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SCIENCE IN CONCERT WITH HISTORY AND ART

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Abstract

This paper discusses how art and history have been successfully integrated in the teaching of science to non-science majors. Students integrate the two disciplines in several ways, including debating critical past and current controversial issues in science, studying paintings displayed in an art museum. They create art that expresses their understanding of selected issues. They offer critical commentary on topical concepts from their science course. Examples of the students' artistic expressions of science and samples of the scientific metaphors they see in famous paintings are presented. Some student feedback and assessment results are included.

KEY WORDS: Science, history, art, science education, galleries, debates

INTRODUCTION

There were times in history when education was a comprehensive learning experience composed of subjects such as rhetoric, music, philosophy, science, mathematics and astronomy. During those times education was accessible to the privileged few, the aristocrats and the clergy, and was seen not as a vocational training, but more as a precondition and a tool for living the good life. The slow emergence of narrow specializations in education is a relatively recent phenomenon, caused to some extent by the industrial revolution and the rapid growth of 20th century science and technology. The explosion of knowledge and the heavy demands for narrower specializations have had a major impact on all aspects of education. No longer just for the elite, education became available to the masses. With more emphasis on practical use, it became essential for the preparation of an efficient work force. As disciplines split into narrower fields, education responded by making the experience discipline specific.

Science education also has changed. Today, science education can be divided into three categories: 1. Students who major in the sciences and have aspirations of becoming professional scientists. 2. Students who plan to become doctors or engineers - professions that demand a solid foundation in science, and 3. Students who major in business (the largest group), the arts and the humanities.

For many years the science education curriculum for this last group did not meet their needs, but merely offered a sample, mainly from courses designed for scientists or engineers. This approach failed miserably. While most academic institutions regard science as a vital component of the core curriculum for all students, they also realize that the non-science students are better served with specially designed science courses that emphasize the concepts, methodology and impact of science, without the in-depth mathematical complexity of courses geared towards scientists or engineers. The lingering problem is that the mere removal of mathematical complexity does not guarantee that students' attitudes towards science will improve. Therefore, more needs to be done if a science course for non-scientists is truly to succeed. One approach is to present science in the context of its history and the arts.

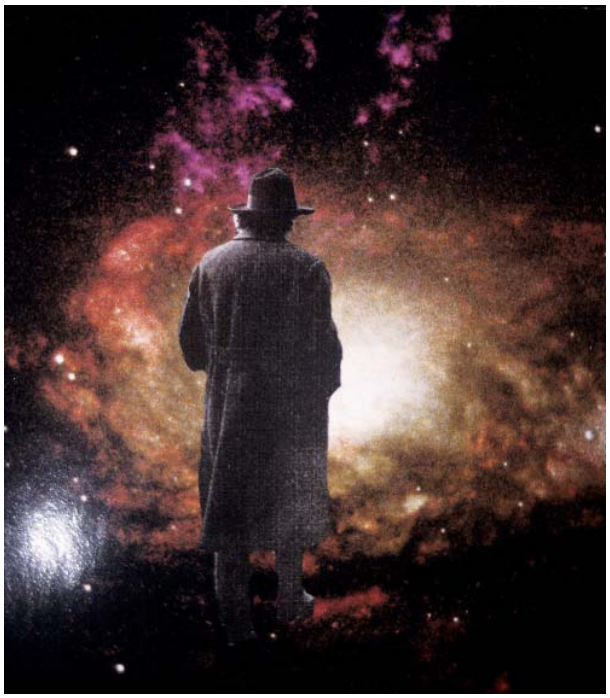
ARTISTIC EXPRESSIONS OF SCIENCE

Columbia College Chicago (CCC), the largest media and arts college in the United States, considers the liberal education component of its programs to be of paramount importance, as is clearly stated in the opening sentence of its mission statement: *"Columbia College Chicago's principal commitment is to provide a comprehensive educational opportunity in the arts, media, and communications within a context of an enlightened and liberal education. Columbia's intent is to educate students who will communicate creatively and shape the public's perceptions of issues and events, and who will author the culture of their times."*

At CCC, the core curriculum requires that each student complete two science courses, including at least one with a lab. Over the years the Science and Mathematics Department developed a curriculum intended for non-science majors. The courses provide science education and complement the major disciplines (e.g., Physics of Dance for dance majors; Chemistry of Fibers and Dyes for fashion design majors; Space, Time and the Arts for all arts majors; Science of Acoustics for music and sound engineering majors etc.). The courses require student participation beyond what is usually expected. This includes making the most of the students' skills and talents in the arts and media.

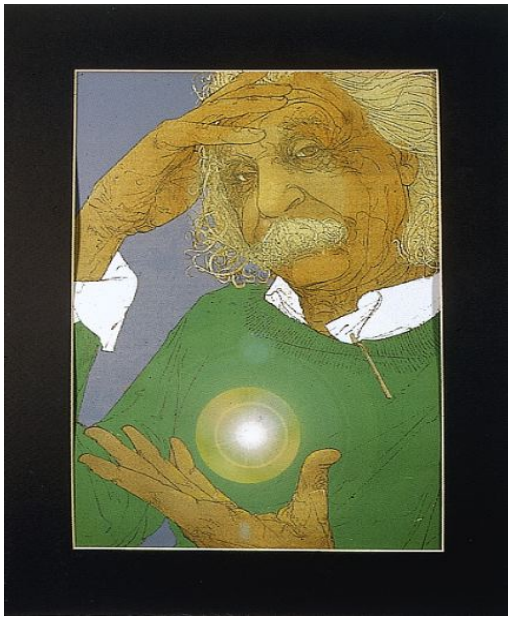
One of the most important examples of this pedagogy is the science-art project assignment in which students create a piece of art that communicates their understanding of or their critical commentary on a science topic included in the course. All visual and performing art forms used at Columbia College are means to reach learning objectives and to facilitate subjective artistic expressions of science. The completed projects are presented and discussed in class at the end of the semester. Examples of these science-art projects are shown below.

One of the most beloved themes for an art project is Einstein and his impact on the understanding of the cosmos. The following pictures represent artwork created by CCC students in a modern physics course for non-scientists entitled *Einstein: His Science and his Humanity*. These pictures are representative of art projects undertaken by CCC students on this subject over the years. For additional examples refer to Papacosta and Hanson [1998].



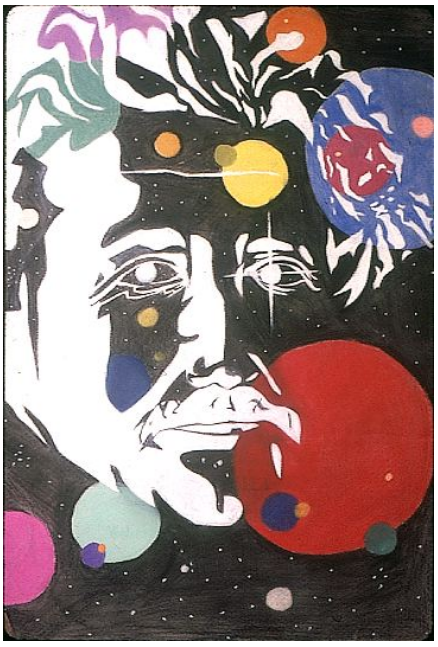
Cheryl Gladfelter portrays an Einstein peering into a galaxy, mesmerized by the lingering question, of whether God had a choice in the architectural design of the universe.

Cheryl Gladfelter (2001)



Lisa Marschetti prefers to present Einstein as a God-like thinking figure holding in his hand the original singularity that produced the Big Bang.

Lisa Marchetti (1993



For Narcisco Lobo the entire universe is filled with the spirit of Einstein, implying that the very fabric of space and time everywhere bears Einstein's fingerprints because of his work on relativity.

Narciso Lobo (1994)

This type of assignment can generate numerous and diverse educational benefits. The student is given the opportunity to "personalize" elements of science by expressing them artistically. Sometimes these artistic expressions are intended to be accurate descriptions of science, such as the depictions of black hole characteristics, features of relativity, and color theory. More often, students choose to express a critical commentary, a sense of awe and wonder, an expression of the mystery or the benefits and potential dangers of science. Examples of these "emotional" expressions about science are plentiful and vary from the horrors of nuclear weapons to the wonders of stellar evolution and the fact that all human beings are made of star "stuff" or atoms cooked from hydrogen inside stars. Others choose to marvel at the bizarre effects of quantum theory or depict one of the many stories in the best-selling book *Einstein's Dreams* by Allan Lightman [1994], a reading assignment for some of the classes.

It is the view of the author, that despite the "emotional" flavor of these projects, the students' artistic expressions of science are powerful means that bring them closer to science, and improved learning. In contrast to courses without these assignments, students connect at a different level with the methods, controversies and benefits of science. The overall student attitude towards science courses improves, as the assessment results show (Figure 1). During class presentations students are required to answer general questions and to explain in detail the specific scientific concepts expressed in their art, whether it was done in an objective or subjective manner.

In response to the question whether the creation of the science-art piece encouraged an in-depth study of the science to which the art project was connected, more than 70% of the students found that the art project promoted a better understanding of the concept (Figure 2). The author plans to administer a similar instrument of assessment to different generations of his former students and examine the long-term impact of art related course assignments.

FIGURE 1

The Science-Art project assignment improved my attitude towards science

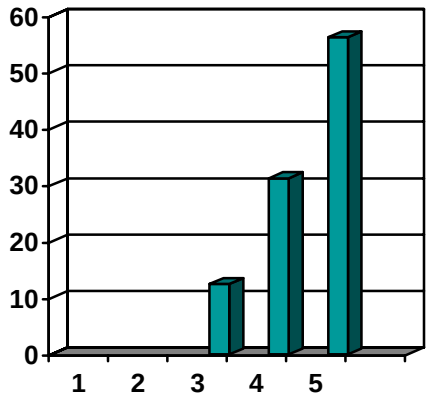
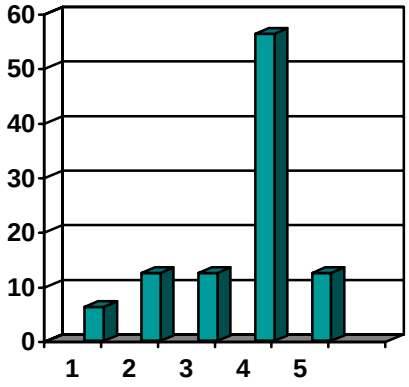


FIGURE 2

The Science-Art project encouraged me to research in-depth and better understand the science component that I chose to express artistically



1 = Strongly disagree 2 = Disagree 3 = No opinion 4 = Agree 5 = Strongly agree

The following are student sample responses from course evaluations on the impact of the project. Negative comments were rare and the overwhelming majority of students appreciated the value of the assignments.

- *This was a great way to remain engaged in science as I was thinking about my project throughout the semester*
- *The possibilities of science through film are endless and I can't' wait to use some of my Einstein knowledge in a film.*
- *I now feel more confident in conveying my thoughts and ideas in terms of art. It was fun to push my limits and see what I could create.*
- *I feel that science is ripe with concepts for the artist to take and use in their medium.*
- *For me the most enlightening aspect of this project was the experience of sharing it with others and seeing how everyone has interpreted science through their art.*
- *I was vaguely aware of how science impacts and compliments art. I never thought of the two together until now.*
- *We use different parts of our brain to create art and through this project I literally connected different thought processes I might not have considered before this project.*
- *Although this project is a great idea for art majors, I do not agree with it because I am not one of them.*

ART INSTITUTE ASSIGNMENT

Students are required to visit the galleries of the nearby Art Institute of Chicago and to identify three paintings that in their view contain in their presentation or artistic style, metaphorical elements of modern science, such as Relativity, Cosmology, or Quantum Theory. This is an unexpected exercise that evokes the ability to be creative in analysis and connects aspects of art with science. Students present the images of their chosen paintings along with an explanation of the modern science component that they associate with each painting in class.

The effects of this method have been impressive. All students speak highly of their experience and in anonymous evaluations they provide numerical assessment of the impact of the assignment. The assessment seeks out feedback, not only how this exercise may have improved their understanding of science, but also how it may have improved their overall attitude towards science. This exercise engages the student in a very different, but just as effective method as a lab exercise would have done. The powerful elements of this learning process are the strengthening of science by association and metaphor, and by sharpening interdisciplinary skills that enhance the creative process.

The following are extracts from the students' reports, chosen for the effective ways in which they describe a series of modern physics metaphors and analogies that they could identify in paintings displayed at the Art Institute.

Erika L. Johnstone, (Space, Time & the Arts course, spring 2006) wrote the following about "*Time Transfixed"* by Rene Magritte (1938)

"*Like Relativity, "Time Transfixed" distorts both space and time. The clock on the mantle as well as the locomotive is expressions of time. The locomotive appears frozen in a particular moment of time. The relative sizes of the locomotive and the fireplace are huge disproportions of space. The locomotive born out of the fireplace (although both burn coal to function) is logic gone astray, that like in Quantum physics suggests a break down of the cause - effect relationship."*

Rene Magritte, Belgian, 1898 - 1967, ***Time Transfixed,*** 1938, oil on canvas. 147 x 98,7 cm, Joseph Winterbotham Collection. 1970.426,The Art Institute of Chicago. Photography © The Art Institute of Chicago.

James Little, (Einstein course, fall 2006) wrote the following about "*The Red Armchair"* by Pablo Picasso (1931)

"I see in this painting the dual nature of reality and matter. A masculine image blending with a feminine image, like the Yin and Yang, they also represent the external reality of the macroscopic universe and the spontaneous universe found in our own subjectivity as well as the quantum world. Two things appear in the same place at once, embraced as one, unpredictable, spontaneous and creative. I feel it as the pulsation between two sides of the Duality that constitutes existence. I don't know how influenced Picasso was by science but it is clear he challenged many conceptions about the world through his art, just as Einstein has done with mathematics and theoretical physics."

Pablo Picasso, Spanish, 1881 - 1973, ***The Red Armchair,*** 1931, Oil and enamel on panel, 131.1 x 98.7 cm. Gift of Mr. and Mrs. Daniel Saidenberg, 1957.72 The Art Institute of Chicago, Photography © The Art Institute of Chicago.

Jeffrey Porter (Einstein, spring 2006) wrote the following about "*In the Magic Mirror"* by Paul Klee (1934)

"In Klee's "Magic Mirror" we see multiple perspectives of the same woman at the same time. This correlates with Einstein's theory of Relativity that redefines the nature and properties of space and time, but also suggest reality has multiple interpretations, each one correct according to the point of view of the observer. This work along with his others and those of his colleagues show a profound interest in reshaping the opinion of space and time in art."

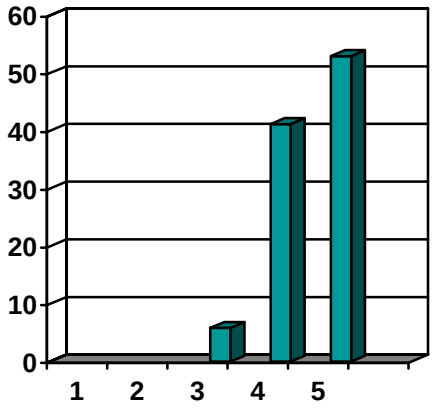
Paul Klee, German b. Switzerland, 1879 - 1940, ***In the Magic Mirror***,1934,Oil on canvas on board, 66 x 50 cm, Bequest of Claire Zeisler, 1991.321, The Art Institute of Chicago. Photography © The Art Institute of Chicago

The students are asked to evaluate how the Art Institute project affected their learning of science. What is shown here represents the typical outcomes of two of the most crucial statement/questions (of a total of seven,) that a class of 17 students was asked to respond to.

Percentage response to the statement (%)

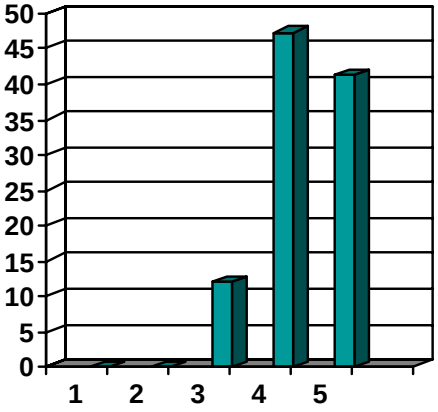
This assignment has improved my overall attitude towards science.

1 = Strongly disagree
2 = Disagree
3 = No opinion
4 = Agree
5 = Strongly agree



This assignment encouraged me to research in-depth and better understand the science concepts that I chose to relate the selected paintings with.

1 = Strongly disagree
2 = Disagree
3 = No opinion
4 = Agree
5 = Strongly agree



The last question of the evaluation asks the students*:*
Has the Art Institute assignment improved your learning and attitude towards science? Explain how.

So far there has never been a single negative statement about the benefits of this assignment. The overwhelming majority expressed a most positive experience. The following represent a sample of statements made by students voluntarily and anonymously.

- *Thankfully I already felt comfortable with the idea of a connection between art & science, but the assignment deepened that connection and encouraged me to do a creative, analytical observation of art that I'd never done before. Thanks!*
- *I find Science, Philosophy and Art are all searching for the truth behind form. I feel they are all expressions of the same need for connectivity, for beauty, for truth.*
- *I never really pondered the relation between science and art before but now when I look at art and learn about science, I feel a want to dig deeper into the subject matter.*
- *I've lived in the Chicago land area my entire life and have visited the Art Institute many times. But never have I had to connect art with science. I believe that this assignment has really improved my appreciation for both art and science, because I had the chance to do something different.*
- *I did not believe that physics and art could work together to create something clearer. It made me understand physics on levels that I can better comprehend as an artist.*
- *This assignment has greatly improved my views and learning attitude towards science. It allowed me to view art in a different context and was a fun way to get me thinking.*

Besides the tabulated class assessments[1], other informal forms of feedback also show that the integration of science with art has lasting positive effects. One such casual form of feedback is the unsolicited comments from alumni. During frequent communications with the author and many years after graduation, they continue to comment with excitement about recent scientific discoveries, whether in physics, astronomy or cosmology, acknowledging also that their continuing interest in science was due to the Columbia College courses that integrate science with the arts. No other group of people can be more convincing in our assessment efforts that this method works. The alumni are indeed the group that can provide the most reliable answers about the long-term effects of college education.

A small and very special group of the students, who have stayed in touch with the author after graduation, have become what the college mission statement describes as "the authors of their culture." These young artists have actually managed to weave science in their professional careers. They have become science journalists and science documentary filmmakers. Two are successful choreographers, one in Chicago and the other in New York, whose dance companies deal mostly with science themes. (As students they chose to choreograph and perform a dance piece for their science project). Another alumnus is a poet in Chicago who composes poetry about stars and environmental issues, something she did for a science project six year ago. Of the few who have gone to become professors in different disciplines one stands out with regards to this subject. He has gone to become a computer expert in animation who now teaches game theory and recently designed computer animations for a major planetarium.

The use of art in the teaching of science, as described above, is not intended to replace the more traditional assignments and labs but to enhance them. For many students this is a refreshing new approach and is often an opportunity to put their artistic talents to creative use. More often it is the instructors who have difficulty with this method. Since most of them were educated in traditional methods, they are very likely to feel uncomfortable or even intimidated by mixing science with arts. Those, however, who genuinely wish to adopt this method, know that it will require a new way of thinking and lots of extra work on their part. But they also know that the rewards are many and worth every effort.

The importance of the role of art as the means of communicating science to the public is slowly being recognized not only by the media but by the scientific community as well. This makes the science-art integration efforts in the teaching of science timely and relevant to the needs of science. The author has stated on numerous occasions that one effective piece of art in the form of a film, a photograph, a song or a poem, a painting, a drama or dance performance, can change the public image of science more effectively than the sincere good efforts of 10,000 scientists. Students must be encouraged to think of their art as a powerful medium that enables them to communicate science to the public. Art can help shape public opinion about science and inspire young people to become scientists. It can help celebrate major discoveries and scientific achievements and help to criticize and warn about scientific issues that impact society and the environment. When art speaks for and about science, the public listens. A public that is more engaged with such matters is also bound to be more appreciative and supportive of science and scientific research. This alone should convince the scientific community everywhere that forming new alliances with the arts is actually good for science.

HISTORY OF SCIENCE ELEMENT

The author believes that history of science provides a great opportunity to enhance the teaching of science in yet another equally important way. The concern is that whenever history is integrated in the science curriculum, it may dilute the quality of science and causes confusion as to what science really is. Sometimes the resistance can come from purists and conservative thinkers who refuse to "step outside the box." Their science is devoid of anything not considered scientific, with mathematics being the only exception. They need to be reminded that science was once called "natural philosophy" and that some of the most important discoveries were made only because scientists dared to think outside the box. By definition, purists would have dismissed even Newton since he spent so much more of his time and effort on such matters as Biblical Numerology, Alchemy and in the latter part of his life on financial matters, as the appointed Warden of the Mint.

The author believes that the process and nature of science, its methodology, triumphs and limitations, can be fully understood and appreciated only through the lens of history. When selected elements of history of science are appropriately integrated in the curriculum, they enhance the learning of science in

many different ways. When students discover the humanity of science that comes through its history, it becomes more appealing and relatable. They discover the rich human drama behind some of the major discoveries, heroes who struggled, persevered and at times persecuted for their science and other beliefs. Students learn through history that these unsung heroes that gave us science came from many different backgrounds, from the poorest to the most aristocratic. They represent a thick slice of humanity and culture, reminding us that science is the collective heritage of all people everywhere, not the philosophical dominion of the few. History also reminds us that although natural phenomena remain the same, it is our explanation of them through science that is constantly being evaluated, refined or even replaced by new theories. This historical quality of science should evoke a sense of humility, a reminder that although we admire science as a process, its explanations are not to be worshipped as dogma. If that were not to occur, science would come to a stop.

Science instructors at all levels, from elementary to graduate school need to first become students of history of science before they can confidently and effectively be able to introduce selected and appropriate elements of it to their classes. When a concept of science is associated with its relevant history, it helps secure that knowledge.

The following are case studies from the history of science that the author includes in the teaching of a standard physics course. It needs be said that these are not just stories. Each case has an underlying and important message about the nature of science and its relationship to society. Through such case studies from history, students can discover the dynamics of how science touches every aspect of society and every live.

Galileo's rebellion, trial and persecution
The apple and the moon. Newton's discovery of the Universal Law of gravity
Galvani's animal electricity and Volta's battery
A constructive failure. The Ether and Michelson-Morley experiment
Three major discoveries of 1896 that shook physics at its core
The historic significance of Einstein's $E = mc^2$ equation
Hubble's discovery of the expansion of the universe

Parts of original texts are often used as a starting point of class discussion. Some of those used are: Selections from Copernicus book *De Revolutionibus* on the heliocentric system; sections from Newton's Third Book of *Opticks*; a selection of Einstein's letters; Galileo's letter of apology and retraction of his support of the Copernican system; Faraday's notes on the concept of electromagnetic field. Sometimes students choose a historical figure or episode as the theme for their artistic expression of science mentioned earlier. Knowledge of history of science also helps the students in another class activity - the class debates where students research and prepare arguments for and against both sides of the topic, since they do not know which one they will be asked to support. This type of activity not only demands good research practices, it also helps students examine objectively and thoroughly both sides of the issue before they make their own informed decisions on a position statement. In a typical 15-week semester, three debates are completed. Following is a list of debates of different science classes taught by the author.

Galileo, Darwin, Einstein and the "conflict" between science and religion
Scientists and the use the Atom Bomb on Hiroshima and Nagasaki
Henrietta Leavitt and the cosmos. The treatment of women in science
Galileo's rebellion, trial and persecution etc.
Nuclear Reactors; Good or bad for the environment?
Picasso and Einstein; Is Cubism connected to Relativity?
Do advances in science and technology improve our humanity?
Billions spent for space exploration. Investment or waste?

When history and art work in concert through the process of association, debate, metaphor, analogy and integration, science learning is not only enhanced, critical thinking skills are also sharpened. Many years from now students may forget much about the content of their science course, but their science artwork will forever remain in their memories along with their visits to the Art Institute and their class debates. They will remember that this was a science class that invited and challenged them to utilize both sides of their brain, breaking down old cultural barriers between science and the arts. They will forever

remember from the class debates that for a truly informed position on any one of the many controversial issues, they will have to carry out objective research that is unbiased and can show all sides of the arguments. With all these experiences they can develop a new mindset that will not only impact their relationship with science but their duties and responsibilities as a citizen of the world. Indeed understanding and properly relating to science, discovering its humanity through its history is not only our right but also our duty as members of society. I. I. Rabi expressed this in the concluding eloquent statement.

> *" Science is an adventure of the whole human race to learn to live in and perhaps to love the universe in which they are. To be a part of it is to understand, to understand oneself, to begin to feel that there is a capacity within man far beyond what he felt he had, of an infinite extension of human possibilities. ...*
>
> *I propose that science is taught at whatever level, from the lowest to the highest, in the humanistic way. It should be taught with a certain historical understanding, with certain philosophical understanding, with a social understanding and a human understanding in the sense of the biography, the nature of the people who made this construction, the triumphs, the trials, the tribulations. "*
>
> I. I. Rabi
> Nobel Laureate in Physics

ENDNOTES

1. Courses at Columbia College are evaluated once a year to assess the teaching effectiveness. The bar graphs presented are based on an assessment instrument designed by the author (see Table 1below). The focus of the questions is on the effectiveness of incorporating art in science learning and attitude changes towards science. This instrument was administered during several semesters in two different courses. The results presented are the cumulative average for a typical class of 18 - 20 students in the following courses:
   - • Einstein: His Science and His Humanity. This new instrument of assessment was administered for the past four semesters. (Course was taught for 20 years)
   - • Space Time and the Arts: This new instrument of assessment was administered for the past two semesters. (Course taught for the past 4 years)

As part of the Art Project students complete the following assessment questionnaire. The instrument for the project 'Visiting the Art Institute' is very similar.

TABLE 1
Assessment Instrument of the Science-Art project

You have been asked to create a Science-Art project, a creative art piece through which you could express your understanding of or your subjective critical commentary of any one concept from the Einstein science course. The purpose of this questionnaire is to assess the success of this assignment, how effective it was in enhancing your learning of and attitude towards science. Please read each statement carefully and respond as best as you can by placing an **X** under the most appropriate number.

1 = Strongly disagree with the statement

2 = Mildly disagree

3 = Neutral (no Opinion)

4 = Mildly agree

5 = Strongly agree with the statement.

Statement	1	2	3	4	5
The Art-Science project encouraged me to research in depth and better understand the science component that I chose to express artistically.					
The experience of the Science-Art project has left me frustrated and more confused about what science really is.					
The Art-Science project assignment improved my attitude towards science.					
Thanks to the Science-Art project I am now able to recognize a wider impact/interaction of science on/ with other disciplines.					
Thanks to the Science-Art project experience I now feel more confident in using my art to communicate science-related issues to the public at large.					
Because of the Science-Art project I am more likely to continue learning about science many years after graduation.					

Has the Art-Science project experience improved your learning and attitude towards science? Yes or No and How? ***(Please be specific)***

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