Learning Science with Art

Anna Ursyn
School of Art and Design
University of Northern Colorado
ursyn@unco.edu

Ruwang Sung
School of Health and Natural Sciences
University of Northern Colorado
ruwang.sung@unco.edu

Abstract

This paper describes the novel approach to cooperative, integrative instruction in science, and examines the effect of non-restrained, spontaneous creation of sketches, versus writings, on the effectiveness of student learning.

Categories and Subject Descriptors
K.3.1. [Computer Uses in Education] Collaborative Learning. J.5. [Fine Arts]

General Terms
Design, Languages

Keywords
Collaborative practice, Interdisciplinary instruction, Novel approach to science – art connection, Computer graphics

1. Introduction

This project describes techniques in physics instruction that are integrative with an art-science connection. These are aimed to improve student cognitive abilities related to visual thinking about scientific processes. In this student-centered learning environment, students are actively involved in studying science by visualizing selected topics and producing graphical illustrations versus written descriptions of concepts they learned. Student cognitive skills enable them to interpret and comprehend the concepts they are studying by the way they make non-verbal representations of ideas and create or receive visual messages about science concepts.

Our instruction is aimed to engage student cognitive processes in seeking out information, selecting and organizing into memory store some useful notions, and then retrieving them for problem solving and decision-making. By drawing and writing activities students transformed what they just learned both into iconic (visual) and semantic (verbal) codes to perform intellectual tasks of choosing images and words relevant to the theme just learnt and creating something useful or beautiful.

Our study consists of two parts that have been designed differently for two separate groups of students:

(1) An experimental study on the effect of activities that arouse the imagination into action, (namely sketching or writing), on student achievement in a physics class. This part involves bringing drawing to the science class.

This part of the study refers to the two ways of enhancing the learning process – through visual and through verbal activity that activates imagination. Contrary to previous studies examining the effects of art instruction on student achievement in science [Ursyn et al 1997, Ursyn 1997], this study is focused on the significance of students' unrestrained cognitive activity evoked by drawing or writing, and its effect on their performance in a physics class, which is a novel approach. Therefore, student sketches, (graphic storytelling), and writing were self-inspired, not supervised, and their cognitive efforts reflected a spontaneous activity of visual presentation of scientific ideas and concepts. Lectures on physics concepts delivered by professor of physics were followed by the guidance from the professor of art.

(2) Cognitive art. The influence of learning about a scientific concept on student artistic production, resulting from mental visualization of this concept. This part of study involves bringing physics to the art room.

The science-inspired art assignments were aimed to develop awareness of scientific concepts and events in everyday life, and facilitate students' self-confidence about their own ability to actively absorb scientific concepts. Our instruction referred to real-life applications and evoked connotations with well-known circumstances, and thus implications in both scientific and artistic perception. Students were given the challenge to visualize artistically a scientific concept.

2. Rationale

There is general consent that students' perception about science has been negatively conditioned, which has resulted in the commonly shared opinion that science learning is difficult, useless, and at odds with everyday life. By creating knowledge-based sketches and graphics, students learn about current approaches to dynamic presentation of data. We train students to be more creative, imaginative, and multi-talented by integrating science, art, and computer technology into science. This research project also continues former explorations of one of the authors [Ursyn 1991].

Educational forums [Wands 2006] deliberate how to balance all of the elements of the traditional art programs, that contain components of theory, art history, critique and studio work, with the digital art program components that focus on software instruction and technological literacy. Such discussions are aimed to provide the best possible educational experience that is conducive to further developing digital literacy of students. Computer graphics specialists design programs to provide research-oriented, interdisciplinary collaborative experiences that engage students from varying disciplines [Palazzi 2006]. Several universities have already developed interdisciplinary programs in computer graphics designed for art and computer science students in a liberal arts environment. In several cases, using computers as design tools and applying computer animation and graphics even served for teaching elementary school level mathematics [Eisenberg 2005; Kilmer and Schields 2006].

The focus of our interdisciplinary instruction was on improving student cognitive abilities related to visual thinking about scientific processes. In other words, the way students learn to understand science concepts, make non-verbal representations of ideas, and create and receive visual messages about science concepts when using a computer graphics environment.

3. Conceptual Framework

Visual thinking involves cognitive thinking and plays the decisive role in building knowledge with the use of communication through art. As Arnheim [1969] stated, artistic activity is a form of reasoning in which perceiving and thinking are indivisibly intertwined. It has been generally accepted that cognitive activities, as the act of knowing, include attention, creativity, memory, perception, problem solving, thinking, and the use of visual imagery and language. Processing information picked up by the senses includes analysis and recoding of stored data, not necessarily represented in consciousness, to use them for various purposes. Visual and verbal means of recoding information draw from iconic memory and allow for storing one's knowledge as visual imagery and semantic material. Every visualization is based on frequently used linguistic pattern (with social or cultural discourse). For example, a 'pie chart' metaphor of market shares uses metaphors about cutting a pie; a 'starry night' metaphor can show it in 3D, etc. Thus, according to Bertschi and Bubenhofer [2005], metaphor is a tool of conceptual economy but also a tool of discovery of structures within novel or unfamiliar situations. Visual metaphors fulfill a dual function: organize and structure information, but also convey an implicit insight through the key characteristics or associations of the metaphor [Eppler and Burkhard, 2005]. Hartman and Bertoline [2005] postulate that a body of knowledge called Visual Science should be studied, practiced, and scientifically verified as a discipline, as about 80% of sensory input comes from our visual system. Students apply creativity to see connections and relationships and to be able to think in intuitive, non-verbal, and visual terms. With flexibility of mind, students are more spontaneous, expressive, and less controlled or inhibited. They also tend to trust their own judgment and ideas – they are not afraid of trying something new.

The use of sensory representations of abstract data to reinforce cognition is the essence of information visualization. Students' ability to artistically visualize a scientific concept is the required quality for understanding the principles of visualization technique and its applications. According to Roger Pouivet [2000], aesthetic experience is a function of cognitive activity, and knowledge is not a non-emotional process. Certain emotions are rational and cognitive (and may be experienced in the field of science as well as in the field of aesthetic experience). In educational psychology visualization means the ability to create symbols that allows communicating knowledge, conveying meaning, and expressing mental representations and images [Escobedo, Bhargava, 1991]. Information visualization in computer programs involves selecting, transforming and representing abstract data in a form that facilitates human interaction for exploration and understanding.

Visualization can be defined as "the creation of graphic images directly from data, and the outcomes form algorithmic manipulation of these data" [Slockum 2004]. Data types are 1D linear, 2D, 3D, and multidimensional [Graham 2005]. Information visualization (IV) can be defined as "the use of interactive visual representations of abstract data to amplify cognition" [Bederson and Schneiderman 2003], in contrast with scientific visualization. Interactive visualization is an essential issue in organizational communication or knowledge media design [Klein 2005]. Knowledge visualization stresses the transfer of knowledge and concentrates on the recipients, other types of knowledge (know-why, know-how), and on the process of communicating different visual formats [Burkhard et al 2005]. Knowledge maps are a subset of knowledge visualization. All of these growing disciplines require possessing the ability to create cognitive visualization and produce exceptional graphics that contain a great amount of information [Hartman and Bertoline 2005, 2006]. It is used to communicate and store information, solve problems, and affect the human experience through the senses.

There is strong interest in graphics programs among prospective students majoring in the arts, education, computer science, business, and marketing. These disciplines are becoming increasingly visual, especially in the web space context, because people think in pictures and knowledge must be recreated in the mind of the receiver. According to Eppler and Burkhard [2006], visualization outperforms text alone and increases our ability to think and communicate. This field offers both visual and verbal types of communication and is probably one of the most integrative fields, combining literature, poetry, music, art, sociology, psychology, and social anthropology with any discipline related to media techniques.

There is growing demand in many disciplines for visual aids– scanned images, graphics, and dynamic images that display information or promotional materials. The ways of data presentation (for example, visual storytelling for animated video) change rapidly. Therefore, teams working on visualization or modeling need students who are apt to employ state-of-the-art media. For instance, magazines and newspaper publishers rely on web video to launch online video advertising. TV networks, newly established firms, and web portals make another venue in the professional marketplace. This is a result of a new competition created by the web users.

Multimedia materials, (images, simulations, sound, video, etc.), designed for lectures, books, references, computers, and web space are widely available and proven to be effective in science, both in teaching and learning. However, these materials are mostly produced by professionals who understand the concepts. Involving learners in the production process of visual illustration of basic science concepts has not been experimented with or reported in physical science courses.

4. Project Design

4.1. Aims of the Project

The goal of this project is to study integrative instruction with the use of activities that arouse the imagination into action, namely by sketching or writing. The experimental research study is aimed to show this enhanced instruction in visual presentation and how it has resulted in the improvement of students' achievement in physics in General Education classes. Students learn to create visual interpretations of concepts in science, and their experiences in visualization engender their curiosity, inventiveness, their ability to perceive relationships, and generate metaphors and associations between nature and physical structures underlying natural events.

The second part of this study involves an exploration in how students' learning about a scientific concept and mental visualization of this concept influence their artistic production of computer graphics.

4.2. Research Hypothesis

The mean student achievement in response to visualizing science with sketches (graphic storytelling – the treatment being tested) is equal to the mean student achievement in the control group. Both responses have the normal distribution with this unknown mean and the same known standard deviation.

4.3. The course of action

Program activities consist of physics instruction. Then, students from the experimental group receive treatment in the form of a 10-minute work on drawing sketches about the current topic. The researchers provide the same exams to both groups. Analysis of the exam scores enables the researchers to compare general performance of the two groups.

4.4. Experimental design

The pretest – posttest control group design was employed for the group comparison in student achievement in the Physics class. The experimental group was visualizing science through sketching; the control group was expressing science concepts as written stories. The writing in the control group was introduced to have students do a different activity when the experimental group was sketching. This way, both groups had the same time and exposure to the topics introduced.

4.5. Population

The population of the study consisted of UNC General Education students attending the Physics class in the Fall 2006 semester. Samples, (groups under comparison), were randomly assigned from among the participants to the experimental group (sketching), and the control group, (creative writing about concepts learned in the class).

4.6. Treatment

All students took a pretest and a posttest. The pretest contained the same questions as the posttest. The treatment was comprised of the 10-minute sketching intended to arouse the students' imagination. In the experimental group, students created their own visualizations through sketching, showing their understanding of the concepts. For the control group, it was the completion of written projects.

In the second part of the project, students artistically visualized scientific concepts presented as a lecture by the physics professor (one of the authors). Students from a Computer Graphics class, taught by the second author, responded to a lecture about the Bing Bang theory, students from the Computer Art class reacted with their artwork to a lecture on Nuclear Energy, while students from another Computer Art class (Fall '05) learned about the OTEC (Ocean Thermodynamic Energy Transmitter) project previous to creating their computer-generated art.

5. Data Collection and Analysis

Data was collected in the form of the final exam scores. We evaluated changes created by the treatment by comparison among groups. Formative evaluation of the results of the study will be attained through statistical data analysis to obtain a structured evaluation of student assessment. While statistical results did not yet prove the effects of the instruction under study, we believe that further explorations are needed to explore this theme.

Instruction in science brought to the computer graphics lab resulted in creation of knowledge-based cognitive art by the students. Selected works are to be presented at ACM SIGGRAPH Conference.

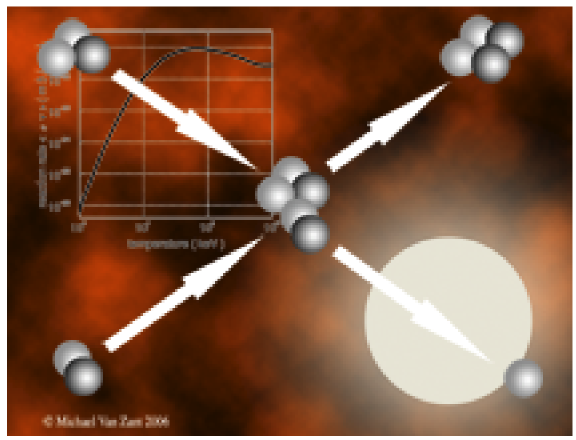

Fig.1. Student Work
Michael Van Zant – Fusion

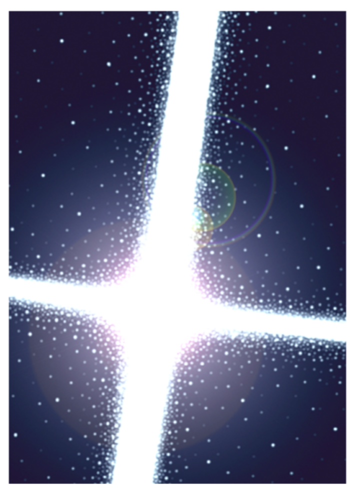

Fig.2. Student Work
Bryan Scanion – Big Bang

6. Discussion

This project may be considered an important departure from existing practice in science instruction. In this program, students' interest, motivation, understanding and involvement in science are enhanced by the process of creative visualization while broadening their knowledge about objects and processes to be shown in knowledge-based sketches, writings, and graphics. Based on the tracking of the research line associated with this project's concerns, one may often notice the researchers' approach focusing on visualizing ideas in the form of presenting data in graphical explanative form, but it is difficult to find any research supporting the understanding of science through artistic expression.

The rationale for this program has been confirmed by the results of one of the authors' previous experimental studies where student achievement in science was tested after students received integrative instruction in computer graphics and created their knowledge based art. However, explorations about the effect of non-restrained, spontaneous creation of sketches and writings on the effectiveness of student learning seem to be novel and unique.

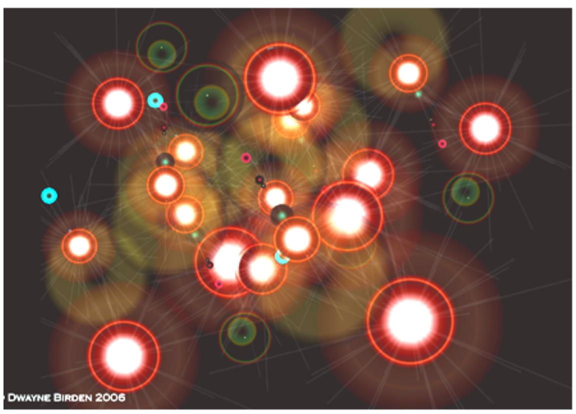

Fig.3. Student Work
Dwaine Birden – Nuclear Energy

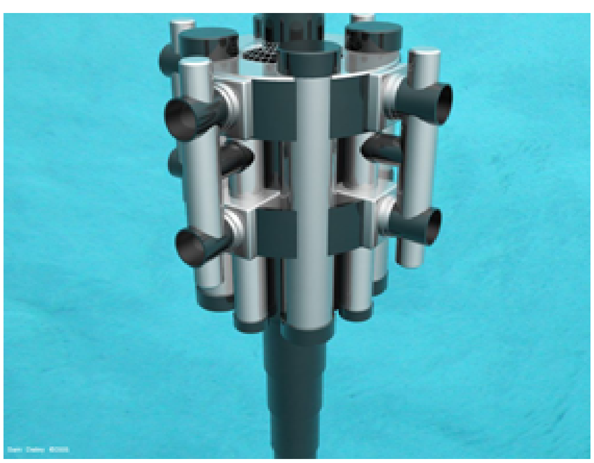

Fig.4. Student Work
Sam Dailey - OTEC (Ocean Thermodynamic Energy Transmitter) project

This project also examines integrated instruction in teaching art and various subfields in physics. Mental visualization of the main fields in physics may facilitate problem solving, and enhance content and the nature of mental imagery in cognition and learning. Cognitive approaches to mental imagery provide a new set of relatively valid methods of research likely to produce more information about the processes of understanding, encoding, and memorizing scientific concepts. Assessment of such far-reaching impact could only be done in terms of improvement in students' understanding and learning of physics.

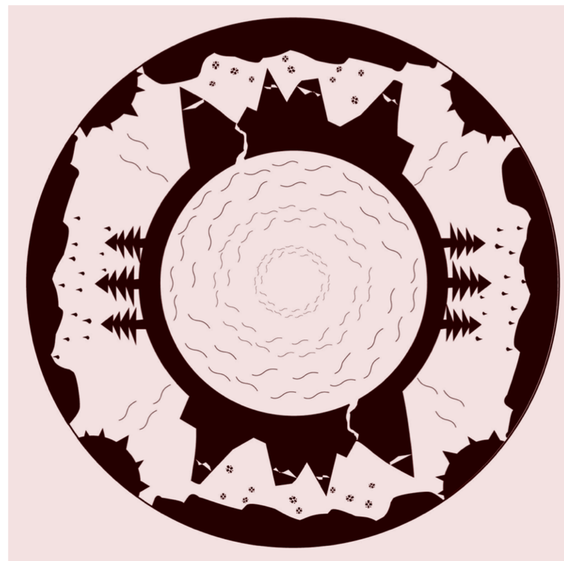

Fig.5. Student Work
Sam Dailey – Water Cycle

References

BEDERSON, B. and SHNEIDERMAN, B. 2003. The Craft of Information Visualization: Readings and Reflections. Morgan Kaufmann Publishers, San Francisco, CA.

BURKHARD, R. et al. 2005. Beyond Excel and PowerPoint: Knowledge Maps for the Transfer and Creation of Knowledge in Organizations. In Proceedings of Ninth International Conference on Information Visualisation (iV 05) (IEEE Computer Society). Los Alamitos, CA, Washington, Brussels, Tokyo), 76-81.

EISENBERG, M. et al. 2005. Mathematical Crafts for Children: Beyond Scissors and Glue. In Art+Math=X International Conference Proceedings, Carla Farsi, Ed., 61-64.

EPPLER, M. J. and BURKHARD, R. M. 2004. Knowledge Visualization, http://www.knowledgemedia.org/modules/pub/view.php/knowledgemedia-67, [01/08/2007].

GRAHAM, D. 2005. Information Visualization Theory and Practice. In Proceedings of Ninth International Conference on Information Visualisation (iV 05) (IEEE Computer Society). Los Alamitos, CA, Washington, Brussels, Tokyo), 2005, 599-603.

HARTMAN, N. W. and BERTOLINE, G. 2005. G. R. Spatial Abilities and Virtual Technologies: Examining the Computer Graphics Learning Environment. Proceedings of Ninth International Conference on Information Visualisation (iV 05) (IEEE Computer Society). Los Alamitos, CA, Washington, Brussels, Tokyo), 992-999.

HARTMAN, N. W. and BERTOLINE, G. R. 2006. Virtual Reality-based Spatial Skills Assessment and Its Role in Computer Graphics Education. The ACM SIGGRAPH Education Committee. Full Conference DVD, a publication of ACM SIGGRAPH.

KILMER L. and SCHIELDS, S. 2006. Incorporating Higher Education Computer Animation Principles into Primary Education Math Systems. The ACM SIGGRAPH Educators Program Panel, Full Conference DVD, a publication of ACM SIGGRAPH.

KLEIN, S. 2005. Knowledge Visualization in Practice: Challenges for Future Corporate Communication. In Proceedings of Ninth International Conference on Information Visualisation (iV 05) (IEEE Computer Society). Los Alamitos, CA, Washington, Brussels, Tokyo), 70-75.

PALAZZI, M. et al. 2006. Designing Collaborative Interdisciplinary CG Experiences in the Curriculum. The ACM SIGGRAPH Educators Program Panel, Full Conference DVD, a publication of ACM SIGGRAPH.

SLOCKUM and al., after LOBBEN, A. 2004. Controlling the Visualization: Evaluating Spatial Data Mining Patterns while Exploring a Familiar Geographic Environment. In Proceedings of Ninth International Conference on Information Visualisation (iV 05) (IEEE Computer Society). Los Alamitos, CA, Washington, Brussels, Tokyo), 2005, 764-769.

URSYN, A., MILLS, L., HOBGOOD, B. and SCOTT, T. 1997, Combining Art Skills with Programming in Teaching Computer Art Graphics. In Proceedings of ACM SIGGRAPH 97, Computer Graphics, 25, 3 (July 97).

URSYN, A.1997. Computer Art Graphics Integration of Art and Science. Learning and Instruction, The Journal of the European Association for Research on Learning and Instruction (EARLI), 7,1, 65-87.

URSYN, A. 1991. The Use of Computer Art Graphics in Art and Science. In Abshere, K. Discovery Through Experimentation, Art and Educational Computing in Secondary Schools. In Proceedings of ACM SIGGRAPH 91 Educator's Program. Computer Graphics, 253, 168-171.

WANDS, B. 2006. Right Brain/Left Brain: Balancing Digital Art Curricula. The ACM SIGGRAPH Educators Program Panel, Full Conference DVD, a publication of ACM SIGGRAPH.

.