Interdisciplinary Teaching of Visual Perception through Art and Science

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This paper tells the tale of an adventure in teaching an interdisciplinary course about visual perception, combining visual art and vision science, called “Making Visual Illusions.” The authors cotught a course that brought together the hands-on methods of the art studio and the science laboratory, using visual illusions as a theme to guide student explorations. One unexpected issue that arose was the time needed to discuss basic concepts and the connections between fields in order to communicate the deeper ideas the students needed to learn. This paper explores aspects of the course that worked well and makes suggestions for improvement.

Visual perception—how we see the world around us—forms the core of both the visual arts and perceptual psychology. Superficially, the goals of visual artists and vision scientists are quite different: to create artworks and to create scientific knowledge, respectively. Interestingly, however, their processes and attitudes are similar. Both seek wonder and the thrill of creation and both follow where questions lead them, even if in unexpected directions [1]. In addition, both disciplines use similar processes, including deliberation, exploration, careful observation and attention to detail [2]. Our motivation to teach an interdisciplinary course together developed from years of learning from one another and a desire to share our different perspectives with students. We use the term interdisciplinarity to refer to connections between the disciplines of visual art and vision science; teaching a combined course can introduce students to those links [3].

DIFFERENT KINDS OF KNOWLEDGE

What benefits would a science student gain from our class? In an exercise such as drawing using linear perspective, a scientist might wonder what more can be gained beyond what is evident in an example illustration. Linear perspective is one type of information that conveys object distance from a viewer, and an illustration provides a depiction of how object size varies with distance. However, what the drawing exercise adds is an immediate and profound connection with how objects’ appearances change with viewing distance. Equally important, the exercise illustrates how the choices required in the course of drawing impact the final result. Tactile and kinesthetic aspects of the activity add to the visual, creating a richer representation of concepts. The exercise provides a richer learning experience of how linear perspective works as well as what it is, furnishing a different type of knowledge to aid in understanding.

What benefits would an art student gain from our class? Knowledge of the visual system can provide a basis for organizing concepts about the visual world and how to represent it. It is also possible that this knowledge could benefit an artist’s exploration by providing alternative ways of thinking about problems. As an example of how this might be useful, let us look at the term spatial frequency.

Spatial frequency is a systematic way to describe spatial scale and the layout of elements in a manner that depends on the distance between the viewer and the object [4]. Everyone is familiar with the fact that one cannot read a book that is across the room because the type is too small. Of course, the physical size of the type is the same wherever the book is, but the size of the type relative to the eye (the image size on the eye) can be too small for the reader to identify the letters. Spatial frequency, in units based on the size of images, provides a way to describe and predict the visibility of different elements in a visual scene. Small elements, such as letters in 12-point font, will only be visible at close distances and will be indistinguishable at large distances.

Artists such as Chuck Close (e.g. Lucas), J.M.W. Turner (e.g. Rain Steam Speed) and Georges Seurat (especially in his drawings, e.g. European Concert) have explicitly explored differences in the appearance of works when viewed from a close distance as opposed to from a farther viewing distance. When we view, for example, a Seurat painting such as...
European Concert from a meter or more, we can see objects in a scene. But if we look at the painting from close up, we can see only brushstrokes and no longer perceive the larger scene. People can more easily see medium spatial frequencies than either higher or lower frequencies [5]. At a close viewing distance, the brushstrokes are in the easy-to-see mid-frequency range, while the depicted objects are in the harder-to-see low-frequency range (Fig. 1). At a farther viewing distance, the brushstrokes are in the hard-to-see high frequencies while the depicted objects are in the easy-to-see mid-frequencies. Spatial frequency terminology provides a way to organize ideas about how different spatial scales become more or less visible at different viewing distances. Knowledge of the visual system's relative sensitivity to different spatial frequencies may be useful in guiding an artist's choices about the size of elements and how much detail to include.

WHY TEACH ART AND SCIENCE TOGETHER?

One of the goals of our course was to teach visual perception in a way that bridged the disciplines of visual art and vision science. To that end, we brought the processes of the art studio and the science laboratory into one class. Co-teaching complementary, hands-on approaches to the same topic to a common language opens the door to discovering similarities between fields. In addition to analyzing artifacts, the struggle to find a common vocabulary has an unexpected side benefit. The same realizations gleaned from comprehending terminology from an unfamiliar field may reveal how one's own jargon reflects one's own discipline. Finding a common language opens the door to discovering similarities between fields.

While artists and scientists may use the same words, the ideas behind them can be different. A good example is the word illusion. Although there may be a great deal of overlap in the two fields, there is one key place where they differ, which points out an important philosophical distinction between the disciplines. An artist would describe the perception of three-dimensional space in a photograph as an illusion. After all, the actual photograph is a flat piece of paper with differently colored areas. However, a vision scientist would not consider this an illusion, because if one views a photo from the right vantage point, the eye's image of the photo matches what one would have seen if standing where (and when) the photographer stood [7]. The object depth information was the same in the camera's image and in the image on the photographer's eye, so the fact that one perceives depth in the photo is what the scientist would predict, hence it is not an illusion. Instead a scientist would use the word illusion to describe perceptions of things that are not actually in the world or are mistakes. The fundamental difference is what is considered as the starting point for perception. For the scientist, the starting point is the eye's image. For the artist, the starting point is what is in the world. Illusion is just one of many terms we had to use.

There are also cultural differences in the teaching of visual art and vision science, including how long classes meet and what students expect. Brown University laboratory science
classes are often 3 hours of lecture plus 1–4 hours of lab time per week, and the lecture instructor is rarely the lab instructor. Rhode Island School of Design (RISD) studio classes are 6–8 hours in one day, and the instructor is in class the entire time. The rhythm of instruction is very different in these two models, so it is not surprising that coauthor Welch has developed a focused, goal-driven teaching approach, while Fasano has developed a more heuristic teaching method that develops an understanding of the relationship between materials and methods over time. Cultivating creativity requires a fine balance among teaching techniques, stimulating curiosity, guidance, group dynamics and respect for an individual’s sense of the creative act [8].

Another cultural difference consists of expectations of performance that students have formed during prior classes. Contrary to stereotypes, we found that some science students were more playful and willing to take risks than some art students. Some of our art students seemed unexpectedly inhibited. Expectations that they imposed upon themselves proved an obstacle to play, and since play is a necessary prerequisite for creativity, they found themselves in a bind. One art student even said that she was poor at science and clearly expected to do poorly on those exercises.

DESIGNING THE COURSE

Visual Illusions as a Method for Teaching Perception

Illusions are intrinsically interesting because they show violations of the basic assumption that what we see is what is actually in the world. A basic principle shown in many types of illusions is that appearance can depend on context, on what other elements are nearby. This idea is so basic to creating art that it seems unnecessary to mention, but illusions help to demonstrate this notion to the uninitiated. In addition, illusions, in the broader sense, are part of the core set of techniques artists use to obtain a desired effect. The dual approach provided complementary evidence about the complexity of visual experience.

Course Aims and Objectives

We expected students to learn about visual perception and develop an appreciation for how both science and art could help them understand the intricacies of how multiple factors contribute to what people actually see. They were to develop skills for exploring visual appearance both artistically and scientifically. These skills included painting, drawing and using Adobe Illustrator. Other skills included scientific methodologies (psychophysical techniques), critical reading and writing lab reports. Every student was expected to make illusions and explore what features were needed for the illusions to work. They were to explore the relationships between objective measures and perceptual appearance. Also they were expected to read and integrate papers by scientists and artists that discussed possible causes and uses of illusions.

We chose readings from science and art sources that paralleled and expanded on the concepts we presented in class. One source was Richard Gregory’s Eye and Brain: The Psychology of Seeing [9]; this text was required reading because Gregory uses illusions heavily to illustrate how visual processing works. We had a course website where we posted materials, links to the library for readings and links to other sites that the students or we found during the semester.

The target audience was Brown or RISD undergraduate students at any level. In the first year the Brown students included two first-year students, two upper-class students studying engineering or computer science and one junior studying both psychology and visual art. In addition, one RISD student audited the course. The second year we had 2 RISD students (apparel major, furniture-making major) and seven Brown students (chemistry, visual arts, applied math, literary arts, neuroscience and visual arts, two undeclared majors). In the Brown course catalogue, the course was listed with the Cognitive, Linguistic and Psychological Sciences (CLPS) Department offerings along with other courses in visual perception.

Both instructors attended every class meeting and each acted as a student for activities led by the other instructor. For example, during the linear perspective exercises, Welch performed the same activities as the students, using ruler, pencil and paper to make the same drawings as the students. During the lab experiments, Fasano participated in data collection in the same way as the students. A major advantage to having the instructors participate as students was the questions we asked during the exercises. These questions helped bring further insight to the students about the challenge of integrating aspects of the two fields into one course. By introducing connections between the two fields, we clarified our intentions behind each exercise.

Student Assessments

The course was designed to allow students to emphasize either the artistic or the scientific aspects of their work by working harder on one or the other. We wanted both science and art students to feel empowered to learn the other area and lend their expertise to other students. Some students who had richer backgrounds than others were able to explore the assignments with greater sophistication. Because of the large differences in students’ backgrounds, we decided to evaluate students relative to where they started the class instead of relative to each other. The wide difference in students’ initial skill levels was expected due to our wide target audience.

Students were asked to keep a journal and add something to it every day: sketch, idea, photo, observation, etc. They had weekly assignments that included short (1- to 2-page) papers, constructions and lab reports. The final project was to explore an illusion, where again students could choose to spend more effort on the art construction aspect or on writing about scholarly explorations.

TEACHING THE COURSE

Our many years of experience teaching our own disciplines did not prepare us entirely for the challenges of an interdisciplinary course. We sometimes failed to appreciate the time students needed to grasp the concepts we presented. Our
understanding of some concepts had developed gradually over several years, and by not adequately considering our own learning curves, we expected too much too quickly from our students. The students’ early written work showed that they sometimes did not understand the underlying concepts within a discipline and often missed the cross-discipline implications. We realized that we needed to allocate more class time for students to become acquainted with these concepts, and with additional time the art-science connections became more apparent to them.

For example, students created examples of color contrast using colored paper [10]. A simple example of a color contrast illusion would include two saturated background colors that would cause neutral gray foreground patches to appear tinted the color complementary to the background (Color Plate B, left). To avoid limiting how students approached this exercise, we did not teach them any color theory before they started the exercise, although we provided several examples of successful color studies. The next step was to measure the illusion, but this required a deeper understanding of color processing than we had yet provided. The students needed to learn about color theory and the ways the brain represents colors [11] and they needed to integrate these concepts. These concepts, which are essential for comprehending how color spaces are designed, provided the scaffolding for understanding what we were doing in this exercise and why.

To measure these color appearance shifts, we wanted to find perceptual matches between the color-shifted patches and similar patches on neutral backgrounds (Color Plate B, right). For each colored background in the color studies, students found a gray background that roughly matched it in lightness. This way the gray background would have the same impact on perceived lightness as the colored background but would not influence apparent hue or saturation much. Once students had found the correct gray background, they searched for a colored chip that appeared to be the same color as the small foreground chip in their color study. They next measured all of the colored papers objectively using a spectrophotometer and then plotted the measurements in color space [12]. The direction of the color shift was expected to depend on the locations of the background, its complement and the foreground color in color space. The relationship between a color and its complement is a key idea in color-opponent processing (science) and a key idea in color theory (art). And yet these ideas were not part of the students’ written lab reports about this exercise. This was an event that prompted us to do some backtracking to make sure the students were able to make the interdisciplinary connections that were key goals for the course. As a consequence of this, our revised course plan had more class time scheduled for discussions of the art-science connections.

Class Activities
Class activities included lectures, demonstrations and hands-on lab and studio investigations. We occasionally left the classroom for tasks that were easier to do outside, such as a measured drawing exercise. We took the class to a part of the Brown campus that provided long views and many examples of simple geometric objects such as tall concrete blocks plus some modern and some older architecture. The students were taught how to use a pencil held at arm’s length as a measuring tool. They established a scale to translate pencil lengths into distances drawn on paper that could be applied to measure and depict any object in the field of view. This method provided a direct, physical connection between the measurement and drawing processes. This exercise is particularly effective for imparting objectivity to the drawing process to aid with more realistic depiction and also to empower novice students to draw objects by providing them an introductory tool.

An example of linked science and art activities began with an experiment on brightness perception. The class sat in the dark for several minutes (to dark-adapt) and then rated the apparent brightness (brightness magnitude estimation) of 10 calibrated light spots shown one at a time on the wall using a slide projector. The class median perceptual ratings were determined, and students plotted class brightness ratings as a function of the spot luminance. Students found that the relationship between objective luminance and subjective brightness was not simple; instead it was nonlinear. Next they calculated the logarithm of the luminance measurements and the brightness ratings and plotted those data. In this log-log plot they found that the data fell close to a straight line, indicating a simple correspondence between objective and subjective measures, similar to what is found in the literature [13]. Our idea was to show students that even for a dimension as simple as brightness, perception may be systematic but it does not match the physical world.

The brightness-perception experiment was linked with a studio exercise to create equal perceptual steps in lightness (value) between black and white. Students mixed black and white paint to create different shades of gray and painted side-by-side rectangles with the different shades. The idea was to teach students about mixing paint and the challenges of getting the paint to match what they wanted. To link the gray studies with the brightness-perception experiment, students were provided with luminance measurements of Color-aid gray-scale papers and Munsell gray-scale papers. They found the relationship between equal perceptual steps (labels on the papers) and luminance was also nonlinear, such that a log-log plot was needed to see a straight-line correspondence between subjective and objective measures. The similarities between the data from their brightness experiment and the gray-scale papers illustrated the similarities in the two domains.

For their final projects, all of the students spent more time on creating illusions rather than on reading or writing despite their differing abilities, and some of their creations were quite wonderful. One student wrote interactive computer programs demonstrating which aspects of display elements influence the strength of motion illusions (stationary displays that appear to move) and of tilt illusions (parallel lines that appear to converge). The programs included user controls for element size, the number of elements and the spacing between elements. He included explanations for the illusions based on the scientific literature [14].

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Another student created an icosahedron (20-sided polyhedron) and painted each face with three triangles of different colors so it appeared to be a great dodecahedron (Fig. 2). Each triangular face was painted with light blue-green, dark blue-green, and black triangles. The orientation of each face relative to the room lights is different, and color appearance depends on the lighting as well as on paint pigments. When viewing the polyhedron in person as well as in the photograph, it is difficult to tell which boundaries are the icosahedron’s edges and which are painted.

LESSONS LEARNED

The visual illusions did capture the students’ imaginations and added a “cool” factor to the course [15]. This added motivation for the work and drew students to try things they had not done before. The students and the instructors both learned a lot about visual perception and about how artists and scientists use and study illusions. The class dynamics were good with all students participating in class and some students teaching techniques with which they were more familiar to others.

While we knew that we could not cover as much material as in a single-area course, we had not appreciated just how much less material could be covered in a hybrid class. We also had not realized that we could not assume any background in our students in either discipline so we began with the most elementary methods and concepts. Since we had not appreciated the amount of class time that would be needed for explicit skill-building, we could not cover as much material as we had planned. The second time we taught this course, we carefully weighed which topics and skills were most important to cover and removed several modules. We spent more time on each fundamental topic to provide students adequate time to integrate the ideas that form the core of this interdisciplinary course. As a result, the students’ science papers and oral descriptions of their work showed much better understanding than in the previous class.

One of our most glaring oversights was not considering the importance of the physical environment of the classroom. The space we were assigned the first time we taught the class would have been fine for a small seminar where students and instructors interacted primarily verbally, but it was ill-suited for art studio work. The class tended to spill out into the area outside the classroom just to find sufficient space to work. The characteristics of the classroom made many exercises difficult and made some planned exercises impossible. For the second course, we were assigned two spaces. One space had large tables, a projector and ample space; the other room had computers and large display monitors. Class time was divided into three 1-hour classes: Monday, Wednesday and Friday for lectures, computer exercises and discussion, respectively. We also had one 4-hour session on...

Fig. 2. Haruko Hashimoto, Icosahedron as Great Dodecahedron, illustration board, plaster, glue, acrylic paint, 15 x 15 x 15 in, 2010. Icosahedron (20-sided polyhedron) with faces painted to appear as a great dodecahedron. (© Haruko Hashimoto. Photo: Leslie Welch.)
Monday afternoon that was mostly devoted to studio exercises. The division of the course into two spaces having different session lengths was suitable for our different sorts of class activities.

Another improvement would be increased frequency of group critiques of the students’ work [16]. Group critiques are an effective way to share the fruits of each student’s investigations with the rest of the class. In addition, fostering an “open source” classroom atmosphere sends a clear message that creativity is never an entirely solitary act; it is nourished by communities of people sharing ideas. One assignment was for students to keep a journal and add something to it each day. We made the mistake of not looking at their journals until the end of the semester instead of giving them feedback throughout the semester. Unexpectedly, some students put little in their journals. This problem might have been avoided if we had asked students to share with the class one thing from their previous week’s journal. The pressure of knowing they had to share something might have helped them to keep up with this assignment. Indeed, for our second course, we had weekly critiques where students pinned up selected journal images. In addition, students handed in their journal contributions weekly. These expectations provided sufficient motivation for students to keep their journals current.

**SUMMARY**

As others who have team-taught interdisciplinary courses have pointed out [17], there are several critical challenges for instructors to make it work. Selecting appropriate workspaces and classroom session lengths is crucial. Recognizing students’ prior experience and academic aspirations may offer insight into how to best spark their enthusiasm and creativity.

Another challenge for us as the instructors was to take the time necessary to acquire knowledge of each other’s subject and to research the culture of the other’s discipline. The terminology, culture, types of knowledge and problem-solving methods differ between artistic fields and between scientific fields, but the differences are even greater between science and art. Even the goals of the two approaches are different: A scientist wants to increase systematic knowledge of the relationship between perception and the physical world. An artist strives to create something that stimulates curiosity and reflection by revealing new ways of thinking and perceiving. However, their exploration processes can correlate with each other on many points, and their knowledge bases in visual perception overlap in fundamental ways. The seminal challenge is to develop mutually tenable terminology and complementary pedagogies.

**References and Notes**

7. This of course ignores all of the interesting ways cameras can be used to create images that differ wildly from what can be seen with the naked eye.

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Leslie Welch, color illusion study. Students chose two background colors (here green and orange) such that they changed the appearance of two superimposed small patches of the same color (here light gray). The left pair of long arrows point to two small patches cut from the same paper (labeled “same actual color”). Students next found a gray paper that they perceived as roughly matching one of the background colors in lightness (labeled “lightness match”). (Here the gray background is similar in lightness [value] to the orange background.) Students then found another color (here the small patch on gray background) that appeared the same as the small gray patch on the orange background. The right pair of long arrows point to these two small patches that appeared the same in this context (labeled “same apparent color”) but they were cut from differently colored papers. (© Leslie Welch) (See article in this issue by Leslie Welch and Carl Fasano.)