Student-Centered Science Activities in Lay Science Disciplines¹

Bernard Hoop, Eric W. Hansberry
Northeastern University

/

Gerard Volland
Illinois Institute of Technology

Abstract

In the spirit of Northeastern University's (NU) Academic Common Experience and Illinois Institute of Technology's Interprofessional Projects, we present examples of cross-disciplinary science activities intended to broaden and enrich the value of learning experiences of undergraduate lay science students. At NU, science activities for lay science students were developed by means of student involvement in an engineering graphics course, and within an introductory physical science course intended primarily for lay science students. Interactive-engagement activities were introduced into lectures and conducted by students. Students were also assigned term projects to propose science activities based either on a lecture activity or on a topic within the student's own major discipline or extracurricular interest. Activities were required to be cross-disciplinary and of direct relevance to study within a discipline other than science. From among more than eighty student contributions, eleven science activities and experiments are summarized, which may accompany a course in visual studies foundations for art majors.

I. Introduction

As part of the time-honored process of higher learning, mature students naturally help one another to undertake new intellectual challenges. This mutual assistance in understanding science concepts is perhaps most difficult to cultivate among students with widely different levels of science preparation, who are majoring in lay science

disciplines¹, i.e., disciplines other than science. Among the potential problems associated with this breadth of professional interest and background preparation in introductory undergraduate science education is the potential for attrition, as well as for inadequate and/or incomplete science literacy.

It is our contention that student-centered interaction and engagement is particularly effective among students who do not perceive themselves threatened by, or at an intellectual disadvantage to one another. In this paper, we describe an attempt to engage students in the development of science activities for lay science students in two different non-threatening ways within a traditional classroom lecture format. The first is by means of a design project of a science laboratory for lay science students in an engineering graphics design course. The second is by means of student-centered interactive-engagement methods in an introductory physical science course to promote conceptual understanding in heads-on and hands-on lecture activities that yield immediate feedback through discussion with peers^{2,3}.

A primary objective of the present study is to empower students to take initiatives to examine the general relevance of the scientific method and to apply their own individual backgrounds and interests to proposing science activities and experiments in disciplines other than science.

II. Background and Methods

Two notable educational reform enterprises serve as models for the present study: Northeastern University's Academic Common Experience (ACE)⁴ and Illinois Institute of Technology's Interprofessional Projects (IPRO) Program⁵. The first model is founded on the premise that the best education instills a spirit of inquiry, a love of learning, and a habit of reflective thought. ACE proposes that the hallmarks of every university student's education are to build on knowledge already acquired, to develop skills and understanding that can be transferred from one academic discipline to another and from the classroom to life experience. The second model offers team-based projects to students across the University which are integrated with traditional programs of study. The IPRO Program is distinctive in that it builds broad participation by students and faculty in projects that integrate professional programs (engineering, science, business, design, law, psychology and architecture) with graduate and undergraduate team members from all educational levels, and faculty advisers who contribute specialized expertise to a team effort.

In the present study, we applied elements of these educational models directly in lecture-based courses for engineering students and for lay science students. We chose two courses offered during the 1999 Spring and Summer Quarters at NU in which to solicit student contributions to science activities for lay science students. In an engineering graphics course (32 students; instructor: EWH) which taught techniques in computer-aided drawing, a term project was assigned to design a science laboratory to accommodate students majoring in disciplines other than science, for science activities and experiments tailored to their disciplines. Designs were required to address three

principal characteristics of the space: aesthetic, technological, and pedagogical. For honors credit, several students prepared comprehensive laboratory manuals of integrated sets of progressive cumulative science experiences for use in their designed spaces.

In an introductory physical science course (49 students; instructor: BH), a number of interactive-engagement activities we call *leading motives* were introduced into lectures. Leading motives are student-conducted lecture demonstrations based on selected ConcepTests², with class discussions taking place before and after presentation of each leading motive. A term project was also assigned, in which each student proposed a science experience based either on a leading motive presented in lecture, or on her/his own major disciplinary or extracurricular interest. The project, intended primarily as an exercise in preparing an experimental scientific protocol, addressed three characteristics: that the experience be cross-disciplinary, that it mesh seamlessly with study within a particular discipline, and that individuals conducting the experience recognize the direct relevance of the experience to the discipline. Students' written reports of term projects cited printed and web-based sources and were required to adhere to the following outline:

1. Purpose and relation to lay science discipline (*"Why should I bother?"*)
2. Scientific question to be asked (*"Why is it important? So what? Who cares?"*)
3. Prior knowledge required (*"OK, I'll do it. Before I start, what do I need to know?"*)
4. General experimental procedure (*"What do I need to do? How do I do it?"*)
5. Equipment and space required (*"What stuff do I need? Where do I do it?"*)
6. Analysis (*"Numbers, observations. What do I make of it?"*)
7. Error analysis (*"How good is what I did?"*)
8. Interpretation of results (*"What does it all mean? What does it tell me?"*)
9. Comparison with theory, with what is known (*"What did WE learn?"*)

III. Results and Conclusions

We were pleasantly surprised to find that students chose topics with little or no duplication and that their written reports are largely commendable models of experimental protocols which follow the above outline.

An overall goal of the present study is to naturally integrate progressive learning experiences in science and technology throughout curricula in disciplines other than science. Our intent in fostering student-centered designs of science activities in other disciplines is that lay science students understand and develop the same critical observational skills expected of science, engineering and technology students.

An example in an art curriculum is a course on visual studies foundations, which introduces the elements and principles of organization that constitutes a pictorial language common to all the visual arts. In this art course, students investigate and understand how visual language is used to communicate thought, feeling, and experience. One purpose of science activities for such an art course is to ensure that

students in the course understand and correctly distinguish between the technical vocabularies of art and of science, of which many identical terms (e.g., volume, mass, value) are used with different meaning.

The following is an instructor's summary of a series of eleven science activities and experiments chosen from among student contributions which may be useful science activities and experiments to accompany a one-Quarter art course in visual studies foundations.

LOOKING⁶

Purpose: Test, train, and distinguish between your artistic and scientific observational skills in looking.

Procedure: Sit in a comfortable position with a notebook and pen and study the image or sculpture your instructor places before you. Record as much detail as you can about the image or sculpture. Organize your notes of observations into general descriptive categories, being mindful of your choices of vocabulary of descriptive terms (scientific or artistic). What conclusions can you draw about what you've been looking at?

LISTENING⁶

Purpose: Test, train and distinguish between your artistic and scientific observational skills in listening.

Procedure: Sit in a comfortable position with a notebook and pen and listen to the audiotape your instructor will play. Record in chronological order as much as you can about everything you hear. From your notes, organize your audio observations into general descriptive categories, being mindful of your choices of vocabulary of descriptive terms (scientific or artistic). What conclusions can you draw about what you've heard?

LOOKING, LISTENING⁶

Purpose: Test and train your combined artistic and scientific observational skills in looking and listening.

Procedure: Sit in a comfortable position and observe an unlit sparkler for 10 minutes. Then light the sparkler and observe it until the sparkler burns out. When the sparkler has burnt out, continue to observe it for an additional 10 minutes. Throughout the entire interval of observation, record as much spatial and temporal detail as you can about what you see, hear (smell, feel). Organize your notes into general descriptive categories, again being mindful of your choices of vocabulary of descriptive terms (scientific or artistic). What conclusions can you draw about the experience.

LOOKING, LISTENING, LEARNING

Purpose: Test and train your combined artistic and scientific observational skills in looking and listening.

Procedure: Take a comfortable seat, notebook in hand, before an audiokinetic sculpture⁷. Record as much as you can about everything you see and hear going on in the sculpture. Organize your notes into categories that distinguish between scientific and artistic characteristics of the sculpture. Identify and make a detailed record of all of

the energy transformations that are taking place. Distinguish between the different kinds of transformations. Record times and events in a systematic fashion.

IS WHAT YOU SEE REALLY WHAT YOU GET?

Purpose: Determine whether wavelength is necessary and/or sufficient to determine what color you see.

Procedure: The Young-Helmholtz⁸ theory of color perception is that there are three color-sensitive kinds of receptor(cones) which respond respectively to red, green, and blue (or violet), and that all colors are seen by mixture of signals from the three systems. Two sounds cannot be mixed to give a different pure third sound, but two colors give a third color in which the constituents cannot be identified. Using a Young-Helmholtz light box⁸ modified to view only one color at a time, mix different primary transmitted colors for viewing. Can you distinguish between, for example, a pure spectral yellow, and a mixture of red and green? For what other mixtures of colors can you not distinguish between the mixture and a pure spectral color? How does this depend on light intensity (value)?

COLORFUL PERSONALITIES

Purpose: Apply the scientific method to a comparison of color preference and personality

Procedure: Can color preference be used to predict personality traits? Administer a personality test to each of a group of students. Then ask each student to choose from a series of hues and color values a set which each finds preferable. Make a statistical comparison between color choice and personality traits. Can you find any correlation between the two? Why or why not? Why is an explanation (theory) of experimental measurement an important part of the scientific method?

ON A ROLL⁶

Purpose: Apply the scientific method in comparing motion under gravitational and frictional forces.

Procedure: Roll a ball down an inclined path onto a carpeted flat surface. Compare the height of elevation of the inclined path with the distance necessary for the ball to come to a complete stop. How does this compare with the expression for velocity in terms of distance and acceleration? How does changing the texture of the flat surface alter this relationship? Why is an explanation (theory) of experimental measurement an important part of the scientific method?

QUICK OF THE BREATH⁹

Purpose: Apply the scientific method in an application of mechanics (fluctuations in body weight) to physiological function (breathing).

Procedure: Stand on a bathroom scale. Observe the reading over an interval of time (say, one minute). What do you observe? Why? Your body weight is supposed to be a relatively constant quantity that changes only slowly (with age, food intake, excretion, diet, etc.) Where do the fluctuations in body weight come from? Make careful measurements of the time variation (frequency) of fluctuations in your body weight. What is the frequency? What other experimental quantities in your body fluctuate with

time? Tabulate the values of fluctuations in body weight and in other measurable quantities. Can you eliminate the effects of a quantity (e.g., weight of air in a breath) by estimating the magnitude of its contribution? By repeating the procedure using the same subject and same scale, you can make several measurements of the same fluctuations and obtain an experimental error (measurement uncertainty). Record your results on the board for comparison with other experimenters. Compare your experimental measurements with an explanation of why your body weight fluctuates. Why is an explanation (theory) of experimental measurement an important part of the scientific method?

MAKE CRATERS, NOT WAVES¹⁰

Purpose: Apply the scientific method in an application of geology and mechanics to astronomy. Craters are common on the surfaces of planets and moons of our solar system. Until about 1960, most astronomers believed that craters are the visible remains of giant volcanos. Apollo missions have proven that craters are the “written” record of impacts of objects measuring up to several tens of kilometers in diameter. Impact cratering is a fundamental evolutionary process in the geology of planets. A current hypothesis is that the Earth’s Moon was formed by the impact of a giant asteroid with Earth.

Procedure: How does crater size depend on the kinetic energy of the impacting object? Drop a ball (rubber or steel) of known mass from a known height onto a flat surface of dry rice or sand. Measure the diameter of the crater in the surface. Change the height to vary the impact energy. Plot the values of crater diameter against the energy. Can you use your results to estimate the energies necessary to produce the kilometer-sized craters which dot the surfaces of the moons and planets? By repeating the procedure using the same ball and same height, you can make several measurements of the same expected diameter and obtain an experimental error (measurement uncertainty). Record your results on the board, for comparison with other experimenters. Compare your experimental measurements with an explanation of how craters are made, e.g., Impact explosion? (Theory #1); Gravitational energy? (Theory #2). Why is an explanation (theory) of experimental measurement an important part of the scientific method?

EYE ON THE PRY

Purpose: Apply the scientific method to measurement of the delay time in a dark-adapting eye.

Procedure: Observe the motion of a pendulum of about one meter in length, swinging in a straight arc normal to your line of sight. Cover one eye with a dark polarizing filter. What does the pendulum appear to be doing? Why? By reducing the light to one eye, the dark filter delays signals from that eye. The retinal receptors take longer to respond, and the dark adaptation produces a delay in the message reaching the brain from the eye. The delay causes the affected eye to see the pendulum bob slightly in the past, and as the bob speeds up in the middle of its swing, this delay becomes more important. The dark adapting eye sees the bob in a position further and further behind the position signaled to the brain by the unaffected eye. This gives an effective horizontal shift of the moving image - as signalled - generating stereo depth. This phenomenon is called the Pulfrich pendulum effect^{8,11,12}. For the brain, it is as though the bob is swinging

elliptically. That is, the increased delay with dark-adaptation is associated with increase in temporal integrating time, as when a photographer uses a longer exposure time in dim light. Make an estimate of the eccentricity of the apparent elliptical orbit of the pendulum, and compare the eccentricity of the orbit with the extent of the filter darkness (increasing the cross-polarization). Can you determine the relative delay time from the apparent eccentricity? Compare your results with an explanation (theory) of the delay time in dark adaptation.

WHY IS LIGHT A WAVE?

Purpose: Apply the scientific method to making measurements of the length of a light wave.

Procedure: What is a wave? Is light a wave? Why? If light of a single hue (color) is a wave, what is the length of the wave (wavelength)? Would this light always cast sharp shadows? Observe light of a known single hue passing through a narrow slit. What do you observe at the edges of the shadow? Why? Where do the light and dark regions in the shadow of the slit edges come from? Using a laser (a light source which emits light of a constant known wavelength), shine the light through a narrow slit onto a screen. Make careful measurements of the distances between the centers of the dark regions on either side of the central maximum. Repeat this for as many of the dark regions as you can see. (These dark and light regions are called “interference fringes.”) Change the distance from the slit to the screen. How do the light and dark regions change? Now use a slit with a different width? How do the regions change for a different slit width? For each value of the experimental quantities, tabulate the values of the measured distances between the centers of the dark regions. By repeating the measurements of the distances between the centers of the dark regions for a given slit-to-screen distance and given slit width, you can make several measurements of the same distances and obtain an experimental error (measurement uncertainty). Record your results on the board for comparison with other experimenters. Compare your experimental measurements with a geometrical explanation of why the crests and troughs of light waves shining through a narrow slit might interfere with each other to cause the dark and light regions. How does this explain why light is a wave? Why is an explanation of experimental measurement an important part of the scientific method?

Other notable examples of individual topics developed by students into science activities for lay science students include: kinetics of slalom skiing; bungee jumping; volleyball serve; geometry of perspective drawing; angular momentum and gyroscopic control; observation of a total solar eclipse; effect of light wavelength on plant growth; sound and hearing; non-verbal communication; perception of optical illusions; echoes in musical performance spaces.

The quality and creativity of students' ideas for science activities and experiences merit inclusion in existing lay science courses for assessment and evaluation, publication, and dissemination via a web site, currently under development.

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BERNARD HOOP

Bernard Hoop is Visiting Scientist in the School of Engineering Technology at Northeastern University and Associate Professor of Medicine (Physics) at Harvard Medical School. He holds a Ph.D. in physics from the University of Wisconsin (Madison) and has served as Fulbright lecturer at the Indian Institute of Technology (Mumbai) and as visiting lecturer in physics at the University of Otago in New Zealand. Prof. Hoop has done research in neural and cardiorespiratory function at Massachusetts General Hospital and currently in nonlinear dynamics at Boston's Beth Israel Deaconess Medical Center.

ERIC W. HANSBERRY

Eric Hansberry is Professor of Design Graphics in the School of Engineering Technology at Northeastern University. He served as Acting Department Head at the Franklin Institute of Boston, and he holds a number of professional registrations, including civil structural design and construction engineering (MA, NH), and mechanical design engineering (NH). He is a founding member of the National Society of Architectural Engineers and an Honorary Member of Tau Alpha Pi. Prof. Hansberry holds B.S. and M.S. degrees in Civil Engineering, respectively, from Tufts University and Northeastern University.

GERARD VOLAND

Gerard Voland is Director of the Undergraduate College, Director of the Interprofessional Projects Program, and Associate Professor of Mechanical Engineering at the Illinois Institute of Technology. He served as Interim Director of the School of Engineering Technology and the Lowell Institute School at Northeastern University, where he coordinated NU's Academic Common Experience program. Prof. Voland holds a Ph.D. in Engineering Design from Tufts University and is the author of several textbooks and the recipient of awards for excellence in teaching, as well as serving as administrator, student advisor, and Faculty Senator.