on planned outreach and publicity activities. Your answer in the space below may not exceed 500 characters.

This project will be promoted through WPI's marketing and community outreach offices, Blank Canvas magazine, local newspapers, and Worcester Public Schools. Promotion through potential exhibition venues such as the Eco Tarium, Arts Worcester, and other local art galleries. We'd like to organize presentations and field trips with local public schools, as well as publicized openings for the community at large.

5. Please detail the qualifications of key artists, humanists, interpretive scientists or organizations involved with leading the cultural component of this project. **Application will be considered incomplete without this information.** Please attach resumes. Your answer may not exceed 500 characters.

Our team consists of three students and two professors from WPI. Student Andres Lopez has a BFA in sculpture and currently has a video sculpture on display at Arts Worcester. Andres also has a BA in psychology and is currently finishing a bioengineering degree. Student Ian Anderson is a photographer and is completing a mechanical engineering degree at WPI. Student Mark Linblad is studying chemical engineering and is interested in molecular imaging. Pr. George Pins Ph.D is in the bioengineering department, and Pr. Jennifer Wilcox Ph.D is in chemical engineering.

BUDGET INFORMATION

Total Project Cost $ 6,000

Matching Funds* $ 4,000 Source of Matching Funds WPI and Waiver of IDC

* Capital expenditures must have a 2:1 match. Check with the local cultural council to see if there are any additional match requirements.

PROJECT EXPENSES

A. Salaries/Fees	
1. Artist/Humanist/ Interpretive Scientist	$
2. Administrative	$ -
3. Other	$
TOTAL Section A	$ 0
B. Space Rental	$
C. Travel	$
D. Marketing	$ 200
E. Remaining Project Expenses	
1. Equipment Rental	$
2. Project supplies or consumables	$ 4500.00
3. Printing	$ 300.00
4. Shipping/Postage	$
5. Utilities/Telephone	$
6. Insurance	$
7. Other Water Jet/Fabrication	$ 1000.00
8. Ensuring Access	$
TOTAL Section E	$ 0
F. Capital Expenditures	$
G. TOTAL PROJECT EXPENSES* (Sum of Totals in Sections A - F)	$ 6000.00

*NOTE: Total Project Expenses and Total Project Revenue must be equal.

PROJECT INCOME

A. Earned Income	$
B. Non-Government	
1. Corporate/Business	$
2. Clubs and Organizations	$ -
3. Other	$
TOTAL Section B	$ 0
C. Government	
1. Other Local Cultural Councils (Attach list specifying LCC names and $)	$ -
2. Other MCC Programs	$
3. Other (Municipal, School, etc.)	$
TOTAL Section C	$ 0
D. Applicant Cash	$ 2,000.00
E. Amount Requested from this LCC	$ 2,000.00
F. In-Kind Contributions (donated space, materials and/or services)	$ 2,000.00
G. TOTAL PROJECT REVENUE* (Sum of Totals in Sections A - F)	$ 6,000.00

Authorized Signature: The signature below is that of the person authorized to testify as to the accuracy of this application and the person who agrees that the required acknowledgment will be given to the Massachusetts Cultural Council and the granting local cultural council, if this application is approved. This person also agrees that reasonable accommodations will be made to insure that people with disabilities have equal physical and communications access, as defined by federal law and as outlined in the MCC's LCC Program Regulations and Guidelines.

Francois D. Lemire

Signature

Francois D. Lemire
Director
Office of Research Administration

Title

10/15/07

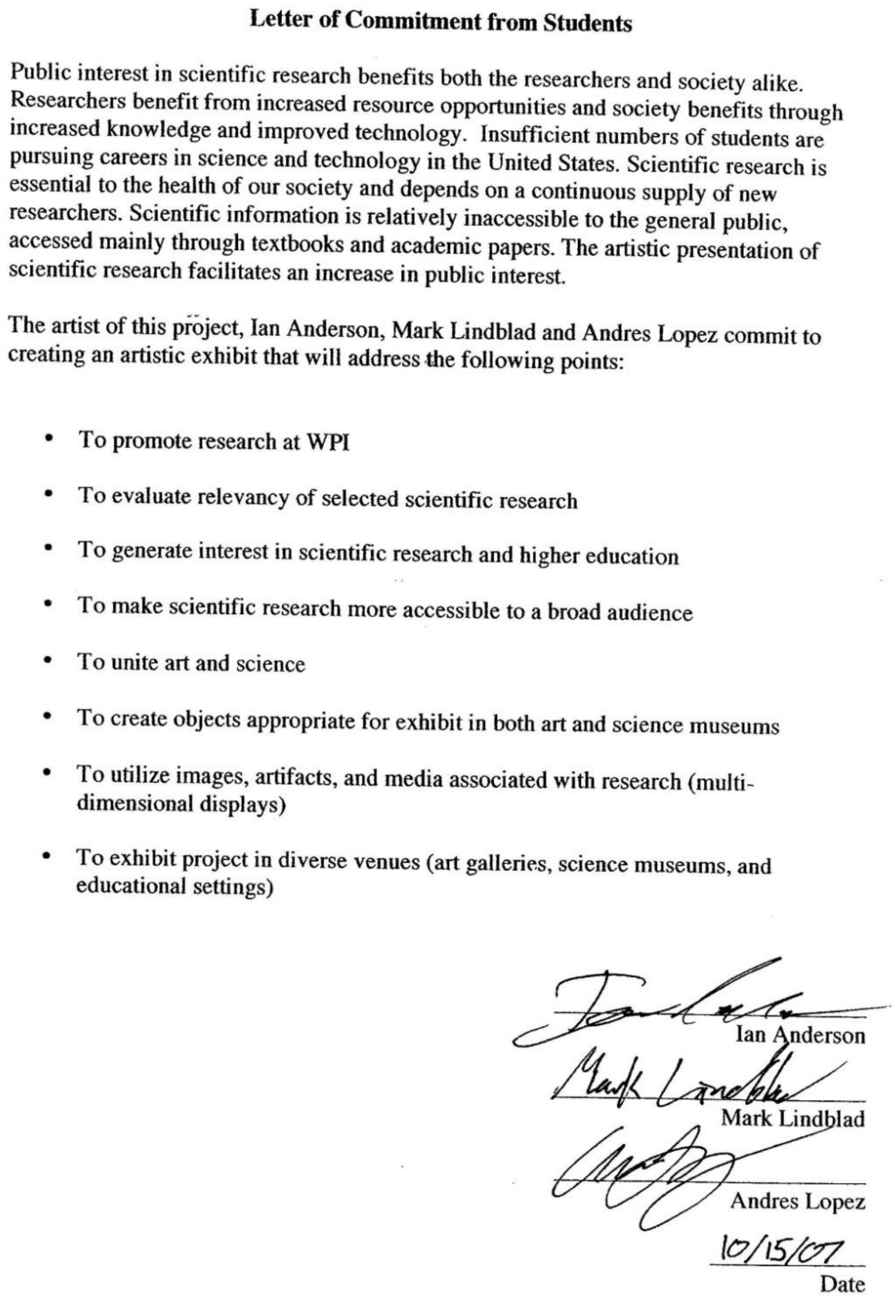
Date

FOR CULTURAL COUNCIL USE ONLY **SUBMITTED BY DEADLINE?** ☐ Yes ☐ No

$

Amount Approved Signature of LCC Chair or Authorized LCC Member Title Date

A1.2 Letter of Student Commitment



Letter of Commitment from Students

Public interest in scientific research benefits both the researchers and society alike. Researchers benefit from increased resource opportunities and society benefits through increased knowledge and improved technology. Insufficient numbers of students are pursuing careers in science and technology in the United States. Scientific research is essential to the health of our society and depends on a continuous supply of new researchers. Scientific information is relatively inaccessible to the general public, accessed mainly through textbooks and academic papers. The artistic presentation of scientific research facilitates an increase in public interest.

The artist of this project, Ian Anderson, Mark Lindblad and Andres Lopez commit to creating an artistic exhibit that will address the following points:

- To promote research at WPI
- To evaluate relevancy of selected scientific research
- To generate interest in scientific research and higher education
- To make scientific research more accessible to a broad audience
- To unite art and science
- To create objects appropriate for exhibit in both art and science museums
- To utilize images, artifacts, and media associated with research (multi-dimensional displays)
- To exhibit project in diverse venues (art galleries, science museums, and educational settings)

Ian Anderson

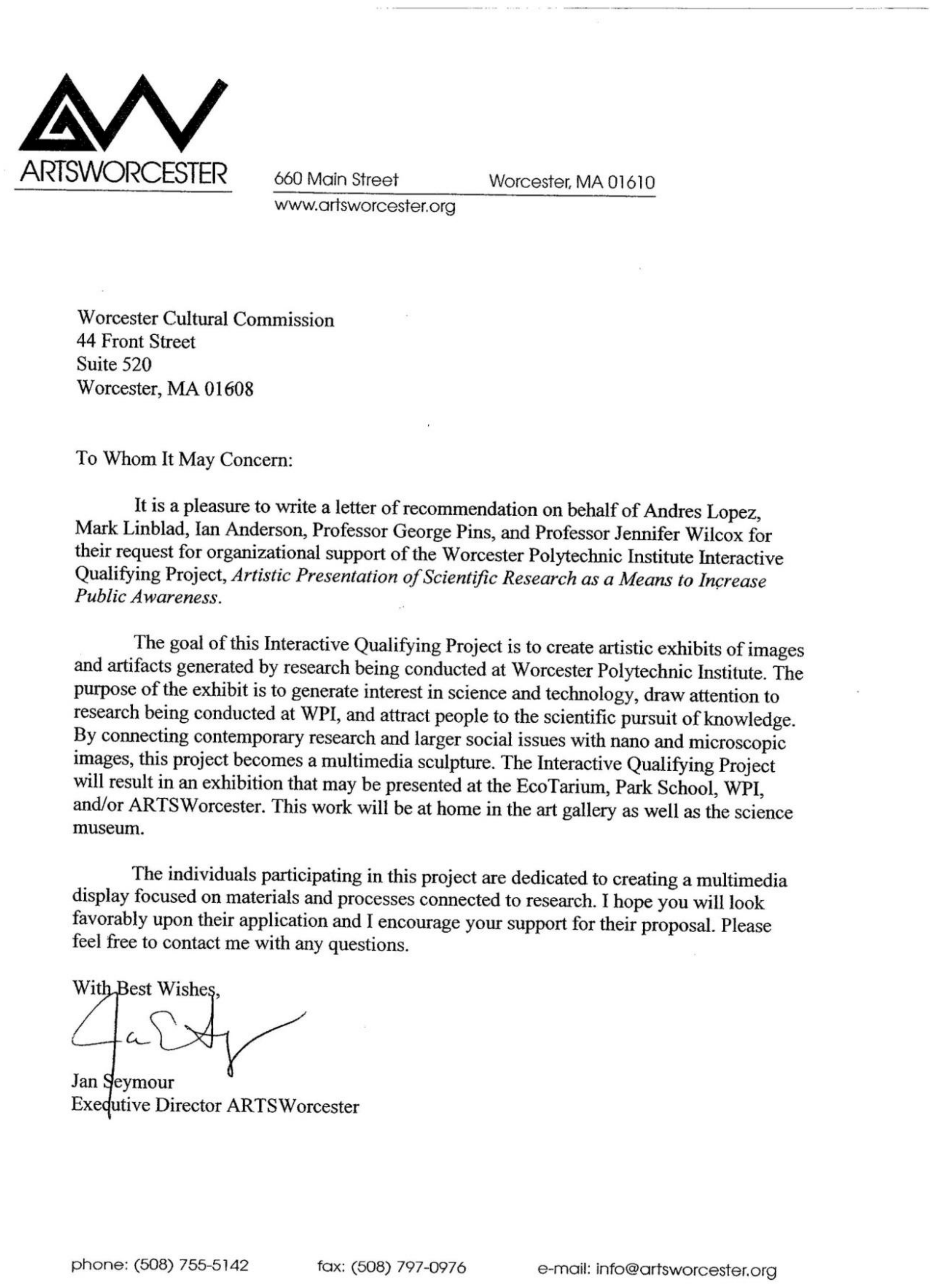
Mark Lindblad

Andres Lopez

10/15/07

Date

A1.3 Letters of Support



ARTSWORCESTER
660 Main Street Worcester, MA 01610
www.artsworcester.org

Worcester Cultural Commission
44 Front Street
Suite 520
Worcester, MA 01608

To Whom It May Concern:

It is a pleasure to write a letter of recommendation on behalf of Andres Lopez, Mark Linblad, Ian Anderson, Professor George Pins, and Professor Jennifer Wilcox for their request for organizational support of the Worcester Polytechnic Institute Interactive Qualifying Project, *Artistic Presentation of Scientific Research as a Means to Increase Public Awareness*.

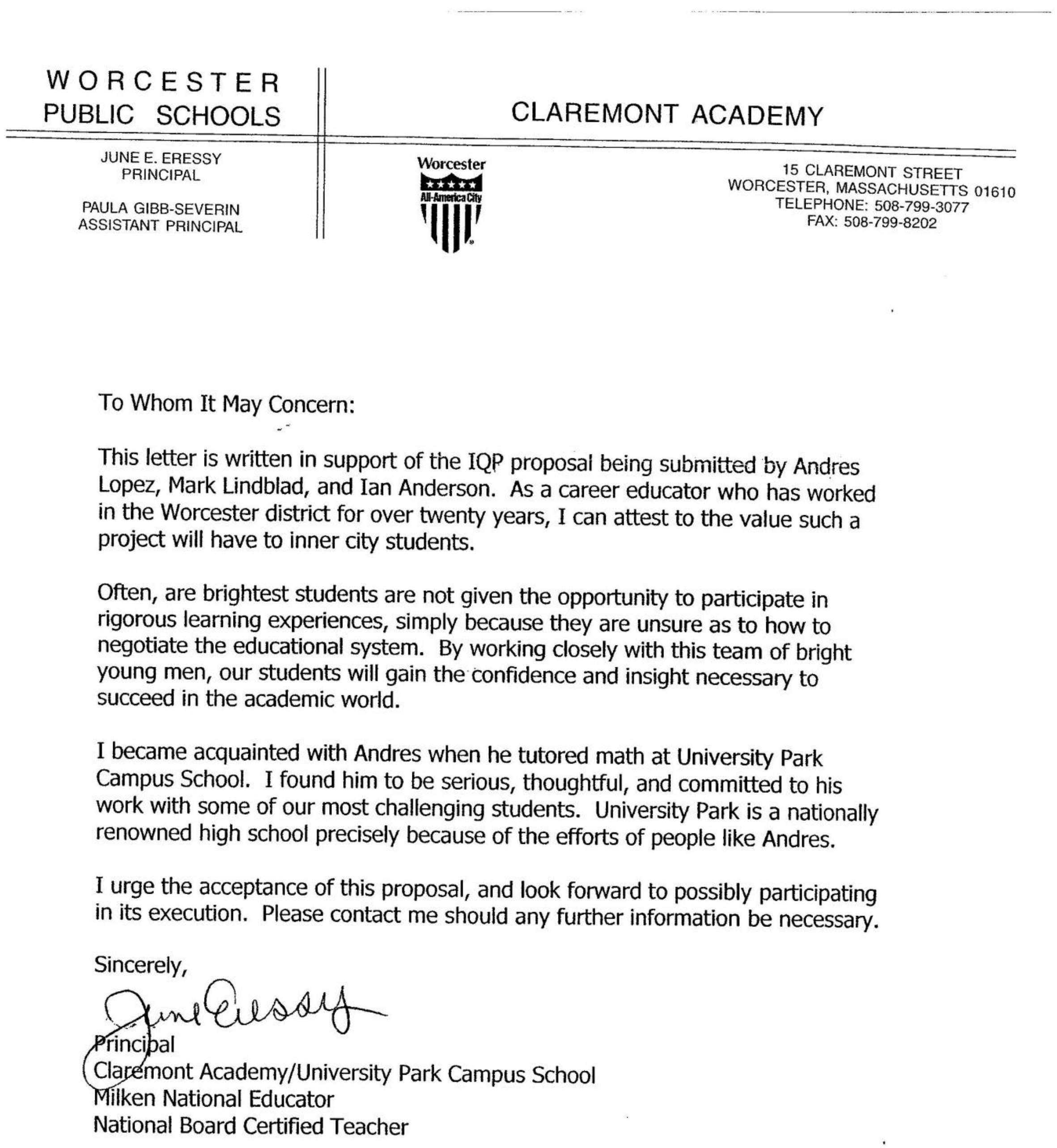
The goal of this Interactive Qualifying Project is to create artistic exhibits of images and artifacts generated by research being conducted at Worcester Polytechnic Institute. The purpose of the exhibit is to generate interest in science and technology, draw attention to research being conducted at WPI, and attract people to the scientific pursuit of knowledge. By connecting contemporary research and larger social issues with nano and microscopic images, this project becomes a multimedia sculpture. The Interactive Qualifying Project will result in an exhibition that may be presented at the EcoTarium, Park School, WPI, and/or ARTSWorcester. This work will be at home in the art gallery as well as the science museum.

The individuals participating in this project are dedicated to creating a multimedia display focused on materials and processes connected to research. I hope you will look favorably upon their application and I encourage your support for their proposal. Please feel free to contact me with any questions.

With Best Wishes,

Jan Seymour
Executive Director ARTSWorcester

phone: (508) 755-5142 fax: (508) 797-0976 e-mail: info@artsworcester.org



WORCESTER
PUBLIC SCHOOLS

CLAREMONT ACADEMY

JUNE E. ERESSY
PRINCIPAL

PAULA GIBB-SEVERIN
ASSISTANT PRINCIPAL

Worcester
All-America City

15 CLAREMONT STREET
WORCESTER, MASSACHUSETTS 01610
TELEPHONE: 508-799-3077
FAX: 508-799-8202

To Whom It May Concern:

This letter is written in support of the IQP proposal being submitted by Andres Lopez, Mark Lindblad, and Ian Anderson. As a career educator who has worked in the Worcester district for over twenty years, I can attest to the value such a project will have to inner city students.

Often, are brightest students are not given the opportunity to participate in rigorous learning experiences, simply because they are unsure as to how to negotiate the educational system. By working closely with this team of bright young men, our students will gain the confidence and insight necessary to succeed in the academic world.

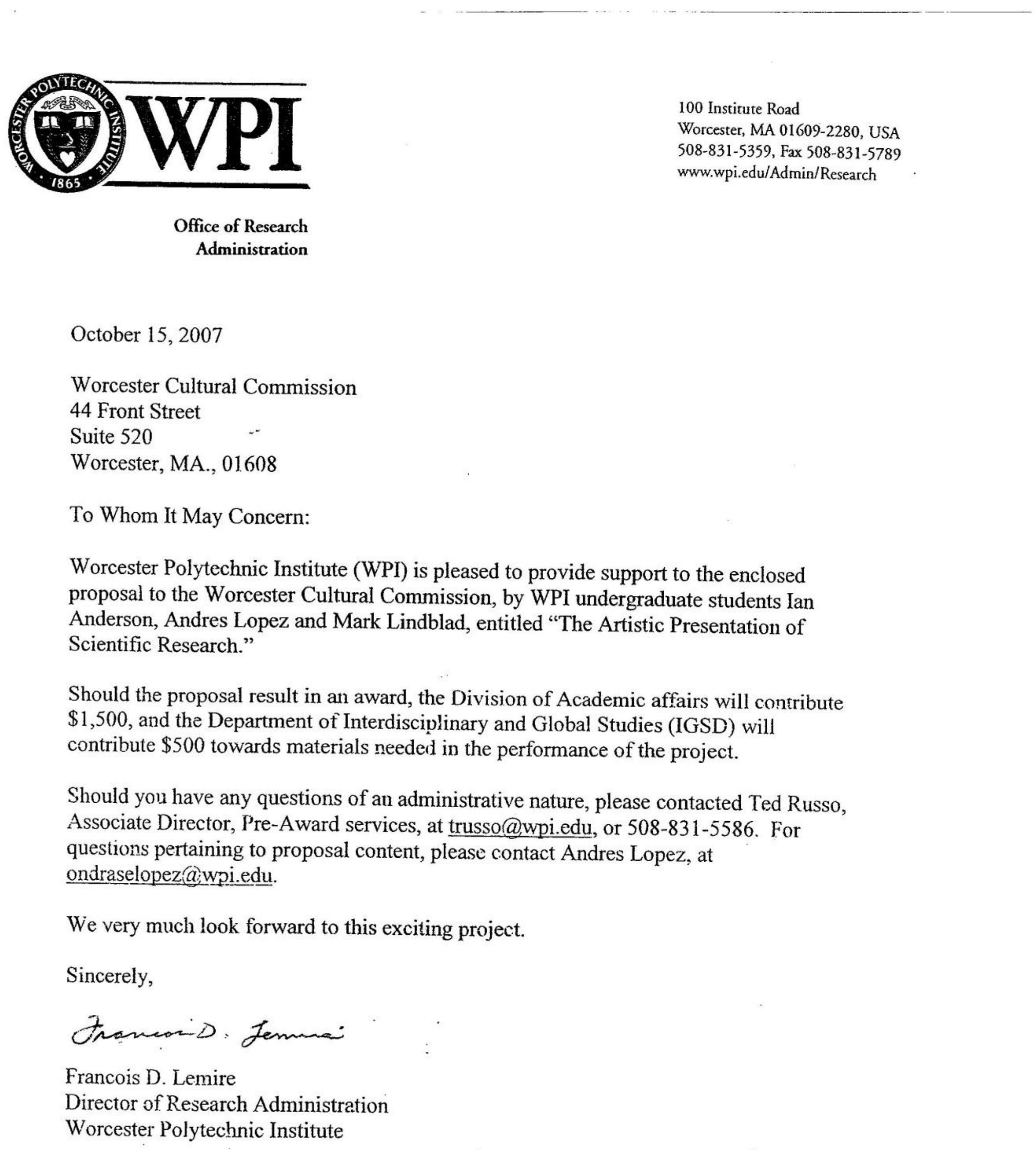
I became acquainted with Andres when he tutored math at University Park Campus School. I found him to be serious, thoughtful, and committed to his work with some of our most challenging students. University Park is a nationally renowned high school precisely because of the efforts of people like Andres.

I urge the acceptance of this proposal, and look forward to possibly participating in its execution. Please contact me should any further information be necessary.

Sincerely,

June Eressy

Principal
Claremont Academy/University Park Campus School
Milken National Educator
National Board Certified Teacher



WPI

Office of Research
Administration

100 Institute Road
Worcester, MA 01609-2280, USA
508-831-5359, Fax 508-831-5789
www.wpi.edu/Admin/Research

October 15, 2007

Worcester Cultural Commission
44 Front Street
Suite 520
Worcester, MA., 01608

To Whom It May Concern:

Worcester Polytechnic Institute (WPI) is pleased to provide support to the enclosed proposal to the Worcester Cultural Commission, by WPI undergraduate students Ian Anderson, Andres Lopez and Mark Lindblad, entitled "The Artistic Presentation of Scientific Research."

Should the proposal result in an award, the Division of Academic affairs will contribute $1,500, and the Department of Interdisciplinary and Global Studies (IGSD) will contribute $500 towards materials needed in the performance of the project.

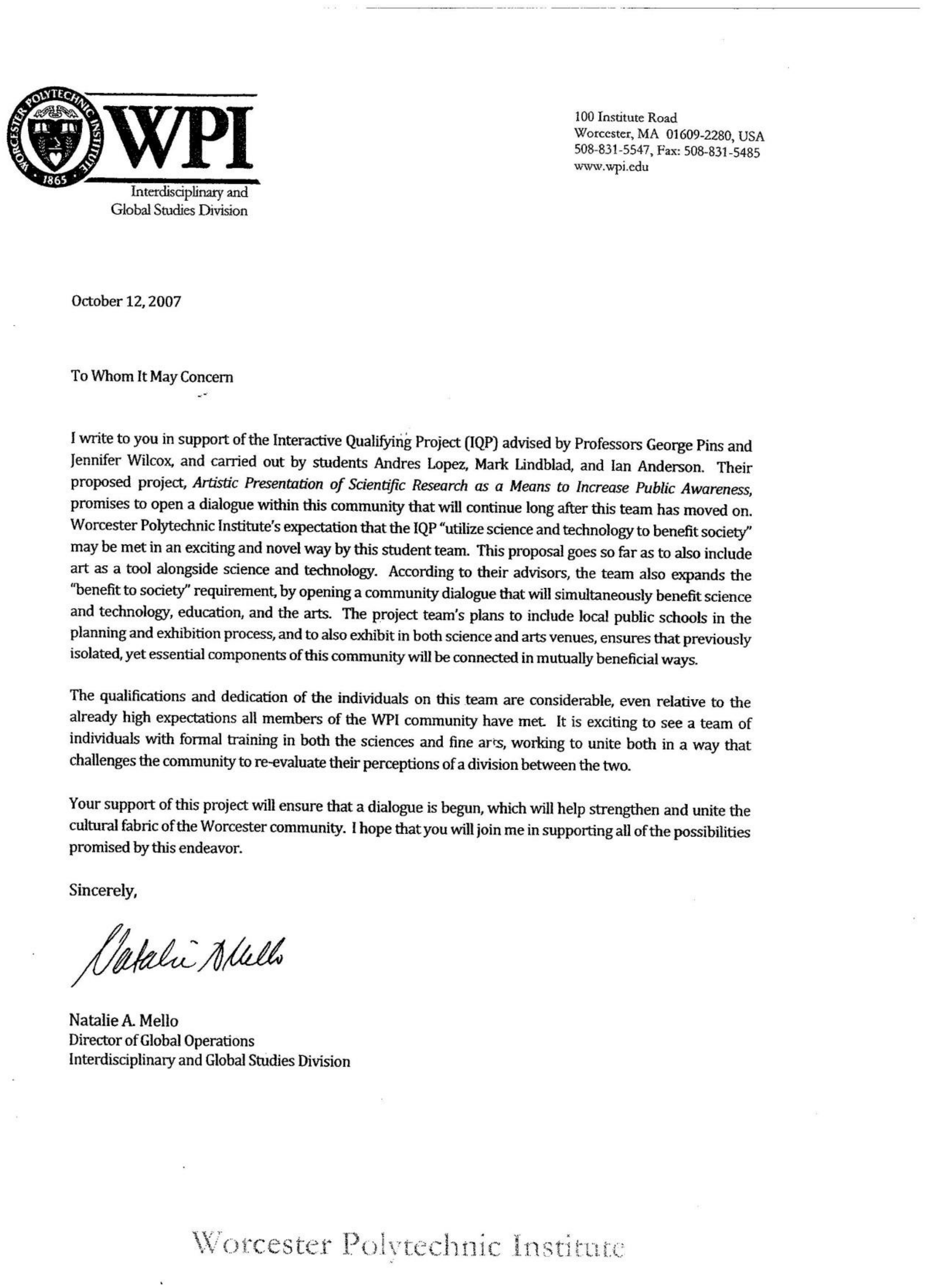
Should you have any questions of an administrative nature, please contacted Ted Russo, Associate Director, Pre-Award services, at trusso@wpi.edu, or 508-831-5586. For questions pertaining to proposal content, please contact Andres Lopez, at ondraselopez@wpi.edu.

We very much look forward to this exciting project.

Sincerely,

Francois D. Lemire

Francois D. Lemire
Director of Research Administration
Worcester Polytechnic Institute



WPI
Interdisciplinary and
Global Studies Division

100 Institute Road
Worcester, MA 01609-2280, USA
508-831-5547, Fax: 508-831-5485
www.wpi.edu

October 12, 2007

To Whom It May Concern

I write to you in support of the Interactive Qualifying Project (IQP) advised by Professors George Pins and Jennifer Wilcox, and carried out by students Andres Lopez, Mark Lindblad, and Ian Anderson. Their proposed project, *Artistic Presentation of Scientific Research as a Means to Increase Public Awareness*, promises to open a dialogue within this community that will continue long after this team has moved on. Worcester Polytechnic Institute's expectation that the IQP "utilize science and technology to benefit society" may be met in an exciting and novel way by this student team. This proposal goes so far as to also include art as a tool alongside science and technology. According to their advisors, the team also expands the "benefit to society" requirement, by opening a community dialogue that will simultaneously benefit science and technology, education, and the arts. The project team's plans to include local public schools in the planning and exhibition process, and to also exhibit in both science and arts venues, ensures that previously isolated, yet essential components of this community will be connected in mutually beneficial ways.

The qualifications and dedication of the individuals on this team are considerable, even relative to the already high expectations all members of the WPI community have met. It is exciting to see a team of individuals with formal training in both the sciences and fine arts, working to unite both in a way that challenges the community to re-evaluate their perceptions of a division between the two.

Your support of this project will ensure that a dialogue is begun, which will help strengthen and unite the cultural fabric of the Worcester community. I hope that you will join me in supporting all of the possibilities promised by this endeavor.

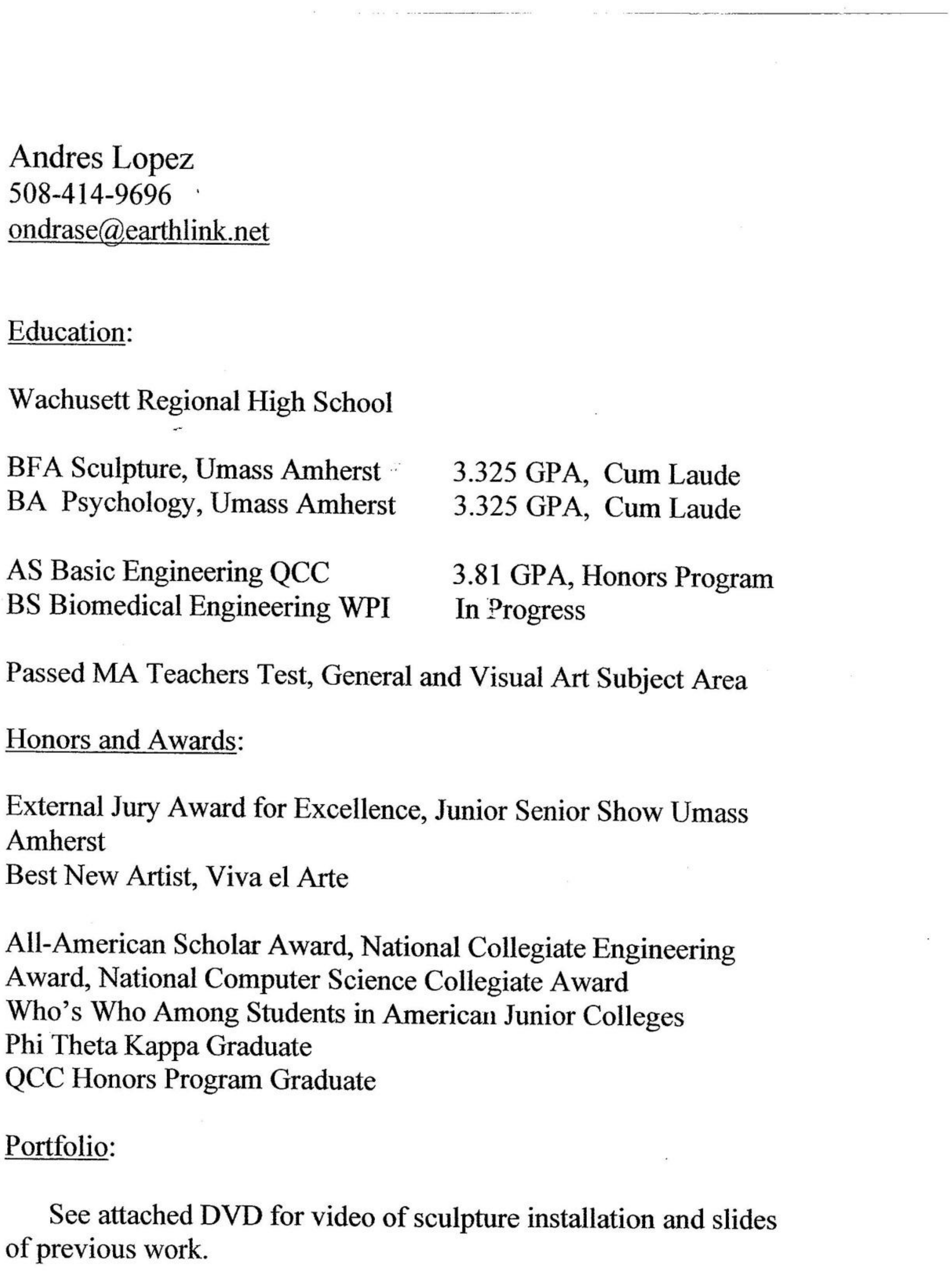
Sincerely,

Natalie A Mello

Natalie A. Mello
Director of Global Operations
Interdisciplinary and Global Studies Division

Worcester Polytechnic Institute

A1.4 Supporting Curriculum Vitae of Project Members



Andres Lopez
508-414-9696
ondrase@earthlink.net

Education:

Wachusett Regional High School

BFA Sculpture, Umass Amherst	3.325 GPA, Cum Laude
BA Psychology, Umass Amherst	3.325 GPA, Cum Laude
AS Basic Engineering QCC	3.81 GPA, Honors Program
BS Biomedical Engineering WPI	In Progress

Passed MA Teachers Test, General and Visual Art Subject Area

Honors and Awards:

External Jury Award for Excellence, Junior Senior Show Umass Amherst
Best New Artist, Viva el Arte

All-American Scholar Award, National Collegiate Engineering Award, National Computer Science Collegiate Award
Who's Who Among Students in American Junior Colleges
Phi Theta Kappa Graduate
QCC Honors Program Graduate

Portfolio:

See attached DVD for video of sculpture installation and slides of previous work.

Participant Condensed Resume:

Mark Alan Lindblad

Current Address
WPI
100 Institute Road
Worcester, MA 01609-2247

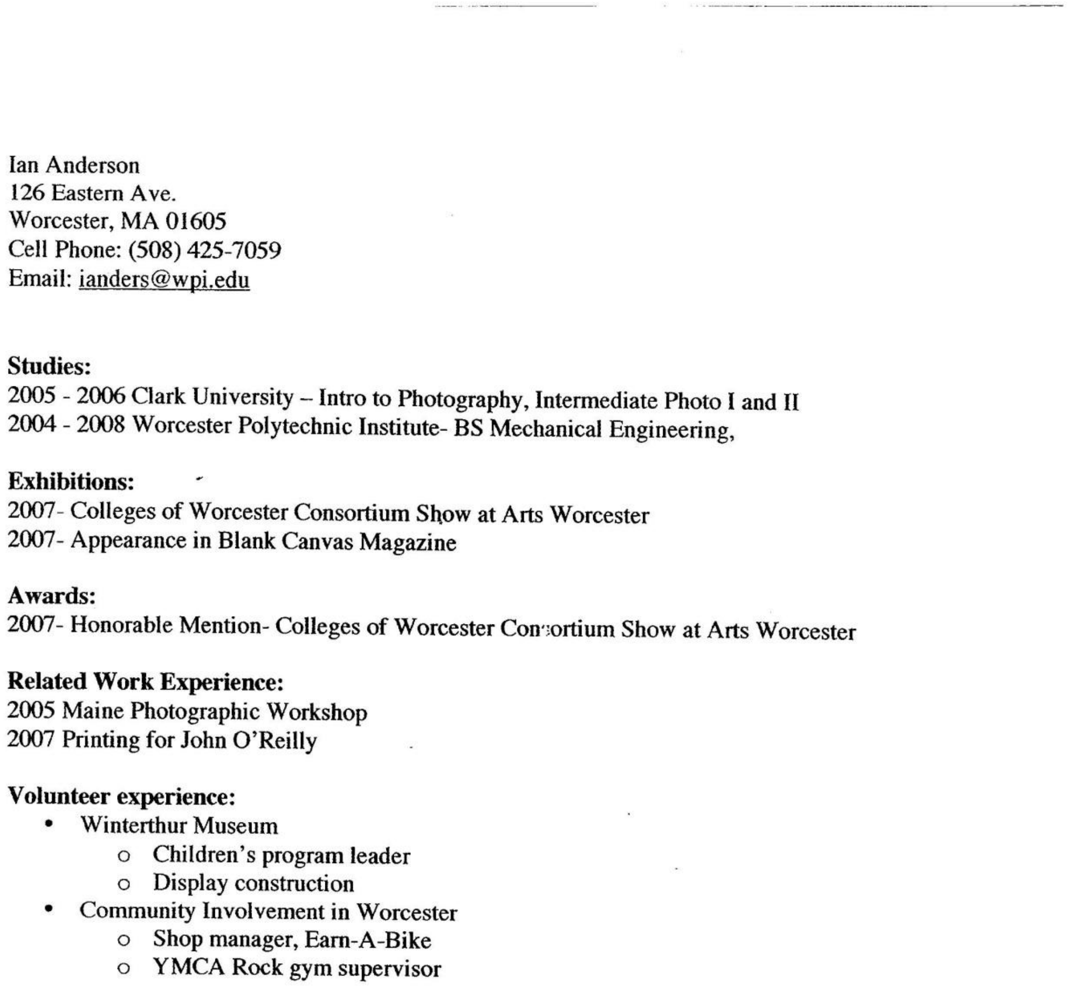
Permanent Address
91 Governor Bradford Road
Brewster, MA 02631

Contact Email
Lindblad@wpi.edu

Education
- Graduate, Salutatorian, May 2005
  Nauset Regional High School
  North Eastham, MA 02651
- BS in Chemical Engineering, expected May 2009
  Worcester Polytechnic Institute
  100 Institute Road
  Worcester, MA 01609

Research/Work Experience
- Wilcox Research Group in Molecular Modeling and Coal Combustion, WPI, 2006-2007
- Circulation Student Staff, Gordon Library, WPI, 2005-2006
- J.C. Ellis Design, Septic Design and Land Surveying, Brewster, MA, Summer 2004, 2005

Related Course Work
- *Worcester Polytechnic Institute*
  -Undergraduate courses in organic chemistry, advanced chemical thermodynamics, chemical statistical mechanics, chemical separation, extraction, and biological engineering, molecular modeling, single and multi-variable calculus, ordinary differential equations, topics in twentieth century and electromagnetic physics, heat and mass transfer, fluid mechanics, American and British Literature including poetry.
  -Graduate level coursework in crystallography, X-ray diffraction, and spectroscopy.
  -Teaching assistant for a graduate level molecular modeling course.
- *Nauset Regional High School*
  -Art metal classes, I –III, elementary techniques, low temperature soldering, various manipulations with sheet metal, elementary wielding, and elementary casting techniques. 2001
  -Formal and independent jewelry making classes, ring forming techniques, silver soldering, marriage of metals. 2002



Ian Anderson
126 Eastern Ave.
Worcester, MA 01605
Cell Phone: (508) 425-7059
Email: ianders@wpi.edu

Studies:
2005 - 2006 Clark University – Intro to Photography, Intermediate Photo I and II
2004 - 2008 Worcester Polytechnic Institute- BS Mechanical Engineering,

Exhibitions:
2007- Colleges of Worcester Consortium Show at Arts Worcester
2007- Appearance in Blank Canvas Magazine

Awards:
2007- Honorable Mention- Colleges of Worcester Consortium Show at Arts Worcester

Related Work Experience:
2005 Maine Photographic Workshop
2007 Printing for John O'Reilly

Volunteer experience:
- Winterthur Museum
    - Children's program leader
    - Display construction
- Community Involvement in Worcester
    - Shop manager, Earn-A-Bike
    - YMCA Rock gym supervisor

Biographical Sketch for George D. Pins

a. Professional Preparation

Rutgers University, School of Engineering	Applied Science	B.S, 1989
Rutgers University and the University of Medicine and Dentistry of New Jersey (Joint Program)	Biomedical Engineering	Ph.D., 1996
Massachusetts General Hospital, Harvard Medical School and Shriners Hospital for Children	Biomedical Engineering	Post-doc, 1996-1999

b. Appointments

2006-present	**Associate Professor**, Biomedical Engineering, Worcester Polytechnic Institute, Worcester, MA
2000-2006	**Assistant Professor**, Biomedical Engineering, WPI
1999-2000	**Research Scientist**, Molecular Geodesics/Tensegra, Inc., Boston, MA
1996-1999	**Postdoctoral Associate**, Center for Engineering in Medicine, Massachusetts General Hospital, Harvard Medical School, and Shriners Hospital for Children, Boston, MA.

c. Five Publications Most Closely Related to Current Project

1. Pins G. D., Toner, M., and Morgan, J.R., Microfabrication of an analog of the basal lamina: Biocompatible membranes with complex topographies, *FASEB Journal,* 2000, 14: 593-602.
2. Pins, G.D., An Analog of the Basal Lamina, *Science and Medicine*, 2000, 7: 6-7.
3. Downing, B.R., Cornwell, K.G., Toner, M. and Pins, G.D., "The influence of microtextured basal lamina analog topography on keratinocyte function and epidermal regeneration." *J. Biomed. Mater. Res.*, 2005, 72A: 47-56.
4. *-Bush, K.A., Downing, B.R., Walsh, S.E., and Pins, G.D., "Conjugation of Extracellular Matrix Proteins to Basal Lamina Analogs Enhances Keratinocyte Attachment", *J. Biomed. Mater. Res.,* 2007, 80A: 444-452.
5. Cornwell, K.G., and Pins, G.D., "Characterization of Discrete Crosslinked Fibrin Microthread Scaffolds for Tissue Regeneration", *J. Biomed. Mater. Res.*, 2007, 82(1):104-12.

Five other Publications

1. Cornwell, K.G., Downing, B.R., and Pins, G.D., "Characterizing fibroblast migration on discrete collagen threads for applications in tissue regeneration." *J. Biomed. Mater. Res.*, 2004, 71A: 55-62.
2. Basu, S., Cunningham, L.P., Pins, G.D., Bush, K.A., Howell, A.R., Wang, J., Campagnola, P.J., "Multi-photon excited fabrication of collagen matrices crosslinked by a modified benzophenone dimer: Bioactivity and enzymatic degradation." *Biomacromolecules*, 2005, 6(3): 1465-1474.
3. Pins, G.D., Bush, K.A., Cunningham, L.P., and Campagnola, P.J., "Multiphoton Excited Fabricated Nano and Micro Patterned Extracellular Matrix Proteins Direct Cellular Morphology". *J. Biomed. Mater. Res.*, 2006, 78(1):194-204.
4. *- Pai, S., Gunja, N., Dupak, E., McMahon, N., Coburn, J.C., Lalikos, J., Dunn, R., Francalancia, N., Pins G.D., Billiar, K., "A mechanical study of rigid plate configurations for sternal fixation", *Ann Biomed Eng.* 2007,35(5):808-16.

---

* Based on undergraduate senior thesis work or summer REU student work

5. Cornwell, K.G., Lei, P., Andreadis, S.T. and Pins, G.D., "Crosslinking of discrete self-assembled collagen threads: Effects on mechanical strength and cell-matrix interactions" *J. Biomed. Mater. Res.*, 2007, 80A:362-371.

d. Synergistic Activities

Faculty Coordinator, Graduate Seminar Series, Biomedical Engineering Department, WPI

Chair, Undergraduate Program Review Committee, Biomedical Engineering Department, WPI

Participant, NSF REU Program "Integrated Research, Education and Outreach Experience for Females and Underrepresented Minorities in Bioengineering at Worcester Polytechnic Institute" I advised 6 undergraduate students on mentored research projects in biomaterials and tissue regeneration. Three of these students presented their work at annual meetings of the Biomedical Engineering Society. Two of these students are currently enrolled in Ph. D. Programs in Biomedical Engineering (Johns Hopkins University, University of Cincinnati). 2005-present.

Faculty Advisor, NSF Program, "Partnership Implementing Engineering Education (PIEE)". I served as a faculty advisor for two teams of students (4 graduate students and 9 undergraduate students, 2 teams of teachers in the Worcester Public Schools (WPS)) that created and delivered lesson plans incorporating engineering into the K-6 curriculum. Fall 2004- Spring 2006.

e. Collaborators and Other Affiliations

(i) Collaborators of past 2 years (not listed as co-authors above or students below)

Maura E. Collins-Pavao, Ph.D., Department of Biology, Worcester State College
Gary Ostroff, Ph.D., Departments of Pediatrics-Molecular Neurobiology, University of Massachusetts Medical School, Worcester, MA
Glenn R. Gaudette, Department of Biomedical Engineering, WPI
W. Grant McGimpsey, Department of Chemistry, WPI

(ii) Graduate and Postdoctoral Advisors

Frederick H. Silver, Ph.D., (Graduate Advisor) Department of Pathology and Laboratory Medicine, University of Medicine and Dentistry of New Jersey
Jeffrey R. Morgan, Ph.D., (Postdoctoral Advisor) Center for Engineering in Medicine, Massachusetts General Hospital, Harvard Medical School and Shriners Hospital for Children (now at Brown University)
Martin L. Yarmush, M.D., Ph.D., (Postdoctoral Advisor) Center for Engineering in Medicine, Massachusetts General Hospital, Harvard Medical School and Shriners Hospital for Children

(iii) Students supervised at WPI

1. Former Students: Brett Downing, M. Eng. 2004, Stuart Howes, M.S., 2007, Kevin Cornwell, Ph.D. 2007
2. Current Students: Katie Bush, Ph.D. candidate, expected 2008, Megan Murphy, M.S. candidate, expected 2008.

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* Based on undergraduate senior thesis work or summer REU student work

BIOGRAPHICAL SKETCH

Jennifer Wilcox

A. Professional Preparation

Wellesley College, Wellesley, MA	Mathematics	B.A., 1998
University of Arizona, Tucson, AZ	Physical Chemistry	M.A., 2004
University of Arizona, Tucson, AZ	Chemical Engineering	Ph.D., 2004

B. Appointments

Assistant Professor, Department of Chemical Engineering, Worcester Polytechnic Institute, Worcester	2004 - present
Research Assistant, Dept. of Chemical and Environmental Engineering, University of Arizona, Tucson	2000-2004
Teaching Assistant, Dept. of Chemical and Environmental Engineering, University of Arizona, Tucson	2003-2004
Adjunct Faculty, Departments of Mathematics and Chemistry, Pima Community College, Tucson	1999-2004
Environmental Scientist, Enviro Engineering, Tucson	1998-1999
Teaching Assistant, Mathematics Dept. Wellesley College	1997-1998

C. Publications

1. J. Wilcox, D.C.J. Marsden and P. Blowers, A Comparison of Quantum Mechanical Methods in Predicting Rate Constants for Mercury Oxidation Reactions Involving Chlorine-containing Species, submitted to *J. of Mol. Struct. (Theochem).*
2. P. Blowers, X. Zheng and J. Wilcox, An Accurate Heat of Formation Estimate for Mercuric Oxide Based on Quantum Chemical Calculations, submitted to *Chemical Physics.*
3. J. Wilcox and P. Blowers, The Decomposition of Mercuric Chloride and its Application to Modeling Mercury in the Flue Gases of Coal Combustion, *Environmental Chemistry*, 1(3) **2004**, 166-171.
4. J. Wilcox, D.C.J. Marsden and P. Blowers, Evaluation of Basis Sets and Theoretical Methods for Estimating Rate Constants of Mercury Oxidation Reactions Involving Chlorine, *Fuel Proc. Technol.* 85 **2004**, 391-400.
5. J. Wilcox A. and P. Blowers, Correction and Improvement of Mercury Speciation Kinetics Estimates from Quantum Chemical Calculations, *J. Mol. Struct. (Theochem)* 674 **2004**, 275-278.
6. J. Wilcox, J. Robles, D.C.J. Marsden, and P. Blowers, Theoretically predicted rate constants for mercury oxidation by hydrogen chloride in coal combustion flue gases, *Environ. Sci. Technol.* 37(18) **2003**,4199-4204.
7. P. Blowers and J. Wilcox, Integration of Communication Skills into the Introductory Material and Energy Balances Course in Chemical Engineering, *Proceedings of the 2001 American Society for Engineering Education Annual Conference & Exposition*, **2001**.

CV: Jennifer Wilcox

D. Synergistic Activities

Incorporation of undergraduates in my research. I currently have three undergraduate researchers working for me in my laboratory over the summer. I have also participated with advising on two senior theses this spring. As a graduate student at the University of Arizona I advised both a high school student and an undergraduate in my research efforts, with the undergraduate student appearing as a co-author on one of my publications.

E. Collaborators and Other Affiliations

Collaborators and Co-Editors
Paul Blowers, University of Arizona
David Marsden, University of Arizona
Joe Robles, University of Arizona
Jost O.L. Wendt, University of Arizona
Xiaobo Zheng, University of Arizona

Graduate Advisors (Ph.D.)
Paul Blowers, University of Arizona, Chemical Engineering
Jost O.L. Wendt, University of Arizona, Chemical Engineering
Graduate Advisor (M.A.)
Andrei Sanov, University of Arizona, Physical Chemistry
Graduate students and Post-doctoral scholars (current)
2004-present: David Urban, M.S.
2005-present: Bihter Padak, Ph.D.
2005-present: Shekar Sonwane, Post-doc

F. Courses Taught, Past 3 years

Pima Community College, Tucson, AZ:
Introductory Chemistry for Nursing, enrollment ~30
College Algebra, enrollment ~40
WPI, Worcester, MA:
Fluid Mechanics (Fall 2004, 2005), enrollment ~50
Kinetics and Catalysis (graduate, Spring 2005), enrollment 4
Molecular Modeling (grad/undergrad, Fall 2005), enrollment 10

Peter H. Levine, M.D.
Health Care Consultant
BDC Advisors, L.L.C.

F. William Marshall, Jr.
Retired

Robert Martin '75
Investor/Management Consultant
(self-employed)

John T. Mollen
Executive Vice President
Human Resources
EMC Corporation

Philip R. Morgan
President and CEO
Morgan Construction Company

Judith Nitsch '75
President
Nitsch Engineering, Inc.

Donald K. Peterson '71
Former Chairman and CEO
Avaya, Inc.

Windle B. Priem '59
President and CEO Retired
Korn/Ferry International

Scott W. Ramsay '68
Former CFO and Executive Vice
President
Shaw's Supermarkets

Leonard E. Redon '73
Vice President, Western Operations
Paychex, Inc.

Stephen E. Rubin '74
Founder
Intellution Inc.

Frederick D. Rucker '81
Managing Partner
Capitol Management Partners

Philip B. Ryan '65
CEO
Merchants Automotive Group

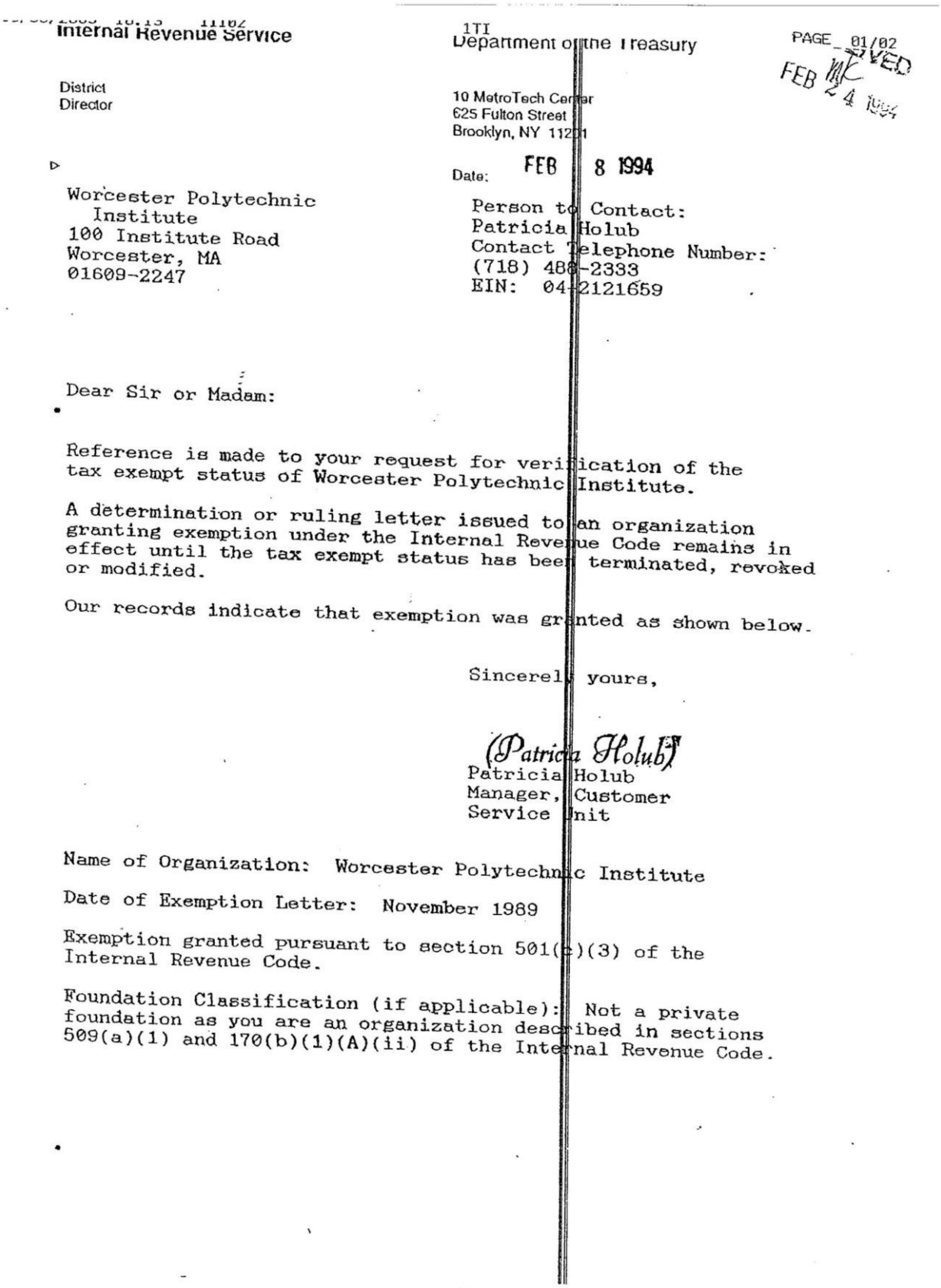
John J. Shields '69
General Partner
Boston Capital Ventures

Glenn Yee '74
CEO
Pacific Can Co. Ltd.

Michael P. Zarrilli '71
Chief Operating Officer
Spectrum Investment Group, L.P.

Donald P. Zereski, '74
President and CEO Retired
Silicon Dimensions

A1.5 Additional Information



Internal Revenue Service

District
Director

1TI
Department of the Treasury

10 MetroTech Center
625 Fulton Street
Brooklyn, NY 11201

PAGE 01/02

FEB 24 1994

Date: FEB 8 1994

Worcester Polytechnic
Institute
100 Institute Road
Worcester, MA
01609-2247

Person to Contact:
Patricia Holub
Contact Telephone Number:
(718) 488-2333
EIN: 04-2121659

Dear Sir or Madam:

Reference is made to your request for verification of the tax exempt status of Worcester Polytechnic Institute.

A determination or ruling letter issued to an organization granting exemption under the Internal Revenue Code remains in effect until the tax exempt status has been terminated, revoked or modified.

Our records indicate that exemption was granted as shown below.

Sincerely yours,

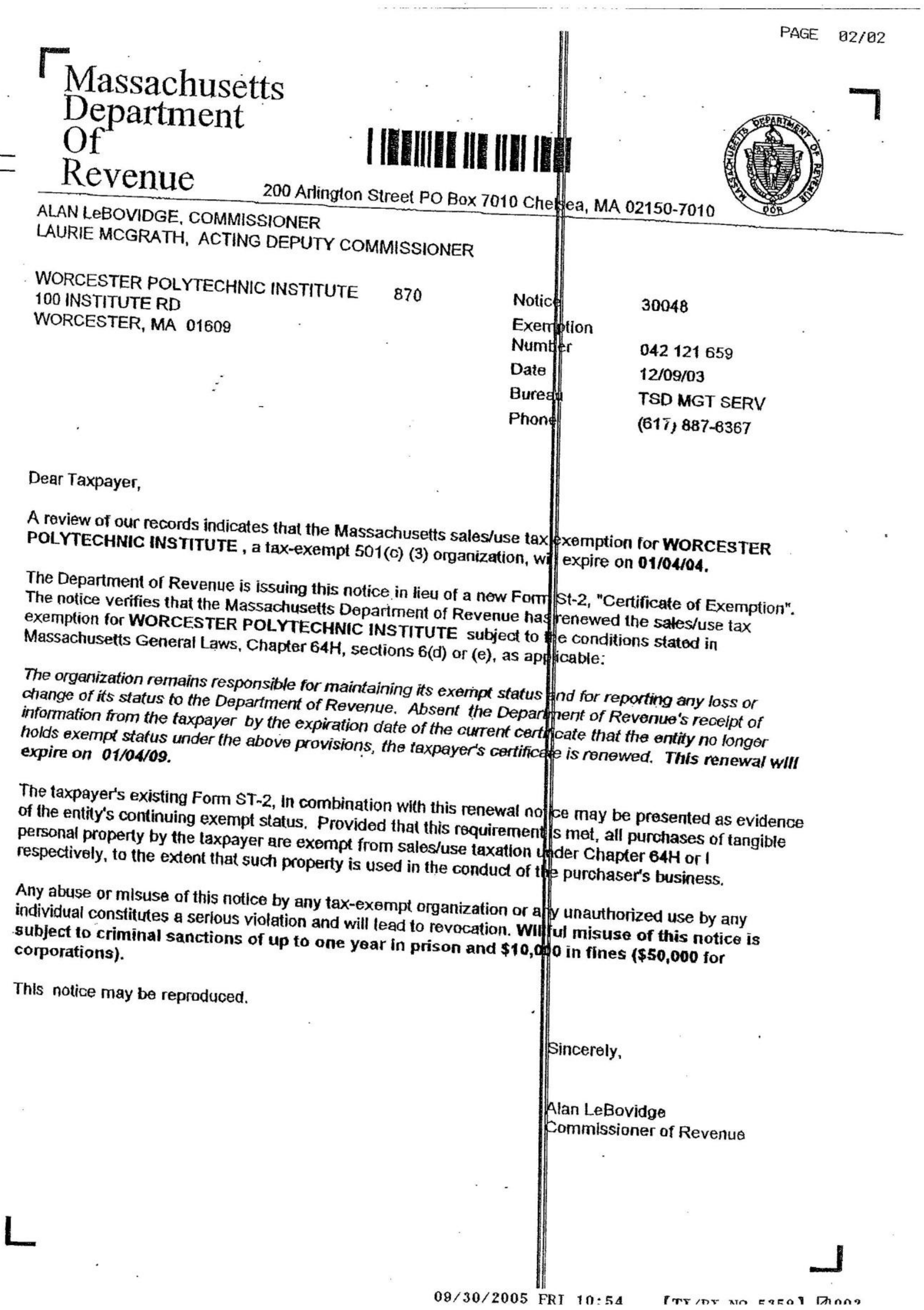
(Patricia Holub)
Patricia Holub
Manager, Customer
Service Unit

Name of Organization: Worcester Polytechnic Institute

Date of Exemption Letter: November 1989

Exemption granted pursuant to section 501(c)(3) of the Internal Revenue Code.

Foundation Classification (if applicable): Not a private foundation as you are an organization described in sections 509(a)(1) and 170(b)(1)(A)(ii) of the Internal Revenue Code.



PAGE 02/02

Massachusetts
Department
Of
Revenue

200 Arlington Street PO Box 7010 Chelsea, MA 02150-7010

ALAN LeBOVIDGE, COMMISSIONER
LAURIE MCGRATH, ACTING DEPUTY COMMISSIONER

WORCESTER POLYTECHNIC INSTITUTE 870
100 INSTITUTE RD
WORCESTER, MA 01609

Notice	30048
Exemption Number	042 121 659
Date	12/09/03
Bureau	TSD MGT SERV
Phone	(617) 887-6367

Dear Taxpayer,

A review of our records indicates that the Massachusetts sales/use tax exemption for **WORCESTER POLYTECHNIC INSTITUTE** , a tax-exempt 501(c) (3) organization, will expire on **01/04/04.**

The Department of Revenue is issuing this notice in lieu of a new Form St-2, "Certificate of Exemption". The notice verifies that the Massachusetts Department of Revenue has renewed the sales/use tax exemption for **WORCESTER POLYTECHNIC INSTITUTE** subject to the conditions stated in Massachusetts General Laws, Chapter 64H, sections 6(d) or (e), as applicable:

*The organization remains responsible for maintaining its exempt status and for reporting any loss or change of its status to the Department of Revenue. Absent the Department of Revenue's receipt of information from the taxpayer by the expiration date of the current certificate that the entity no longer holds exempt status under the above provisions, the taxpayer's certificate is renewed. **This renewal will expire on 01/04/09.***

The taxpayer's existing Form ST-2, in combination with this renewal notice may be presented as evidence of the entity's continuing exempt status. Provided that this requirement is met, all purchases of tangible personal property by the taxpayer are exempt from sales/use taxation under Chapter 64H or I respectively, to the extent that such property is used in the conduct of the purchaser's business.

Any abuse or misuse of this notice by any tax-exempt organization or any unauthorized use by any individual constitutes a serious violation and will lead to revocation. **Willful misuse of this notice is subject to criminal sanctions of up to one year in prison and $10,000 in fines ($50,000 for corporations).**

This notice may be reproduced.

Sincerely,

Alan LeBovidge
Commissioner of Revenue

09/30/2005 FRI 10:54 [TX/RX NO 5359] ☑002

A2 Preliminary Research Interviews

* More to follow

Glenn Gaudette- BME
Research focuses on cardiac regeneration. Heart disease is the number one killer in the U.S. and thus this research is of tremendous relevance to the health and welfare of a large portion of the population. The research focuses on restoring mechanical function to a diseased heart mainly by restoring contractile cells lost during a myocardial infarction. Scaffold patches of natural or synthetic origin are placed over surgically created holes in animal hearts and impregnated with cells (presently cardiac myocytes) in an attempt to restore normal heart function. Imaging used in research includes SEM images of cell matrix interactions and surgical high-speed video recording of patch movements on a beating heart as well as light microscopy.

David Adams- Bio
Research made the cover of Nature and is thus likely to be of interest to a very broad audience as Nature is a popular magazine. Implications of research published in Nature are the development of an Alzheimer's mouse model and possible treatments for Alzheimer's disease. Another topic of significant relevance is his research into the use of adult stem cells in place of embryonic stem cells and research into the basic mechanisms of trans differentiation. Imaging used in research consists of light microscopy and PET scans.

Lauren Mathews- Bio
Research focuses on the study of crayfish behavior and physiology in order to better understand the mechanisms of evolution by natural selection and evolutionary ecology. Classification of new species of crayfish is also an important component of current research. Images of interest include classification illustrations used in establishing physiological characteristics of new species, video of crayfish behavior, and field photographs. She is very interested in using the SEM to examine the structure of sexual organs on crayfish and would be very helpful in assisting us with specimen preparation if we wish to gather SEMs on our own of crayfish, images could reveal information suitable for publication.

Samuel Politz- Bio
Research focuses on studying the pathways of gene expression and developmental biology. Transparent nematodes are used as a model due to the fact they have only 302 neurons and an adult consists of only 1,000 cells. Specifically genes involved in surface composition are studied as their effects are more easily observed. Imaging techniques used consist of fluorescent light microscopy.

Joseph Duffy- Bio
Fruit flies are used to study early developmental cell communication and signal transduction. Patterns of development and cell interactions are examined to determine what external signals cause cells to do what they do. Major application is in understanding the reasons cancer cells

stop obeying the natural messages of the body. The ability to induce nerve cells to regrow is also a possible future outcome of the information being discovered through this research.

ReetaPrusty- Bio
Fungal pathogenesis is the focus of her research. Arresting the cell cycle of fungi is the goal of research in order to create effective controls for pathogenic fungi. Petri dishes and direct observation along with light microscopy comprise the main methods of investigation. C. Elegans are infected with fungi also to study pathology.

Eric Overstrom- Bio
Research focuses on developmental biology. Eggs and sperm are studied with focus on gene expression in both, and the fertilization process timing and intricacies. Relevance to human fertility and industrial agriculture are some main implications. Methods to expel DNA from eggs chemically are being examined in order to set the stage for effective cloning.

A3 Important Science and Art Quotes

The first mistake is to think of mankind as a thing in itself. It isn't. It is part of an intricate web of life. And we can't think even of life as a thing in itself. It isn't. It is part of the intricate structure of a planet bathed by energy from the Sun.

ISAAC ASIMOV (1920-1992), U.S. BIOCHEMIST

We pass the word around; we ponder how the case is put by different people; we read the poetry; we meditate over the literature; we play the music; we change our minds; we reach an understanding. Society evolves this way, not by shouting each other down, but by the unique capacity of unique, individual human beings to comprehend each other.

LEWIS THOMAS (1913-1993), U.S. BIOLOGIST

A human being is part of a whole called by us a universe – a part limited in time and space. He experiences himself, his thoughts and his feelings, as something separate from the rest, a kind of optical delusion of his consciousness. This delusion is a kind of prison for us; it restricts us to our personal decisions and our affections to a few persons nearest to us. Our task must be to free ourselves from this prison by widening our circle of compassion to embrace all living creatures and the whole of nature in its beauty.

ALBERT EINSTEIN (1879-1955)
SWISS-AMERICANN PHYSICIST

We did not arrive on this planet as aliens. Humanity is part of nature…. The more closely we identify ourselves with the rest of life, the more quickly we will be able to…. acquire the knowledge on which an enduring ethic, a sense of preferred direction, can be built.

EDWARD O. WILSON (B. 1929) U.S. BIOLOGIST

The world is indeed only a small tide pool; disturb one part and the rest is threatened.
GREGORY BATESON (1904-1980)
U.S. ANTHROPOLOGIST

If you see a single blood cell in my veins and follow it, it will drift along; you won't be able to predict anything. But if you study the body as a whole, you might say, "I injured my finger and now my immune system is reacting." There's a global response to the injury and this is why this blood cell goes there. It's quite evident to me that the movement and development of one part is part of the pattern of organization of the larger system. In that sense I can see a purpose.
FRITJOF CAPRA (B. 1939), U.S. PHYSICIST

Imagination is more powerful than knowledge.
ALBERT EINSTEIN (1879-1955)
SWISS-AMERICANN PHYSICIST

Newton's passage from a falling apple to a falling moon was an act of the prepared imagination.
JOHN TYNDALL (1820-1893), IRISH PHYSICIST

An act of imagination, a speculative adventure . . . underlies every improvement of natural knowledge.
SIR PETER BRIAN MEDWAR (1915-1987)
BRITISH ZOOLOGIST

The modern physicist and anyone who would understand what he is up to, must therefore learn to work in two worlds. One is a world of brass and glass and wax and mercury and coils and lenses and vacuum pumps . . . the other is a world of visualization and creative imagination . . . .
HERBERT SPENCER (1820-1903), BRITISH ANTHROPOLOGIST

We do not understand much of anything, from . . . the "big bang", all the way down to the particles in the atoms of a bacterial cell. We have a wilderness of mystery to make our way through in the centuries ahead.
LEWIS THOMAS (1913-1993), U.S. BIOLOGIST

If we want to solve a problem that we have never solved before, we must leave the door to the unknown ajar.
RICHARD P. FEYNMAN (1918-1988), U.S. PHYSICIST

The ignition point at which interest will take fire to make the warmth of purpose is often so high that we cannot by ourselves generate the necessary heat to accomplish it. Desire and aspiration come oftener from something outside us, from the ideas and personalities of others.
EDMUND W. SINNOTT (1888-1968), U.S. BIOLOGIST

The value of science remains unsung by singers, so you are reduced to hearing – not a song or a poem, but an evening lecture about it.

RICHARD P. FEYNMAN (1918-1988), U.S. PHYSICIST

In this momentous question as to the nature and quality of life we should not limit ourselves to an approach through science only, important as this is. The philosopher, the poet, the artist, and the mystic should all contribute their insights here, for all are concerned with life.

EDMUND W. SINNOTT (1888-1968), U.S. BIOLOGIST

Science is one of the grand human activities. It uses the same kind of talent and creativity as painting pictures and making sculptures. It's not really very different, except that you do it from a base of technical knowledge.

MAXINE SINGER (B. 1931), U.S. GENETICIST

The important thing is not to stop questioning. Curiosity has its own reason for existing. One cannot help but be in awe when he contemplates the mysteries of eternity, of life, of the marvelous structure of reality. It is enough if one tries merely to comprehend a little of this mystery every day. Never lose a holy curiosity.

ALBERT EINSTEIN (1879-1955)
SWISS-AMERICANN PHYSICIST

By contrast with the emptiness of space, the living world is crammed with detail at every level . . . For example, a drop of water contains rather more than a thousand billion billion water molecules.

FRANCIS CRICK (B.1916), BRITISH BIOPHYSICIST

It is obvious that microbiologists will not run out of work for a couple of centuries.

JOSTEIN GOKSOYR (B.1922)
NORWEGIAN MICROBIOLOGIST

It is interesting to contemplate an entangled bank, clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth, and to reflect that these elaborately constructed forms, so different from each other . . . have all been produced by laws acting around us.

CHARLES DARWIN (1809-1882), BRITISH BIOLOGIST

In one pool, on the right side of the path, is a family of otters; on the other side, a family of beavers . . . I was transfixed. As I now recall it, there was only one sensation in my head: pure elation mixed with amazement at such perfection. . . . I wished for no news about the physiology of their breathing, the contraction of their muscles, their vision, their endocrine systems, their digestive tracts. I hoped never to have to think of them as collections of cells. All I asked for was the full hairy complexity, then in front of my eyes, of whole, intact beavers and otters in motion.

LEWIS THOMAS (1913-1993), U.S. BIOLOGIST

I think that the novelty of nature is such that it's variety will be infinite – not just in changing forms but in the profundity of insight and the newness of ideas. . . .

ISIDOR ISAAC RABI (1898-1988)
AUSTRIAN-AMERICAN PHYSICIST

I can imagine no terminal point of human inquiry into nature, ever.

LEWIS THOMAS (1913-1993), U.S. BIOLOGIST

A4 Project Expenditures

White House Custom Color	
(Photographic prints)	257.25
D.B Cotton	
(Steel/Bending)	468.00
Vangy Tool Co.	
(Steel/Water Jet)	688.00
National Glass Works	240.00
(Glass)	
Hardware/Foam Core/Clear Coat	150.00
Video Display	260.00
Reception Catering/Flyer	600.00

Total2663.25

A5 Survey Responses

A5.1 How would you describe this exhibit to a friend?

1. With enthusiasm! And many hand Gestures!
2. Very professional display of interesting pictures.
3. a mixture of microscopic images presented in an artistic manner
4. Science as art
5. scientific images arranged to create an art exhibit
6. pictures of God's design
7. Art on a scale rarely explored

8. the art of science
9. Inspirational and eye opening
10. The exhibit existed at the interface of art and science and questions the pictures that we typically think of as beautiful
11. This exhibit encompasses both art and science. It was clearly well developed from conception to completion. It holds it’s own as an art piece.
12. a collection of science related images including magnified things.
13. As a beautiful and aesthetic display of microscopic experimentation
14. A series of photographs showing us the world as no human eye can see. Though the application of art and science we’re given a glimpse into the inner life of biology, chemistry, physical materials and ultimately how science works.
15. descriptive, interesting and worth checking out
16. microscopic, structured, good
17. Materials as art, beauty in science?
18. It is a window into the microscopic details of our world- the subtle masterpieces that are life
19. “techno-artsy” scale-less creation
20. “Fucking awesome”
21. microscopy of cells and materials (polymer)
22. it is an interesting collection of images from the natural world
23. Beautiful photographs of subjects not normally seen
24. Interesting intersection of art and science
25. beautiful, well displayed microscopy photography, but lacking in descriptions & explanations
26. microscopic photos in great framing (the strength and unchanging of the metal)
27. an art exhibit that explores, scientifically, things natural and man-made at a level that our human eye could never see. And a level that the human mind rarely considers. It is beautiful and the quote on the video display of the guy about no songs or poems about science. So true. Good quote. This exhibit addresses that issue to bring it justice.
28. a beautiful display of images from scientific with the freedom of artistic expression
29. a very nice display of science
30. Science presented in an interesting way
31. artful presentation of science
32. A fresh way to see science
33. an art science exhibit
34. So exciting, inspiring
35. interesting and beautiful
36. it’s a series of images from science arranged in an artistic fashion, mostly in metallic frames
37. fantastic art and science show
38. great
39. amazing presentation of science
40. an intriguing unification of science
41. a must see
42. worth catching

A5.2 How has this exhibit affected your definitions of art and science, if at all?

1. Not much
2. it hasn't really affected either. If anything it presented them as intertwined with one another
3. It definitely makes me appreciate images from microscopes more
4. it can be interesting when presented in the right way
5. The intricacies of matter on such a small scale makes apparent the complexity of our world
6. It gave a unique perspective to science and showed a connection which is often forgotten or overlooked
7. It has completely changed my worldview
8. Art is very much a part of science. This exhibit shows that art is happening all around us, we don't always have the microscope to see it! It's nice to think of that fact that art and science do have an interface. People try to deny that.
9. I think that it is clearly moving toward a combination of the two. It would be interesting to see photographic endeavors mixed in as well
10. I have always felt that there should not be a narrow definition of art, so I can certainly accept these as a presentation of the two coming together.
11. Because of the unique presentations, the endless ways to look at one subject matter to find the sublime.
12. Art and science have always been lined by the shared value of exploration. However, artists often fail to see themselves as scientists and scientists often neglect to see creative expressions in their discoveries. This show is a wonderful statement to how these can both be seen coexistent.
13. art and science go fabulously together
14. that the lines between can easily blur with a little change in perspective
15. It reminds me of why I originally got interested in materials science and why I enjoyed spending so much time taking that perfect photograph.
16. Science is the ultimate art- the spontaneous creations made through millions of mutations are the most breathtaking pieces of art.
17. not really- I have always associated good science (and especially engineering) with art
18. very aesthetic
19. not really much
20. I have always felt that art and science are intrinsically related. The age we live in separates things too much. Leonardo daVinci had the right idea.
21. Shows that expression is infinite
22. It hasn't particularly, but I recognize its part of an important, useful trend that I'm totally excited about. It isn't surprising that these images are beautiful- I could use some more science.
23. I have always felt that there is beauty to be found in all things- this exhibit expresses that belief.
24. Yeah- you don't see scientific images in art exhibits, yet they are images of microscopic really natural things- at a level you would otherwise never see. My imagination woke up- I saw things from outer space, deep sea and other planets. Wow.

25. I found myself at the apex of some fundamental question, what do we call art and what do we really call science? The exhibit provided a strong case for the intersection of art and science, something that I had not thought was possible.
26. There is beauty in everything. Science is the empirical study of this, while art presents it in a more emotional manner. This exhibit has reinforced my viewpoint.
27. It has helped me realize that art and science are not as different as I thought.
28. this exhibit has given me a new appreciation for science. I now see why so many people are excited about science.
29. It has helped me see the creativity involved in science
30. I am glad that other people can now see the artistic creativity that is required to make scientific breakthroughs
31. Seem similar now
32. they seem very connected now
33. what I saw in the exhibit was a balance of art and science playing in harmony with each other
34. such an interesting combination of the two
35. very interesting, perspectives have changed
36. has created a link between
37. im not sure I would call art and science different from each other anymore
38. I see science as more beautiful now
39. still thinking about them now

A5.3 Which aspect of this Exhibit will you remember most?

1. I loved the frames!
2. Very vivid colors and cool depth on the b&w ones
3. the relief looking photos in the back corner next to the video display
4. the close ups of the steel from the WTC
5. The fluorescent microscopy
6. the colors
7. Electrospun fibers
8. This exhibit was great and I enjoyed the melding of two fields(art and science) in a unique and effective way
9. The giant walrus was a tremendous touch
10. The frames were well done. I liked the way everything was displayed.
11. The large multi images were really powerful and really created a story and narrative within themselves.
12. Frames were very solid
13. Presentation: the clear and powerful handling of materials.
14. The amazing grid entitled electrospun fibers.
15. the giant sculpture when you first walk in. the black and white is captivating!
16. the large grids of small black and whites
17. The layout and arrangements and the quality of the framing really stands out. Definitely two “types” of photos- biological materials and synthetic materials
18. The haphazard yet perfectly designed nerve cell
19. I have enjoyed the video connections. The research and reality of the art form

20. Painstaking work put into display
21. the formats- metal “frames”. Cool images, too – well planned, good variety
22. the presentation of the images
23. The stand with the DVD player and the B&W mouse oocytes
24. Electrospinning
25. Images of steel beams from the WTC
26. The mixture of the metal framing and the photos.
27. Antibodies and muscle cells- they’re in my body- I never think of them and certainly never consider their beauty.
28. It is a delightful experience to visualize the worlds of the macro and microscopic and witness the similarities between both realms. Almost begs the question, do we need to separate these scales?
29. I will remember how something as mundane as electrospun fibers can be breathtaking when shown as these students presented them.
30. I will remember how beautiful images from science can be
31. The presentation was amazing!
32. The video that talked about the actual science
33. I loved the display of the electrospun fibers
34. So original, the art science combination
35. how beautiful science can be
36. being a witness to the diversity of people present at the exhibit
37. the diversity of people attending the opening
38. the fluorescent images
39. quotes by scientist on video screen
40. the amazing piece of electrospun fibers and uniqueness of all the fine structures found in this research area
41. The beauty and design, professional
42. the interesting combination of people attending the opening

A5.4 Please share any Additional responses to the Exhibit

1. Would love to know more about what the photos are
2. Nice presentation
3. I enjoyed the images but wish it was in a larger space with more images.
4. it was a unique take on science
5. I liked how it was arranged
6. should have a bigger room
7. This exhibit was great and I enjoyed the melding of two fields(art and science) in a unique and effective way
8. The crowd at the opening had quite an uncouth manner!
9. Thank you for sharing your art
10. Beautifully presented
11. Looks good!
12. Nice Job guys. They look fantastic and the EcoTarium is a perfect venue!
13. Very nice job. A+
14. enjoyable change of pace (for a studio art major such as myself)

15. I found myself wanting to know how the researchers were using or interpreting the images.
16. The sculptures celebrates the beauty of life in the simplest forms
17. I would have enjoyed a stronger connection to the macro- sized feature. For example, a real sized photo/sketch of the features alongside the "art"
18. size works well, repetition of type is impressive. God use of collaboration between students and scientists/artists
19. The presentation/framing/choice of the photos was very artistically creative
20. Nice display. You might want to consider presenting it as a poster session where each group would present what, why, who… etc.
21. Please add descriptions (in layman's terms!) of what we're looking at, why it's significant and how these images were accomplished. Great exhibit!
22. I enjoyed the size of the gallery area- good for the exhibit size
23. Really cool display- the frames, especially the 100+ frames are beautiful. Ian & company really brought science and art together in this way. Encore!
24. The exhibit was a refreshing mixture of color, imagery and metal
25. This is really amazing! I would love to see more!
26. This is a really nice way to find out about some science that is important to my life
27. I would love to see more exhibits like this!
28. I really enjoyed how you all connected art and science
29. Would like to see more video
30. inspirational
31. room was not perfect match for exhibit, wall space utilized well though more light required. Good mix of color and black and white images
32. seems like a valuable exhibit for the community to come see
33. so glad I came
34. very professional, beautiful
35. would be nice to see more pieces and pictures in future shows
36. Makes me interested in science again
37. I see WPI in a different way now

A5.5 Demographics

Total Surveyed: 42

Female
Under 18, 1
18-25, 11
26-35, 3
35+, 4

Male
18-25, 11
26-35, 4
35+, 8

A6 Exhibit Invitation

science

The EcoTarium
222 Harrington Way
Worcester, MA
(508) 929-2700

Opening reception
Free Admission
Thursday April 24 from 5:30-7:30
Exhibit open through May

art

A multimedia exhibit uniting artists and scientists from WPI

A7 Blank Exhibit Questionnaire

Exhibit Exit Questions

How would you describe this exhibit to a friend?

How has this exhibit affected your definitions or perspectives of art and science, if at all?

Which aspect of this exhibit will you remember most?

Please share any other responses to the exhibit.

Please Circle the Appropriate Response

Gender: Male Female
Age Group: Under 18 18 – 25 26 – 35 36 and older

Initials of parent or guardian if under 18 __________

A8 Grounded Theory Survey

How would you describe this exhibit to a friend?

Response #	**Person 1**	**Person 2**	**combo 1**
1	enthusiastic	indirect, positive emo	non des +
2	interesting, professional	positive design imagery	non des +
3	artistic	microscopic , SART	sci dom
4	art	SART	sci dom
5	art	SART	sci dom
6	beautiful	Images god's design	non des +
7	fresh	microscopic art	non des +
8	artistic	A-Sci	Art dom
9	inspirational	Indirect, postive emo	non des +
10	positive	Equality of science and art	equal
11	well developed	Equality of science and art	equal
12	neutral	science	science
13	beautiful experimentation	microscopic display, beauty	non des+
14	very susessful	SART, microscopic	sci dom
15	interesting	indirect, positive emo	non des +
16	slightly positive	microscopic, positive emo	non des +
17	sucsesful	materials as art, beauty in science	equal
18	window into world	microscopic delight	non des +
19	techno-artsy	techno artsy , w/o scale creation	art dom
20	very positive	indirect, positive emo	non des +
21	neutral	microscopy	non des =
22	interesting	Imagery, interesting	non des +
23	beautiful, new	Imagery, beauty	non des +
24	neutral	Equality of science and art	equal
25	beautiful, lacking description	microscopy, beauty	non des -
26	great, strong	Imagery, beauty	non des +
27	very positive	A-Sci, rare level	Art dom
28	beautiful, artistic	Equality of science and art	equal
29	very nice	science	science
30	interesting	science	science
31	artful	SART	sci dom
32	fresh	science	science
33	neutral	Equality of science and art	equal
34	exciting,inspiring	indirect, positive emo	non des +
35	interesting	indirect, positive emo	non des +
36	artistic	Equality of science and art	equal
37	fantastic	Equality of science and art	equal
38	great	indirect, positive emo	non des +
39	amazing presentation	science	science
40	intriguing, unification	science	science
41	must see	indirect, positive emo	non des +
42	postitve	indirect, positive emo	non des +
Non Response			0

How has this exhibit affected your definitions or perspectives of art and science?

Response #	**Person 1**	**Person 2**	
1	not much	minimal effect	neutral
2	intertwined defanitions	minimal efect, intertwined	no related
3	apreciate more	appreciation of microscopy	yes
4	can be interesting	interesting	yes
5	complex	micro to macro	not relevant
6	unique perpective, connection	unique science view	yes
7	changed worldview	high impact, worldview	yes
8	art all around, in science	art and science communicate	yes
9	moving toward combination	art and science communicate	yes
10	good joint presentation	art and science communicate	yes
11	enless ways , one subject	single subject , many views to the sublime	yes
12	wonderful statement to connection	art and science communicate, exploration	yes
13	got together well	art and science communicate	yes
14	lines blured with change in perspective	art and science communicate	yes
15	very positive	reminder of science field, pefect photo	no related
16	science ultimate art	science is the ultimate art	no related
17	not really- already support combination	minimal effect	no related
18	very aesthetic	aesthetic	not relevent
19	not much	minimal effect	neutral
20	not much, already related	art and science communicate	not related
21	infinite expression	single subject, many expressions	yes
22	not really, need more science	minimal effect, beauty is not surprising	no unique
23	not much, reinforces	beauty in all things	no related
24	yes- imagination woke up	science not usually in art, successful, interesting	yes
25	strong connection	micro to macro	yes
26	no, reinforces	beauty in all things, art and science communicate	no related
27	yes, not as different as thought	art and science communicate	yes
28	new appreciation for science	science, appreciation	yes
29	now see creativity	science, creativity	yes
30	reinforces	science, creativity	no related
31	similar now	art and science communicate	yes
32	connected now	art and science communicate	yes
33	balace, harmony between two	art and science and communicate	no relates
34	interesting combination	separate, yet interesting	no unique

		combination		
35	changed, interesting	high impact	yes	
36	created a link	art and science communicate	yes	
37	not so different	single subject	yes	
38	science more beautiful	science, beauty	yes	
39	yes, still thinking	high impact	yes	
Non Response				3

Additional responses?

Response #	**Person 1**	**Person 2**
1	more about photos	more info
2	nice presentation	congrats
3	more space	larger space, more images
4	unique	unique take on science
5	good arrangement	good arrangement
6	needs bigger space	larger space
7	great, unique	congrats, combo of art and science
8	/	joke, outlier
9	thank you	appreciation
10	beautifull	positive support
11	looks good!	positive support
12	perfect venue, good job	positive support
13	A+	positive support
14	nice change of pace	change of pace from art pov
15	more about images	more info
16	selebrated beauty	beauty of life
17	would like connection to macro scale	more info, macro world
18	good collaboration	positive support
19	very artistically created	positive support, artistically creative
20	poster session, more info	positive suport, poster display
21	more descriptions	positive support, more info
22	good size	adequate size
23	great display	frames, display, union of art and science
24	refreshing	color, imagery, metal
25	amazing, want to see more	positive support, wants more
26	good way to find out about science	good way to learn about science
27	like to see more like this	positive support, wants more
28	good connection	art and science connected well
29	more video	more video
30	inspirational	inspirational
31	room perfect	larger room, good color/contrast
32	valuable exhibit for community	positive support, applicable to more people
33	glad to see	appreciation
34	professional, beautiful	beautiful, professional
35	like to see more like this	more!

36	interested in scinece again	promotes interest in science
37	see WPI differently	different prespective of wpi

Which aspect will you remember most?

Response #	**Person 1**	**Person 2**	
1	frames	frames	frames
2	vivid colors, depth	colors, contrast	images
3	oocytes	oocytes	oocytes
4	wtc	WTC	WTC
5	fluorescent miroscopy	fluorescent microscopy	Muscle
6	the color	colors, contrast	images
7	fibers	e-spun	fibers
8	unique combination	union of art and science	other
9	/	giant walrus ?	other
10	frames, display	frames, design	frames
11	narative of large pieces	large matrices	oocytes fibers
12	frames	frames	frames
13	presentation, material selection	design	presentation
14	fibers	e-spun	fibers
15	fibers	black and white	fibers
16	fibers, oocytes	oocytes	fibers oocytes
17	layout, framing	design, frames, diverse areas	presentation
18	muscle cells	muscle	muscle
19	video connections	video, validity as an art from	video
20	diplay	display	presentation
21	frames, good images	display, design, frames	frames, images
22	image presentation	display	presentation
23	video, oocytes	video, oocytes	video, oocytes
24	fibers	e-spun	fibers
25	wtc	WTC	WTC
26	frames, photos	frames	frames
27	muscle cells	muscle	muscle
28	macro-micro scales	macro mirco worlds	other
29	beauty of simple things	e-spun	fibers
30	beauty in science	beauty of science	other
31	presentation	display	presentation
32	video	video	video
33	fibers	e-spun	fibers
34	originality, connection b/w art science	orginality of combo	other
35	beauty in science	beauty of science	other

36	diversity of people at opening	diversity of people at exhibit	divese audience
37	diversity of people at opening	diversity of people at exhibit	divese audience
38	fluorescent images	fluorescent microscopy	muscles
39	quotes in video	quotes	video
40	fibers, uniqueness	e-spun	fibers
41	design beautiful, professional	design	presentation
42	diversity of people at opening	diversity of people at exhibit	divese audience

A9 Media Usage Forms and Exhibit Questionnaires

Media Usage and Inclusion Permission

The following agreement shall secure proper permission for the inclusion of media from the specified research group into the WPI IQP (JW1-9507), entitled the Artistic Presentation of Scientific Research as a Means to Increase Public Awareness.

The agreement includes the right to reproduce the provided media in a suitable size format for the project's needs as well as the ability to "crop and/or depixelate" the provided images. Video content, if present, shall not include any sound in the final included version.

It shall be the responsibility of the of the IQP team to obtain final permission from the research team whose media appears in the final project version before it is submitted. The IQP team will present the final media form to the research group and obtain the appropriate set of signatures. The IQP team will not include any media into the final project without the aforementioned final permission.

The research group reserves the right to remove any media content subject to be included in the IQP at any time before the final permission is obtained. In the event that special cases arise regarding the removal of media from the project, a simple dialogue between the IQP team and the research group will be opened in order to resolve the situation.

Additionally, the IQP team shall give proper citation and credit for the media included. If normal citation standards are not acceptable by the research group, then the IQP team is to reference the media in the following way provided by the research group:

Prasad S. Sarangapani, Nathan T.-H. Neal, Matthew R. Knott, Robert W. Thompson, and Anthony S.T. Chiang. (2006) Harvesting and Manipulating Zeolite Nanocrystals. Advances in Science and Technology Vol. 45 pp- 2096 - 2704.

Finally, all signatures from all parties represented must be present at all stages of the project in order for inclusion into the final IQP.

Description of Specific Media from Research Group

SEM photomicrographs of as-synthesized polymer/zeolite particles
Nano sized clusters of Dowex ion exchange resin particles coated by thin layer of zeolite

Research Group Information

Zeolite research both novel and optimization studies. Main applications focus on remediation efforts

Final Signatures of Permission and Approval

IQP (JW1-9507) Team

Ian Anderson Date 4/23/08

Mark Lindblad Mark A. Lindblad Date 4/23/08

Andres Lopez Date 4/23/08

Research Team

RW Thompson Date 4/23/08

Date

Date

Media Usage and Inclusion Permission

The following agreement shall secure proper permission for the inclusion of media from the specified research group into the WPI IQP (JW1-9507), entitled the Artistic Presentation of Scientific Research as a Means to Increase Public Awareness.

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Finally, all signatures from all parties represented must be present at all stages of the project in order for inclusion into the final IQP.

Description of Specific Media from Research Group

Research Group Information

Satya Shivkumar ME Professor,
Goki Eda WPI Graduate Student, ME
Xiaoshu Dai WPI Graduate Student, ME

Final Signatures of Permission and Approval

IQP (JW1-9507) Team

Ian Anderson ____________ Date 4/14/08

Mark Lindblad Mark A. Lindblad Date 4/14 /08

Andres Lopez ____________ Date 4/14/08

Research Team

____________ Date 4/14/08

____________ Date ____________

____________ Date ____________

Media Usage and Inclusion Permission

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The agreement includes the right to reproduce the provided media in a suitable size format for the project's needs as well as the ability to "crop and/or depixelate" the provided images. Video content, if present, shall not include any sound in the final included version.

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Additionally, the IQP team shall give proper citation and credit for the media included. If normal citation standards are not acceptable by the research group, then the IQP team is to reference the media in the following way provided by the research group:

Finally, all signatures from all parties represented must be present at all stages of the project in order for inclusion into the final IQP.

Description of Specific Media from Research Group

metallographic cross section of steel beams from the WTC Building 7 showing high temperature attack of the steel by a slag.

Research Group Information

Ron Biederman, Professor, WPI
George Vander Voort, Buehler Inc
Rich Sisson, Professor, WPI

Final Signatures of Permission and Approval

IQP (JW1-9507) Team

Ian Anderson ______________________ Date 4/14/08

Mark Lindblad Mark A. Lindblad Date 4/14/08

Andres Lopez ______________________ Date 4/14/08

Research Team

______________________ Date 4/14/08

______________________ Date ______

______________________ Date 4/14/08

Media Usage and Inclusion Permission

The following agreement shall secure proper permission for the inclusion of media from the specified research group into the WPI IQP (JW1-9507), entitled the Artistic Presentation of Scientific Research as a Means to Increase Public Awareness.

The agreement includes the right to reproduce the provided media in a suitable size format for the project's needs as well as the ability to "crop and/or depixelate" the provided images. Video content, if present, shall not include any sound in the final included version.

It shall be the responsibility of the of the IQP team to obtain final permission from the research team whose media appears in the final project version before it is submitted. The IQP team will present the final media form to the research group and obtain the appropriate set of signatures. The IQP team will not include any media into the final project without the aforementioned final permission.

The research group reserves the right to remove any media content subject to be included in the IQP at any time before the final permission is obtained. In the event that special cases arise regarding the removal of media from the project, a simple dialogue between the IQP team and the research group will be opened in order to resolve the situation.

Additionally, the IQP team shall give proper citation and credit for the media included. If normal citation standards are not acceptable by the research group, then the IQP team is to reference the media in the following way provided by the research group:

Courtesy of Center for Inorganic Membrane Studies

Finally, all signatures from all parties represented must be present at all stages of the project in order for inclusion into the final IQP.

Description of Specific Media from Research Group

Top surface & cross-sectional SEI micrographs of oxidized, activated and Pd and/or Ag deposited porous (or nonporous) sintered metal supports.

Research Group Information

The Center for Inorganic membrane studies at WPI is led by Prof Yi Hua Ma (Frances B. Manning Prof. of Chem. Eng.). The goals of the Center is to develop industry and university collaboration for inorganic membrane research and to promote & to expand the science of inorganic membranes as a technological base for industrial applications through fundamental research.

Final Signatures of Permission and Approval

IQP (JW1-9507) Team

Ian Anderson Date 4/22/08

Mark Lindblad Mark A. Lindblad Date 4/22/08

Andres Lopez Date 4/22/08

Research Team

Date 4/22/08

M. Engin Ayturk Date 4/22/08

Date

Media Usage and Inclusion Permission

The following agreement shall secure proper permission for the inclusion of media from the specified research group into the WPI IQP (JW1-9507), entitled the Artistic Presentation of Scientific Research as a Means to Increase Public Awareness.

The agreement includes the right to reproduce the provided media in a suitable size format for the project's needs as well as the ability to "crop and/or depixelate" the provided images. Video content, if present, shall not include any sound in the final included version.

It shall be the responsibility of the of the IQP team to obtain final permission from the research team whose media appears in the final project version before it is submitted. The IQP team will present the final media form to the research group and obtain the appropriate set of signatures. The IQP team will not include any media into the final project without the aforementioned final permission.

The research group reserves the right to remove any media content subject to be included in the IQP at any time before the final permission is obtained. In the event that special cases arise regarding the removal of media from the project, a simple dialogue between the IQP team and the research group will be opened in order to resolve the situation.

Additionally, the IQP team shall give proper citation and credit for the media included. If normal citation standards are not acceptable by the research group, then the IQP team is to reference the media in the following way provided by the research group:

All images should be directly + obviously cited to the research group.

Finally, all signatures from all parties represented must be present at all stages of the project in order for inclusion into the final IQP.

Description of Specific Media from Research Group

* Microscopy images of mouse oocytes + Somatic Cells

Research Group Information

Christine Lima + Eric Overström

Worcester Polytechnic Institute

Dept. of Bio + Biotech.

Final Signatures of Permission and Approval

IQP (JW1-9507) Team

Ian Anderson ______________________ Date 4-5-08

Mark Lindblad Mark A. Lindblad Date 4-8-08

Andres Lopez ______________________ Date 4-8-08

Research Team

______________________ Date 4-3-08

Christine Lima Date 4.8.08

______________________ Date ______________

Exhibit Exit Questions

How would you describe this exhibit to a friend?

Worth catching

How has this exhibit affected your definitions or perspectives of art and science, if at all?

Still thinking about them now

Which aspect of this exhibit will you remember most?

The interesting combination of people attending the opening

Please share any other responses to the exhibit.

I see WPI in very different way now

Please Circle the Appropriate Response

Gender: [✓ Male] Female

Age Group: Under 18 [✓ 18 – 25] 26 – 35 36 and older

Initials of parent or guardian if under 18 __________

Exhibit Exit Questions

With enthusiasm! And many hand gestures.

How would you describe this exhibit to a friend?

How has this exhibit affected your definitions or perspectives of art and science, if at all?

I loved the frames!

Which aspect of this exhibit will you remember most?

Would love to know more about what the photos are.

Please share any other responses to the exhibit.

Please Circle the Appropriate Response

Gender: [✓ Male] Female

Age Group: Under 18 18 – 25 26 – 35 [✓ 36 and older]

Initials of parent or guardian if under 18 __________

Exhibit Exit Questions

Very professional display of interesting pictures

How would you describe this exhibit to a friend?

Not much

How has this exhibit affected your definitions or perspectives of art and science, if at all?

Very vivid colors in Colored ones + cool depth in B & Ws

Which aspect of this exhibit will you remember most?

Nice presentation

Please share any other responses to the exhibit.

Please Circle the Appropriate Response

Gender: [✓ Male] Female

Age Group: Under 18 18 – 25 26 – 35 [✓ 36 and older]

Initials of parent or guardian if under 18 __________

Exhibit Exit Questions

How would you describe this exhibit to a friend?

A must see

How has this exhibit affected your definitions or perspectives of art and science, if at all?

I see science as more beautiful now

Which aspect of this exhibit will you remember most?

The beauty and design, professional

Please share any other responses to the exhibit.

Made me interested in science again

Please Circle the Appropriate Response

Gender: Male Female
Age Group: Under 18 [✓ 18 – 25] 26 – 35 36 and older

Initials of parent or guardian if under 18 __________

Exhibit Exit Questions

Science as art

How would you describe this exhibit to a friend?

How has this exhibit affected your definitions or perspectives of art and science, if at all?

The close ups of the steel from the WTC.

Which aspect of this exhibit will you remember most?

It was a unique take on science

Please share any other responses to the exhibit.

Please Circle the Appropriate Response

Gender: Male [✓ Female]

Age Group: Under 18 [✓ 18 – 25] 26 – 35 36 and older

Initials of parent or guardian if under 18 __________

Exhibit Exit Questions

How would you describe this exhibit to a friend?

An intriguing unification of art and science; A must-see!

How has this exhibit affected your definitions or perspectives of art and science, if at all?

I'm not sure if I'd call art and science so different from each other anymore

Which aspect of this exhibit will you remember most?

The amazing power of the electrospun fibers piece and uniqueness of all the fine structures found in this research area

Please share any other responses to the exhibit.

Would be nice to see more pieces and pictures in future showings

Please Circle the Appropriate Response

Gender: [✓ Male] Female

Age Group: Under 18 [✓ 18 – 25] 26 – 35 36 and older

Initials of parent or guardian if under 18 __________

Exhibit Exit Questions

scientific images arranged to create an art exhibit

How would you describe this exhibit to a friend?

It definitely makes me appreciate images from microscopes more

How has this exhibit affected your definitions or perspectives of art and science, if at all?

The flaurescent microscopy

Which aspect of this exhibit will you remember most?

I like how it was arranged

Please share any other responses to the exhibit.

Please Circle the Appropriate Response

Gender: Male [✓ Female]

Age Group: Under 18 [✓ 18 – 25] 26 – 35 36 and older

Initials of parent or guardian if under 18 __________

Exhibit Exit Questions

Pictures of God's design

How would you describe this exhibit to a friend?

it can be interesting when presented in the right way

How has this exhibit affected your definitions or perspectives of art and science, if at all?

the colors

Which aspect of this exhibit will you remember most?

Should have had a bigger room.

Please share any other responses to the exhibit.

Please Circle the Appropriate Response

Gender: Male [✓ Female]

Age Group: Under 18 [✓ 18 – 25] 26 – 35 36 and older

Initials of parent or guardian if under 18 __________

Exhibit Exit Questions

How would you describe this exhibit to a friend?

Art on a scale rarely explored.

The intricacies of matter on such a small scale makes apparent the complexity of [redacted] our world.

How has this exhibit affected your definitions or perspectives of art and science, if at all?

Which aspect of this exhibit will you remember most?

Electrospun Fibers

Please share any other responses to the exhibit.

Please Circle the Appropriate Response

Gender: [✓ Male] Female
Age Group: Under 18 [✓ 18 – 25] 26 – 35 36 and older

Initials of parent or guardian if under 18 __________

Exhibit Exit Questions

How would you describe this exhibit to a friend?

The art of science

How has this exhibit affected your definitions or perspectives of art and science, if at all?

It gave a unique perspective to science and showed a connection which is often forgotten or overlooked.

Which aspect of this exhibit will you remember most?

The frames

Please share any other responses to the exhibit.

The exhibit was great and I enjoyed the melding of two fields (art & science) in a unique & effective way.

Please Circle the Appropriate Response

Gender: Male [✓ Female]
Age Group: Under 18 [✓ 18 – 25] 26 – 35 36 and older

Initials of parent or guardian if under 18 __________

Exhibit Exit Questions

Inspirational and eye-opening.

How would you describe this exhibit to a friend?

It has completely changed my worldview.

How has this exhibit affected your definitions or perspectives of art and science, if at all?

The giant walrus was a tremendous touch

Which aspect of this exhibit will you remember most?

The crowd at the opening had a quite uncouth manner!

Please share any other responses to the exhibit.

Please Circle the Appropriate Response

Gender: Male [✓ Female]

Age Group: Under 18 18 – 25 26 – 35 [✓ 36 and older]

Initials of parent or guardian if under 18 __________

Exhibit Exit Questions

How would you describe this exhibit to a friend?

Amazing Presentation of Science

How has this exhibit affected your definitions or perspectives of art and science, if at all?

Has created a link between

Which aspect of this exhibit will you remember most?

Quotes by scientists and Video screen

Please share any other responses to the exhibit.

Very professional, beatiful

Please Circle the Appropriate Response

Gender: [✓ Male] Female
Age Group: Under 18 [✓ 18 – 25] 26 – 35 36 and older

Initials of parent or guardian if under 18 __________

Exhibit Exit Questions

How would you describe this exhibit to a friend?

Great

How has this exhibit affected your definitions or perspectives of art and science, if at all?

Very interesting, perspectives have changed

Which aspect of this exhibit will you remember most?

The flourescent images

Please share any other responses to the exhibit.

So glad I came

Please Circle the Appropriate Response

Gender: Male [✓ Female]

Age Group: [✓ Under 18] 18 – 25 26 – 35 36 and older

Initials of parent or guardian if under 18 ________

Exhibit Exit Questions

How would you describe this exhibit to a friend?

The exhibit ~~was an interesting mix be~~ existed at the interface of art & science & questions the pictures that we typically think of as beautiful.

How has this exhibit affected your definitions or perspectives of art and science, if at all?

ART IS VERY MUCH A PART OF SCIENCE. THIS EXhibit shows that art is happening all around us, we just dont always have the microscope to see it! It's nice to think of that fact that art & science do have an interface; People try to denie that.

Which aspect of this exhibit will you remember most?

The ~~exp~~ frames were well done. I liked the way everything was dispayed.

Please share any other responses to the exhibit.

Thank you for sharing yer art ♡

Please Circle the Appropriate Response

Gender: Male [✓ Female]
Age Group: Under 18 [✓ 18 – 25] 26 – 35 36 and older

Initials of parent or guardian if under 18 ____________

Exhibit Exit Questions

How would you describe this exhibit to a friend?

This exhibit encompasses both art and science. It was clearly well developed from conception to completion. It holds it's own as an art piece

How has this exhibit affected your definitions or perspectives of art and science, if at all?

I think it is clearly moving toward a combination of the two. It would be interesting to see other photographic endevors mixed in as well

Which aspect of this exhibit will you remember most?

The large multi images were really powerful and really created a story & narative within themselves

Please share any other responses to the exhibit.

Beautifully presented

Please Circle the Appropriate Response

Gender: Male [✓ Female]

Age Group: Under 18 [✓ 18 – 25] 26 – 35 36 and older

Initials of parent or guardian if under 18 ________

Exhibit Exit Questions

A collection of science-related images,

How would you describe this exhibit to a friend?

including magnified things.

How has this exhibit affected your definitions or perspectives of art and science, if at all?

I've always felt that there should not be a narrow definition of art, so I can certainly accept these as a presentation of the two coming together

Which aspect of this exhibit will you remember most?

frames were very solid.

Please share any other responses to the exhibit.

Looks good!

Please Circle the Appropriate Response

Gender: Male [✓ Female]

Age Group: Under 18 [✓ 18 – 25] 26 – 35 36 and older

Initials of parent or guardian if under 18 __________

Exhibit Exit Questions

How would you describe this exhibit to a friend?

Fantastic art and science show

How has this exhibit affected your definitions or perspectives of art and science, if at all?

Such an interesting combination of the two

Which aspect of this exhibit will you remember most?

The diversity of the people attending the opening.

Please share any other responses to the exhibit.

Seems like a valuable exhibit for the community to come see.

Please Circle the Appropriate Response

Gender: [✓ Male] Female
Age Group: Under 18 18 – 25 [✓ 26 – 35] 36 and older

Initials of parent or guardian if under 18 __________

Exhibit Exit Questions

How would you describe this exhibit to a friend?

AS A BEAUTIFUL AND AESTHETIC DISPLAY OF MICROSCOPIC EXPLORATION.

How has this exhibit affected your definitions or perspectives of art and science, if at all?

BECAUSE OF THE UNIQUE PRESENTATION, THE ENDLESS WAYS TO LOOK AT AND SUBJECT MATTER TO FIND THE SUBLIME.

Which aspect of this exhibit will you remember most?

PRESENTATION: THE CARE AND PROFESSIONAL HANDLING OF MATERIALS.

Please share any other responses to the exhibit.

Please Circle the Appropriate Response

Gender: [✓ Male] Female

Age Group: Under 18 18 – 25 26 – 35 [✓ 36 and older]

Initials of parent or guardian if under 18 __________

Exhibit Exit Questions

How would you describe this exhibit to a friend?

A series of photographs showing us the world as no human eye can see. Through the application of science we're given a glimpse into the inner life of biology, chemistry, physical materials, and ultimately how science works.

How has this exhibit affected your definitions or perspectives of art and science, if at all?

Art and science have always been linked by the shared value of exploration. However, artists often fail to see themselves as scientists and scientists often neglect to see the creative expressions in their discoveries. This show is a wonderful statement to how these can both be seen coexistent.

Which aspect of this exhibit will you remember most?

The amazing grid titled "electrospun Fibers"

Please share any other responses to the exhibit.

Nice Job guys. They look fantastic and the Ecotarium is A perfect venue!

Please Circle the Appropriate Response

Gender: [✓ Male] Female

Age Group: Under 18 18 – 25 [✓ 26 – 35] 36 and older

Initials of parent or guardian if under 18 __________

Exhibit Exit Questions

How would you describe this exhibit to a friend?

BEAUTIFUL PHOTOGRAPHS OF SUBJECTS NOT NORMALLY SEEN

How has this exhibit affected your definitions or perspectives of art and science, if at all?

I HAVE ALWAYS FELT THAT ART + SCIENCE ARE INTRINSICALLY RELATED. THE AGE WE LIVE IN SEPARATES THINGS TOO MUCH. LEONARDO DA VINCI HAD THE RIGHT IDEA

Which aspect of this exhibit will you remember most?

THE STAND W/ DVD PLAYER AND THE B+W MOUSE OOCYTE'S

Please share any other responses to the exhibit.

THE PRESENTATION/FRAMING/CHOICE OF THE PHOTOS WAS VERY ARTISTICLY CREATIVE

Please Circle the Appropriate Response

Gender: [✓ Male] Female
Age Group: Under 18 18 – 25 26 – 35 [✓ 36 and older]

Initials of parent or guardian if under 18 HA!

Exhibit Exit Questions

How would you describe this exhibit to a friend?

It's a series of images from science research arranged in an artistic fashion, mostly in metallic frames

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How has this exhibit affected your definitions or perspectives of art and science, if at all?

What I saw in the exhibit was a balance of art and science playing in harmony which each other.

Which aspect of this exhibit will you remember most?

Th Being a witness to the diversity of people present at exhibit

---

Please share any other responses to the exhibit.

Room was not a perfect match for exhibit, wall space utilized well though more light required

Good mix of color and black + white images

Please Circle the Appropriate Response

Gender: [✓ Male] Female
Age Group: Under 18 [✓ 18 – 25] 26 – 35 36 and older

Initials of parent or guardian if under 18 __________

Exhibit Exit Questions

How would you describe this exhibit to a friend?

descriptive, interesting and worth checking out

How has this exhibit affected your definitions or perspectives of art and science, if at all?

art x science go fabulously together.

Which aspect of this exhibit will you remember most?

the giant sculpture when you first walk in.
the Black + white is captivating !!

Please share any other responses to the exhibit.

Very nice Job. A+

Please Circle the Appropriate Response

Gender: Male [✓ Female]
Age Group: Under 18 [✓ 18 – 25] 26 – 35 36 and older

Initials of parent or guardian if under 18 __________

Exhibit Exit Questions

How would you describe this exhibit to a friend?

- Microscopic - structured - good

How has this exhibit affected your definitions or perspectives of art and science, if at all?

that the lines between can easily blur with a little change in perspective

Which aspect of this exhibit will you remember most?

the large grids of small black and whites

Please share any other responses to the exhibit.

enjoyable change of pace (for a studio art major such as I)

Please Circle the Appropriate Response

Gender: [✓ Male] Female
Age Group: Under 18 [✓ 18 – 25] 26 – 35 36 and older

Initials of parent or guardian if under 18 __________

Exhibit Exit Questions

How would you describe this exhibit to a friend?

INTERESTING AND BEAUTIFUL

How has this exhibit affected your definitions or perspectives of art and science, if at all?

THEY SEEM VERY CONNECTED NOW

Which aspect of this exhibit will you remember most?

HOW BEAUTIFUL SCIENCE CAN BE

Please share any other responses to the exhibit.

INSPIRATIONAL

Please Circle the Appropriate Response

Gender: Male Female
Age Group: Under 18 18 – 25 26 – 35 [✓ 36 and older]

Initials of parent or guardian if under 18 __________

Exhibit Exit Questions

How would you describe this exhibit to a friend?

It is a window into the microscopic details of our world — the subtle masterpieces that are life.

How has this exhibit affected your definitions or perspectives of art and science, if at all?

Science is the ultimate art — the spontaneous creations made through millions of mutations are the most breathtaking pieces of art.

Which aspect of this exhibit will you remember most?

the haphazard yet perfectly designed nerve cell.

Please share any other responses to the exhibit.

- The sculptures celebrate the beauty of life in the simplest of forms

Please Circle the Appropriate Response

Gender: Male [✓ Female]

Age Group: Under 18 [✓ 18 – 25] 26 – 35 36 and older

Initials of parent or guardian if under 18 __________

Exhibit Exit Questions

How would you describe this exhibit to a friend?

"Techno-artsy"
Scale-less creation

How has this exhibit affected your definitions or perspectives of art and science, if at all?

Not really - I've always associated good science (and especially engineering.) with art.

Which aspect of this exhibit will you remember most?

I enjoyed the video connections. The research & reality of the art & form.

Please share any other responses to the exhibit.

I would have enjoyed a stronger connection to the micro-sized feature, for example a real size photo/sketch of the features alongside the "art"

Please Circle the Appropriate Response

Gender: [✓ Male] Female
Age Group: Under 18 18 – 25 26 – 35 [✓ 36 and older]

Initials of parent or guardian if under 18 __________

Exhibit Exit Questions

"Fucking awesome"

How would you describe this exhibit to a friend?

As a artistically inclined engineer, it merely

How has this exhibit affected your definitions or perspectives of art and science, if at all?

reinforces my appreciation of scientific beauty.

Painstaking work put into display.

Which aspect of this exhibit will you remember most?

Please share any other responses to the exhibit.

O.k.

Please Circle the Appropriate Response

Gender: [✓ Male] Female

Age Group: Under 18 [✓ 18 – 25] 26 – 35 36 and older

Initials of parent or guardian if under 18 __________

Exhibit Exit Questions

How would you describe this exhibit to a friend?

So Exciting, Inspiring

How has this exhibit affected your definitions or perspectives of art and science, if at all?

Seem Similar Now

Which aspect of this exhibit will you remember most?

So original, the art science combination.

Please share any other responses to the exhibit.

Would Like To See More Video

Please Circle the Appropriate Response

Gender: [✓ Male] Female

Age Group: Under 18 [✓ 18 – 25] 26 – 35 36 and older

Initials of parent or guardian if under 18 __________

Exhibit Exit Questions

How would you describe this exhibit to a friend?

an Art Science exhibit

How has this exhibit affected your definitions or perspectives of art and science, if at all?

I am glad that other people can now see the artistic creativity that is required to make scientific breakthrough

Which aspect of this exhibit will you remember most?

I loved the display of the electrospun fibers

Please share any other responses to the exhibit.

Please Circle the Appropriate Response

Gender: [✓ Male] Female
Age Group: Under 18 18 – 25 [✓ 26 – 35] 36 and older

Initials of parent or guardian if under 18 __________

Exhibit Exit Questions

microscopy of cells + materials (polymer)

How would you describe this exhibit to a friend?

very aesthetic

How has this exhibit affected your definitions or perspectives of art and science, if at all?

the formats - metal 'frames'

Which aspect of this exhibit will you remember most?

cool images, too - well-planned, good variety

size works well, repetition of type is

Please share any other responses to the exhibit

impressive. Good use of collaboration btw. students + scientists/researchers.

Please Circle the Appropriate Response

Gender: Male [✓ Female]
Age Group: Under 18 18 – 25 26 – 35 [✓ 36 and older]

Initials of parent or guardian if under 18 __________

Exhibit Exit Questions

It's an interesting collection of beautiful images from the medical world.

How would you describe this exhibit to a friend?

Not overly much.

How has this exhibit affected your definitions or perspectives of art and science, if at all?

The presentation of the images.

Which aspect of this exhibit will you remember most?

—

Please share any other responses to the exhibit.

Please Circle the Appropriate Response

Gender: [✓ Male] Female

Age Group: Under 18 [✓ 18 – 25] 26 – 35 36 and older

Initials of parent or guardian if under 18 __________

Exhibit Exit Questions

How would you describe this exhibit to a friend?

A FRESH WAY TO SEE SCIENCE

How has this exhibit affected your definitions or perspectives of art and science, if at all?

IT HAS HELPED ME SEE THE CREATIVITY INVOLVED IN SCIENCE

Which aspect of this exhibit will you remember most?

THE VIDEO THAT TALKED ABOUT THE ACTUAL SCIENCE

Please share any other responses to the exhibit.

I REALLY ENJOYED HOW YOU ALL CONNECTED ART AND SCIENCE

Please Circle the Appropriate Response

Gender: [✓ Male] Female

Age Group: Under 18 18 – 25 26 – 35 [✓ 36 and older]

Initials of parent or guardian if under 18 __________

Exhibit Exit Questions

How would you describe this exhibit to a friend?

Interesting intersection of art and science

How has this exhibit affected your definitions or perspectives of art and science, if at all?

Shows that expression is infinite

Which aspect of this exhibit will you remember most?

Electro spinning

Please share any other responses to the exhibit.

Nice ~~exams~~ display. You might want to consider presenting it as a poster session where each group would present what, why, who .. etc.

Please Circle the Appropriate Response

Gender: [✓ Male] Female

Age Group: Under 18 18 – 25 26 – 35 [✓ 36 and older]

Initials of parent or guardian if under 18 __________

Exhibit Exit Questions

How would you describe this exhibit to a friend?

artful presentation of science

How has this exhibit affected your definitions or perspectives of art and science, if at all?

This exhibit has given me a new appreciation for science. I now see why so many people are excited about science.

Which aspect of this exhibit will you remember most?

The presentation was amazing!

Please share any other responses to the exhibit.

I would love to see more exhibits like this!

Please Circle the Appropriate Response

Gender: [✓ Male] Female
Age Group: Under 18 18 – 25 [✓ 26 – 35] 36 and older

Initials of parent or guardian if under 18 __________

Exhibit Exit Questions

How would you describe this exhibit to a friend?

an art exhibit that explores, scientifically, things natural + man-made at a level that our human eye could never see... and a level that the human mind rarely considers. It is beautiful and the quote on the video display by the guy about a good text + exhibit. no songs or poems about science. So true. This quote addresses that issue + brings it justice.

How has this exhibit affected your definitions or perspectives of art and science, if at all?

Yeah - you don't see scientific images in art exhibits & yet they are images of really natural things - a microscopic level you would never otherwise see. My imagination woke up - I saw things from outer space, deep sea + other planets. wow.

Which aspect of this exhibit will you remember most?

antibodies + muscle cells - they're in my body - I never think of them + certainly never consider their beauty.

Please share any other responses to the exhibit.

Really cool display - the frames, esp. the 100+ frames, are beautiful. A big thanks to Ian & Company who brought science + art together in this way. Encore!

Please Circle the Appropriate Response

Gender: Male [✓ Female]

Age Group: Under 18 18 – 25 [✓ 26 – 35] 36 and older

Initials of parent or guardian if under 18 __________

Exhibit Exit Questions

How would you describe this exhibit to a friend?

science presented in an interesting way

How has this exhibit affected your definitions or perspectives of art and science, if at all?

it has helped me realize that art and science are not as different ~~than~~ as I thought

Which aspect of this exhibit will you remember most?

I will remember how beautifull images from science can be

Please share any other responses to the exhibit.

this was a really nice way to find out about some science that is important to my life

Please Circle the Appropriate Response

Gender: [✓ Male] Female
Age Group: Under 18 [✓ 18 – 25] 26 – 35 36 and older

Initials of parent or guardian if under 18 __________

Exhibit Exit Questions

How would you describe this exhibit to a friend?

Materials as art, Beauty in science ?

How has this exhibit affected your definitions or perspectives of art and science, if at all?

It reminded me of why I originally got interested in materials science and why I enjoyed spending so much time taking that perfect photomicrograph.

Which aspect of this exhibit will you remember most?

The layout and arrangements and the quality of the framing really stands out. Definetely two "types" of photos - biological materials & synthetic materials

Please share any other responses to the exhibit.

I found myself wanting to know how the researchers were using or interpreting the images.

Please Circle the Appropriate Response

Gender: Male [✓ Female]
Age Group: Under 18 18 – 25 26 – 35 [✓ 36 and older]

Initials of parent or guardian if under 18 __________

Exhibit Exit Questions

How would you describe this exhibit to a friend?

a Mixture of microscope images presented in an artistic manner

How has this exhibit affected your definitions or perspectives of art and science, if at all?

It hasn't really affected either. If anything it presented them as intertwined w/ one another

Which aspect of this exhibit will you remember most?

the relief looking photos in the back corner next to the video display

Please share any other responses to the exhibit.

I enjoyed the images but wish it was in a larger space w/ more images.

Please Circle the Appropriate Response

Gender: Male [✓ Female]

Age Group: Under 18 [✓ 18 – 25] 26 – 35 36 and older

Initials of parent or guardian if under 18 __________

Exhibit Exit Questions

How would you describe this exhibit to a friend?

a very nice display of science

How has this exhibit affected your definitions or perspectives of art and science, if at all?

There is beauty in everything. Science emperically studies this, while art presents it in a more emotional manner. This exhibit has reinforced my veiwpoint.

Which aspect of this exhibit will you remember most?

I will remember how something as mundane as electrospin - fibers can be breathtaking when shown as these students presented them.

Please share any other responses to the exhibit.

This was really amazing! I would love to see more!

Please Circle the Appropriate Response

Gender: Male [✓ Female]

Age Group: Under 18 18 – 25 [✓ 26 – 35] 36 and older

Initials of parent or guardian if under 18 __________

Exhibit Exit Questions

How would you describe this exhibit to a friend?

microscopic photos in great framing (the strength & unchanging of the metal)

How has this exhibit affected your definitions or perspectives of art and science, if at all?

have always felt there is beauty to be found in all things - this exhibit expresses that belief.

Which aspect of this exhibit will you remember most?

the mixture of the metal framing and the photos

Please share any other responses to the exhibit.

enjoyed the size of the gallery area - good for exhibit size.

Please Circle the Appropriate Response

Gender: Male [✓ Female]

Age Group: Under 18 18 – 25 26 – 35 [✓ 36 and older]

Initials of parent or guardian if under 18 ________

Exhibit Exit Questions

How would you describe this exhibit to a friend?

A beautiful display of images from scientific research using the freedom of artistic expression.

How has this exhibit affected your definitions or perspectives of art and science, if at all?

I found myself at the apex of some fundamental question, what do we call art and what do we really call science? The exhibit provided a strong case for the intersection of art and science, something that I had not thought was possible.

Which aspect of this exhibit will you remember most?

It is a delightful experience to visualize the worlds of the micro- and macro-scopic and witness the similarities between both realms. Almost begs the question, do we need to separate these scales?

Please share any other responses to the exhibit.

The exhibit was a refreshing mixture of color, imagery, and metal

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Please Circle the Appropriate Response

Gender: [✓ Male] Female
Age Group: Under 18 18 – 25 [✓ 26 – 35] 36 and older

Initials of parent or guardian if under 18 __________

Exhibit Exit Questions

How would you describe this exhibit to a friend?

beautiful, well-displayed microscopy photographs, but lacking in descriptions & explanations

How has this exhibit affected your definitions or perspectives of art and science, if at all?

It hasn't particulary, but I recognize it's part of an important, useful trend that I'm totally excited about

It isn't surprising that these images are beautiful - I could use more science.

Which aspect of this exhibit will you remember most?

images of steel beams from World Trade Center

Please share any other responses to the exhibit.

please add descriptions (in layman's terms!) of what we're looking at, why it's significant, and how these images were accomplished. Great exhibit!

Please Circle the Appropriate Response

Gender: Male [✓ Female]
Age Group: Under 18 [✓ 18 – 25] 26 – 35 36 and older

Initials of parent or guardian if under 18 __________