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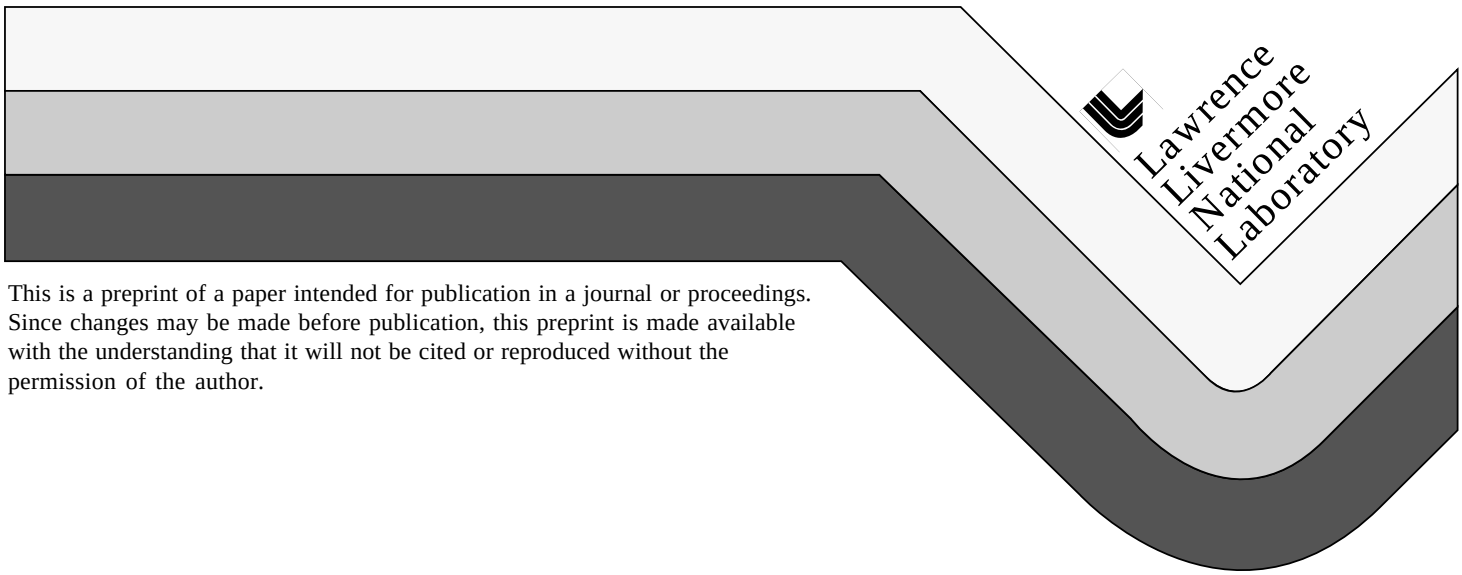

Science into Art: A study of the creative process

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Abstract

The objective of this study was to examine the creative process, demonstrated by five student participants enrolled in a class conducted at the Art Center College of Design in Pasadena, California, from the germ of the creative idea, through the final creative product. The students, drawn from classes sponsored by the Lawrence Livermore National Laboratory, were assigned the problem of representing “big” science, as practiced at Lawrence Livermore, in a graphic, artistic, or multimedia product. As a result of this study we have discovered that the process of creativity with these students was not linear in nature, nor did it strictly follow the traditional creativity schema consisting of five steps: preparation, incubation, insight, evaluation and elaboration.

Of particular interest were several emergent themes of the creative process: the spontaneous use of metaphor to describe the Laboratory; a general lack of interest in “school” science or mathematics by the American art students; a well developed sense of conscience; and finally, the symbolism inherent in the repeated use of a single artistic element by the students in the creation of their projects. This use of the circle revealed a continuity of thinking and design perhaps related to the idealistic bias mentioned above. The study revealed what we think are important clues to the creative process.

Introduction

The original class held in 1995, at the Art Center College of Design was entitled "Creating an Identity for a National Laboratory." The Public Relations Department of Lawrence Livermore National Laboratory, as client, had requested a new "corporate image," a typical project for Art Center students. In 1996, under the tutelage of the Education Department of Lawrence Livermore National Laboratory, the scope of the class was broadened. The class was renamed, "A Visual Synergy of Science." The change in scope offered the students taking the class at the Art Center College of Design a more conceptual and experimental educational opportunity from which both entities, as well as the general public, might benefit.

In the redesigned class, “A Visual Synergy of Science,” students were told they could go beyond corporate image if they chose, and produce their concept of "big" science as practiced at Lawrence Livermore National Laboratory. The learning experience and how they arrived at their product

were to be the focus of the class. The instructor, Greg Thomas, stated in the class syllabus: ". . . it is important for you to realize the direction the project will go and what the end result [is] are up to you."

Students were encouraged to research the history of the Laboratory, and to use this information to establish a foundation for their project. The Lawrence Livermore National Laboratory is operated by the University of California for the U.S. Department of Energy. It serves as a research and development center in applied science and engineering. Students were given a tour of the Livermore facility, including the sections on: Lasers, Human Health, Biology, (including the Human Genome Project), and the Atmospheric Release Advisory Capability.

Many students in the newly expanded class continued to produce corporate identification systems, typically: a logo to be used by the client on cards, stationery, signage, vehicles, and ID badges for the various departments: Lasers, Human Health, Biology, etc. Some students produced interactive computer programs, videos or CD-ROMs. One student produced and modeled, as a part of his identity system, a T- shirt with his new Livermore National Laboratory logo emblazoned on it.

The five student research participants who responded to our call for volunteers were comparatively homogenous in their final products. Three of the five students produced books, and the remaining two participants worked as a team producing two products: a book and an interactive computer program. The final creative products, however, are as individual as the students themselves.

The research team viewed the creativity process from two different perspectives: Science and Art. Stephen Sesko, has worked for the Education Department of the Lawrence Livermore National Laboratory for 17 years, teaching science to the public, to students, and to teachers. He has also taught computer programming to gifted children for the Laboratory. Melanie Marchant brought to the team an art perspective. She has studied art since 1966; taught art--both art history and studio art--for Cosumnes River College, Folsom Lake Center, in Folsom, CA since 1988; and has produced art privately and professionally since childhood. Both researchers have specialized in creativity, and in gifted education. They have utilized computer programming and drawing, respectively, as teaching and learning strategies.

Literature

The creative process is not a new subject of study. Nearly fifty years ago, Brewster Ghiselin published The Creative Process (1952) a compendium of thirty-eight "brilliant men and women," explaining their creative works. Included were Einstein, Nietzsche, Mozart, Jung, Poincaré, Gertrude Stein, van Gogh, and Henry Moore. Arthur Koestler introduced The Act of Creation in 1964, another seminal work, which follows the process of creativity in science and art for over 700 pages. The Creativity Question (1974)

edited by Albert Rothenberg and Carl R. Hausman is directed at a “twofold inception,” the factors of control or design, and chance in the process of creativity. It contains writings by Immanuel Kant, Francis Galton, Freud, Maslow, Edgar Allan Poe, Ann Roe, B.F. Skinner, Carl Rogers, and others, on the subject of creativity.

With the advent of cognitive psychology in the mid-1970s, the study of the process of creativity accelerated. Vital and dynamic research has been undertaken by Howard Gruber on the scientific creative processes of Darwin in his book, Darwin on Man: A Psychological Study of Scientific Creativity, (1974). Howard Gardner explored creativity in the arts in Art, Mind and Brain (1982) and theorized concerning different ways of thinking. Gardner isolated what he called logical-mathematical thought from musical "intelligence"; these from "spatial [visual] intelligence;" and the "personal intelligences," offering a broad spectrum of cognitive competencies in his book, Frames of Mind: The Theory of Multiple Intelligences (1983). In his Creating Minds (1993), he followed his thesis with case histories of the creative process in distinguished representatives of those identified intelligences: Einstein, Freud, Picasso, Gandhi, Martha Graham, and others.

Numerous books correlate art with science: Art & Physics: Parallel Visions in Space, Time & Light, by Leonard Shlain (1991), Disappearing Through the Skylight, by O.B. Hardison, Jr. (1989), Insights of Genius: Imagery and creativity in science and art, by Arthur I. Miller (1996), and A Brief History of Everything (1996), by Ken Wilber, to name a few. Mihalyi Csikszentmihalyi recently released a study of ninety-one creative artists and scientists in his book, Creativity (1996). No book of which we are aware actually demonstrates the process of science being intentionally, consciously, transformed by artists into art.

In the late nineteenth century the creative process was mapped out in three stages by German physiologist and physicist, Herman Helmholtz, describing his own pattern of discoveries. Helmholtz' pattern consisted of three steps or phases: saturation, incubation, and illumination (Edwards, 1986). This schema differs somewhat from that of Graham Wallas, who in 1976, expanded these to four phases which he designated as: preparation, incubation, illumination and verification (Rothenberg and Hausman, 1976).

Subsequent studies, by Getzels and others, expanded these stages of creativity to five: first insight, saturation, incubation, illumination ("The Aha!"), and verification (Edwards, 1986). The traditional schema identified by Csikszentmihalyi (1996), also consists of five slightly different phases: preparation, incubation, insight, evaluation, and elaboration.

THE EVOLUTION OF THE STAGES OF CREATIVITY

Helmholtz	Saturation	Incubation	Illumination	
Wallas	Preparation	Incubation	Illumination	Verification

Getzels	First Insight	Saturation	Incubation	"Aha!"	Verification
Traditional	Preparation	Incubation	Insight	Evaluation	Elaboration

The creative process is difficult to examine for many reasons, one of which is that, by nature, the process is inchoate. It is much easier to examine a creative product than the process that preceded it. The researchers attempted to determine whether the creative process utilized by the student subjects at the Art Center College of Design had conformed to, or differed from, the stages of creativity described by Helmholtz, Wallas, Getzels, and the traditional one mentioned by Csikszentmihalyi.

Methodology

During the first day of class sponsored by the Lawrence Livermore National Laboratory, the students were informed by their instructor, Greg Thomas, that a research project was being planned based on the creative work they would be doing throughout the fourteen-week class. Student participants were recruited from these classes. The researchers toured the Lawrence Livermore facility with the students from one class, and spoke with them during the lunch break. We described the proposed study, told them what we hoped to accomplish, and distributed a written description of the project and informed consent forms. The students who volunteered were asked to keep both journals and sketch books to record their cognitive and intuitive processes, which would then be used by for analysis. The final day of class consisted of student presentations of their personal "Visual Synergy of Science."

Survey methods: questionnaire, telephone and face-to-face interviews were used in the examination of the process of creativity.

Qualitative research methods, including the grounded theory method of thematic analysis were also used in this investigation.

Patton (1982) writes that there are four different kinds of questions commonly asked in questionnaires: opinion questions, knowledge questions, behavior questions, and feeling questions.

The students were asked their opinions about things as divergent as religion and their interest in women. Knowledge questions centered on when, where, and how their creative ideas came to them. Behavior questions elicited a past history of their preferences: whether they were introverts, extroverts, shy, aloof, or rebellious as children, and so on. Feeling questions, such as emotional involvement with their projects, and whether or not they had a strong concern for other people were designed to illuminate affect.

Face-to-face interviews are recommended (Jaeger, 1988) for many reasons. This method seemed to us the obvious choice for the primary collection of data. It is superior to written responses because the researcher has access to spoken and visual cues which cannot be translated from textual materials. The interview process also allows us to request immediate

clarification on nebulous answers, and offers the opportunity to rephrase questions if they are not immediately understood by the respondent. Face-to-face interviews also offer the advantage of emotional cues derived from tone of voice, including urgency, irony, humor, and excitement.

The students were interviewed individually for approximately one hour. The interviews were audio taped and later transcribed and coded for analysis according to the concepts developed by Strauss and Corbin (1991). This included open, axial, and selective coding. These codes were used to determine themes, which were considered provisional until quite late in the process. The importance of the emergent themes was relative to the researcher. Spirituality, affect, and the search for truth were of great importance to the art education researcher, while of limited importance to the science education researcher. Face-to-face interview questions were designed to be open-ended and followed up by the use of verbal probes, and later, especially concerning emergent data, with E-mail questionnaires, followed up by telephone questions.

Materials produced during the creative process were collected, copied, and analyzed by the researchers. These materials, in the form of sketches and written notes, held several important themes, as did the final creative products. The final projects were analyzed, compared and contrasted, to determine themes both similar and divergent.

In addition to attempting to determine whether the students' creative process followed the traditional five-step pattern, other questions were of particular interest from the art point of view. The following questions concerning art and creativity were entertained:

1. Where did the germ of the idea for the project come from?
    a. Words spoken on the tour of the lab.
    b. Pictures seen on the tour of the lab.
    c. Words written in the literature from the lab.
    d. A scene in the video shown on the tour of the lab.
    e. No specific picture or word sequence.
2. Did the concept evolve in your mind as you drew?
3. Do your creative ideas come to you at any specific time? For example, while driving, in the shower, or when you are going to sleep?
4. In what ways did you research your idea?
5. How long did the development of the idea take?
6. Are you emotionally involved with your project in any way?
7. How do your thoughts come to you? In words, pictures, shapes, colors, and so on.

The students were interviewed about their personal creative process by asking the questions above, although the interviewers did not always ask the questions in the exact order or use exactly the same words. Subsequent to the initial interviews, E-mail questions were sent to the participants in an effort to clarify certain areas, or add precision to the students' answers, or request

additional information concerning emergent themes. These E-mail questions are contained in Appendix A.

Participants

The sample selected for this study is what Patton (1990) would call "typical case" sampling (p. 173). This kind of sample can be taken from survey or similar data. Its purpose is to provide a "qualitative profile of one or more typical cases to describe what is typical...not to make generalized statements.... The sample is illustrative, not definitive." (p. 173)
The five participants in this study were self-selected from four classes which took place over a period of nearly two years.

The five volunteer participants were all Caucasian males in their early twenties: one was 23; one was 25; three were 24. The youngest was a senior student, the other four were juniors. Four were majoring in Graphics/Packaging, one majored in Communication design.

Data

The following are five narratives of the creative process.

SEAN

Sean's artistic product was a book on dwarfism, specifically examining achondroplasia, the most frequently diagnosed form of dwarfism. It is entitled, Dwarfism: Achondroplasia. The book contains illustrations of the physical attributes of achondroplasia, the genetic chances of its inheritance, and discusses the medical procedure for limb lengthening.

The researchers were interested in exactly what had been the stimulus for the germ of the idea for each student's creative product. When asked about this, Sean said that he thought the germ of the idea for his project had been triggered during the field trip to the Laboratory. One division of the Laboratory is the Bio-Medical facility, and it was in this section of the tour that Sean heard the words that were the germ of his project:

> "I was kind of interested in the Bio-Med aspect. It was pretty foggy on what I was going to do specifically, and when I went on the tour, B.J. [scientist/guide]. . . mentioned finding the dwarf gene, and that's what I latched on to. It interested me."

Lawrence Livermore Laboratory has been charged with mapping chromosome #19, and there is a long paper strip mapping the chromosome on the wall at the Bio-Med facility, with notations marking the location of many of the identified genes along the length of the chromosome. During the scientist's description of the Human Genome Project, he mentioned that the gene for dwarfism had been discovered by the Laboratory in 1994, and mapped, along with many other characteristics to which chromosome #19 holds the genetic key.

The idea of the gene for dwarfism caught Sean's attention, and appears in his first sketches of the trip to the Laboratory (See Figure 1). In his sketched

notes under the title “LAB VISIT,” is a sketch of a geodesic spheroid, with the words, “NIF NATIONAL IGNITION Facility.” Under this note is a printed directive: “MAP OUT WHAT CAUSES DWARFISM.”

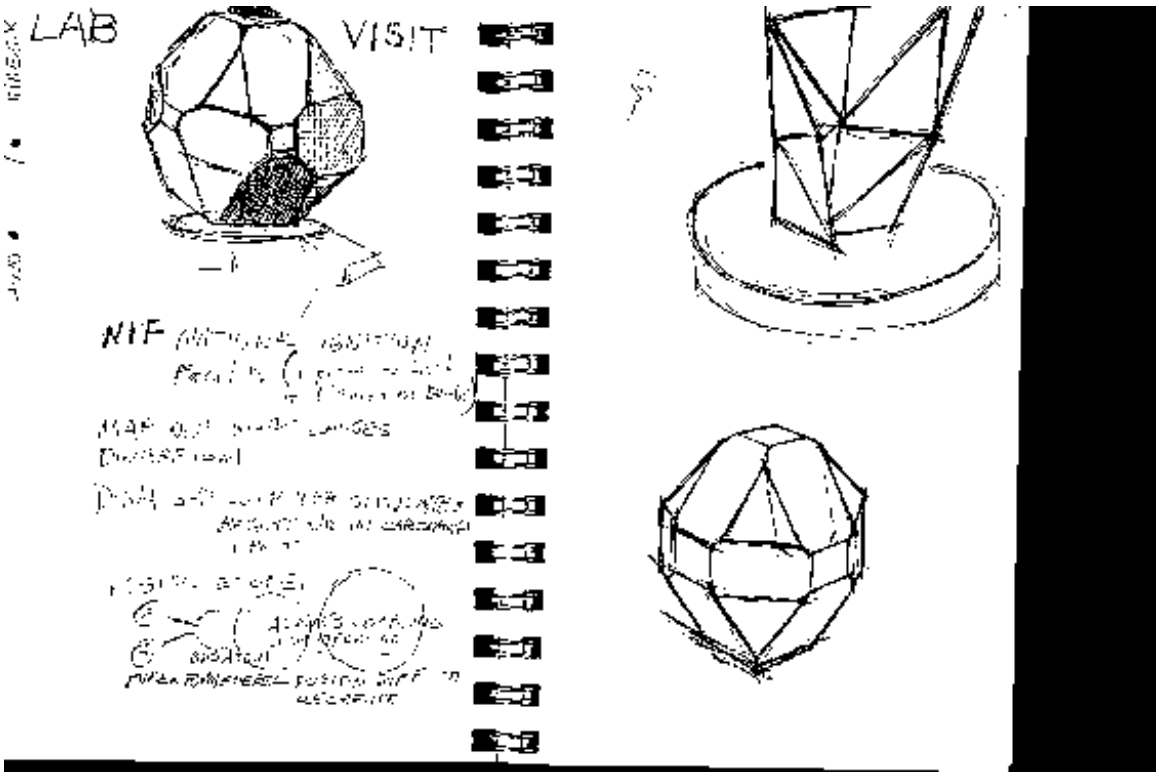

Figure 1. Sean’s sketches of spheres and written directive.

When asked why the particular bit of information about the dwarf gene caught his attention, he replied, "I guess it's just personal. I have, I guess I have, this fascination for the strange, or something like that. Not to offend the little people, but it’s just--I like different things, to put it mildly." Sean began his research on dwarfism through the Internet, which was new to him, and from there progressed to a personal interview with Billy Barty, an authority on dwarfism. Sean commented that Barty was witty and helpful, and offered insight into the social aspects of Dwarfism.

We asked Sean whether or not the physical act of drawing seemed to facilitate his thinking about the project. The question was, “Did the concept evolve in your mind as you drew?” To which he replied: “Specifically draw? I think, yeah, I think it did evolve visually.”

When asked if his creative ideas usually came to him at any specific time, Sean replied that many times ideas occurred to him on awakening. But a lot of his ideas came to him at a particular place: "It's on the freeway, [#]134, and I know exactly where, it always happens in the same place, it's very strange." He also got creative ideas while sitting in front of the computer

screen, where he saw shapes and images within shapes, artistic “aspects” that he could utilize.

When asked how long the project took him to complete, he replied, "[I] Couldn’t tell you. Hours. That seems too minimal, I’d say days. The class is 14 weeks, probably, maybe, if you packed everything side by side, 24 hours." The researchers believe this time estimate of 24 hours much too brief, considering his creative product, which is a beautifully illustrated, professional quality book, replete with original drawings, graphs, and quotations.

A second reason why we felt that Sean had indicated a very truncated time spent on his project was that he discussed with us that he had become "stuck" at one point on his book about dwarfism, and had switched his attention to designing the corporate Logo/ID instead of finishing his original concept. He then reconsidered, realized, “there wasn’t enough time,” to complete the corporate ID, returned to his original idea, and finished his project by the deadline for the class.

Sean said he thought he'd looked at his project objectively, in reply to the question about whether he had any emotional involvement with the project. He seemed very much concerned that he might say or write something that would offend the little people, perhaps by his very exploration of the subject:

> “And I didn’t want to get into the social aspects, and a lot of it was that I wasn’t sure if I was going to offend or not. And that was something that I guess I had to put out of my mind because it would somehow haunt me and I’d mess up somehow and become disastrous. And trying to stay in line with the assignment as being a Livermore research thing, so [I] stuck to the medical aspect.”

The question: "How do your thoughts come to you?" elicited this reply, "I don't think I could narrow it down to one thing, I mean however it comes, I'm really open." He did not state a preference for any particular way of thinking.

In reply to the science question, "Did you see anything at the Laboratory that you thought was artistic?" Sean affirmed that he did like the shape of the laser target chamber, which is a gigantic shiny silver ball. "I just naturally have an attraction for spheres or circles, ellipses." He then described a “strange thing” at the entrance to the visitor’s center, “a sculpture thing...like a little geodesic dome but not as intricate, I don’t know what it was.”

Sean’s notes from the trip to the Laboratory are comprised of both sketches and written words, his very first note, below the heading LAB VISIT is a sketch of a geodesic spheroid, shaded and cross-hatched, and the page across from it contains two additional detailed attempts to sketch this visual stimulus (See Figure 1., above).

The cover for his book on Dwarfism is also composed in the shape of an ellipse. It is a striking painting of a mask-like face with a fetus subtly indicated in lighter tones where the brain would be.

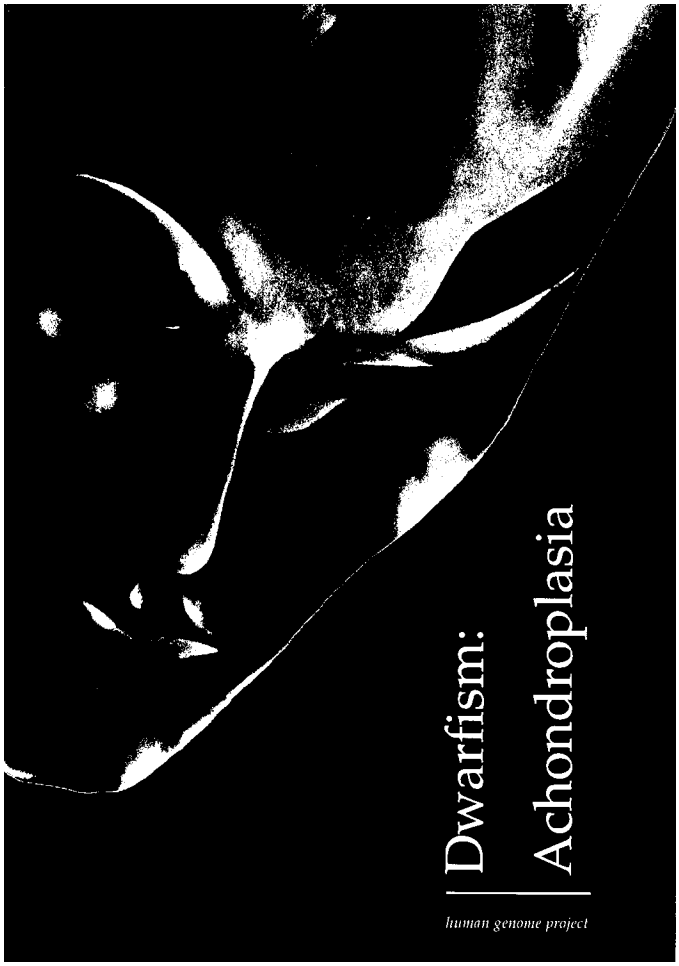

Figure 2. Cover of Sean's book showing ellipse-shaped face.

Sean told us this cover of his book on dwarfism was not painted for the project, but existed before taking the class:

> "Actually, it was a painting I had before, and I just did for a visual aspect that I wanted to get out. But I seemed to think that it applied because there was this fetus here, which related to the logo as the Human Genome Project, with the fetus inside the egg. And this kind of paved the way as far as the color palette, for the rest [of the book] as far as the blue and orange, and the black, so I just extracted that and carried it through and you can see, [blue], orange, and black."

The illustrations in Sean's book on dwarfism bear out his statement that he has "an attraction for spheres, circles and ellipses." It is filled with

these shapes. The mask/face on the cover is generally spherical, but the dedication page has a black and white image of an elliptical fetus within an elliptical egg.

Figure 3. Human Genome Project, fetus curled within an egg/ellipse.

This fetal image also resembles the stylized letter "G" and is labeled "human Genome project." Sean has designed a logo for this particular part of the facility.

Sean's drawings of the various kinds of dwarfism; achondroplasia, SED, and Diastrophic Dysplasia, are all composed of ellipses and spheres, representing developing fetuses with arm and leg buds, and very spherical heads (Figure 4).

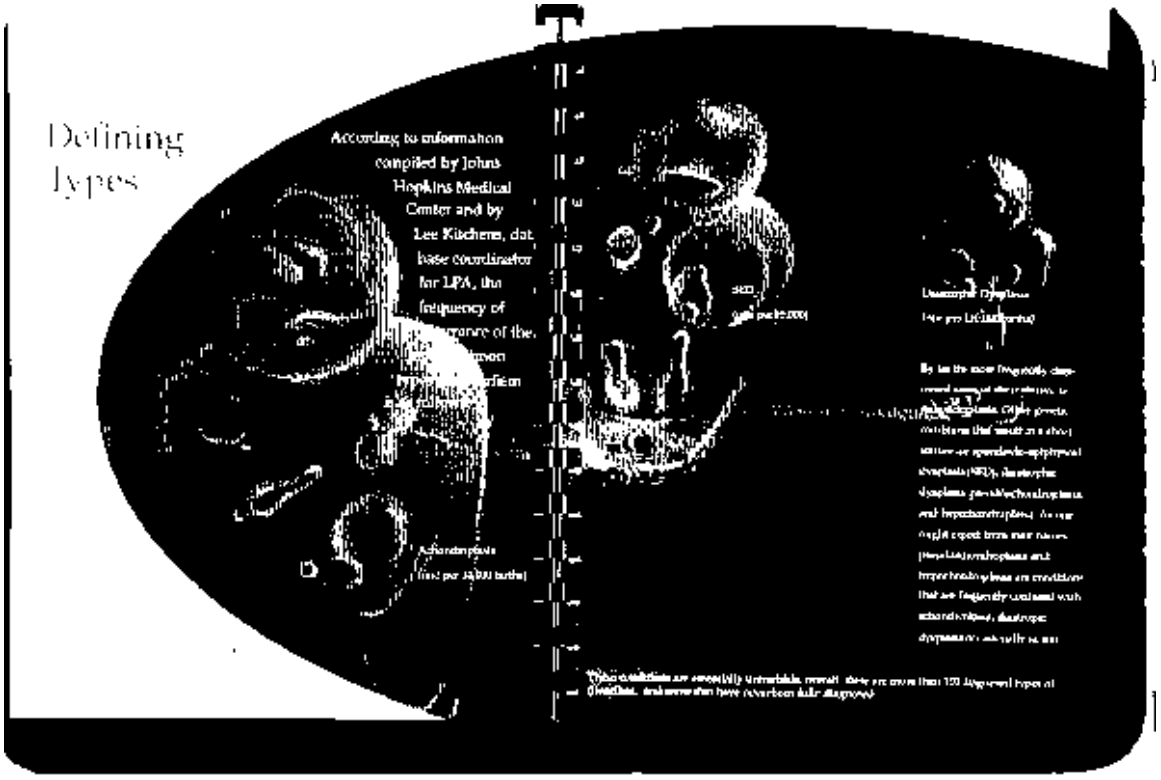

Figure 4. Illustration using ellipses and spheres.

Other illustrations utilize the sphere as a frame for the physical attributes of dwarfism. An illustration of DNA is composed of larger and smaller spheres, giving an over-all look of soap bubbles. The pie-graphs depicting the chances of inheritance are ellipses. Virtually every page of his book evidences Sean's attraction for spheres or circles.

The illustration for the medical process of limb lengthening (Figure 5) is a figure composed entirely of ellipses and spheres, with a metal wood screw appearing through the biceps of the spherical figure drawn with the proportions of a dwarf.

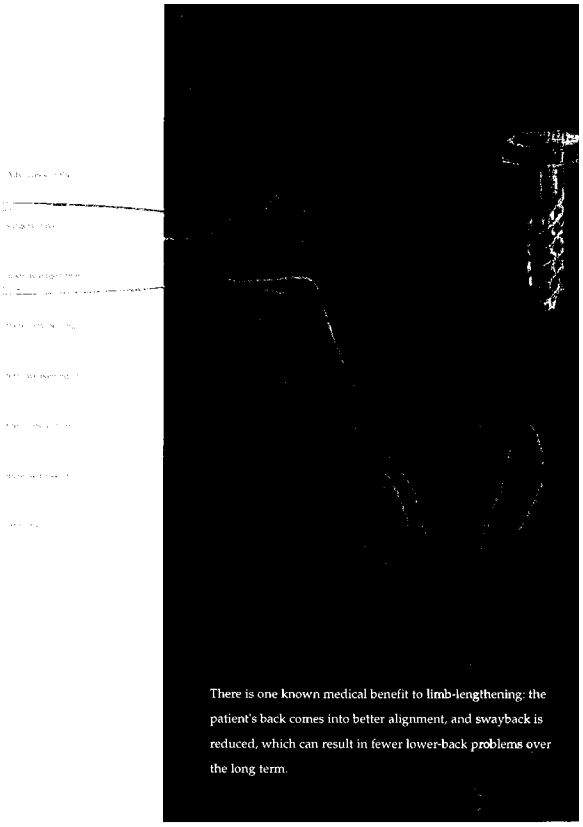

Figure 5. Illustration of the process of limb lengthening.

Sean's drawing, illustrating his artistic concept of limb lengthening, and depicting a wood screw piercing the arm of the human body is an effective juxtaposition of elements: organic and mechanical, or human and medical / scientific.

Sean's over-all creative process seemed not to follow Wallas' schema of creativity (Rothenberg and Hausman, 1976); or Getzel's, (Edwards, 1986); or even the traditional one described in Csikszentmihalyi (1996); but to draw something from each of them.

Wallas	Preparation	Incubation	Illuminatio n	Verificatio n	
Getzels	First Insight	Saturation	Incubation	"Aha!"	Verificatio n
Traditional	Preparatio n	Incubation	Insight	Evaluation	Elaboration

Unless one considers the preparation step so broadly as to incorporate works of art executed before the beginning of the project, Sean's pre-project book cover, the painting of the face with the fetus-as-brain, cannot be placed within an existing framework of creativity.

When he combined his first insight, experienced at the Laboratory, with a work of art he had already created, Sean became the architect of a step in the creative scaffolding that could only be called "pre-preparation."

The class assignment, to create “A Visual Synergy of Science,” easily correlates with Wallas’ (and Csikszentmihalyi’s) first stage, preparation. The week between the class assignment and the trip to the Laboratory could be assigned to the incubation phase. The words spoken at the lab, “dwarf gene” are the illumination or “Aha!” step, and the evaluation stage could probably include the incorporation of the pre-existing painting used as the cover of the book. The choice of paper, the drawing of illustrations, the graphs, type, and selection of text are all part of the elaboration stage.

But the links of Sean’s creative process did not connect as smoothly as the above rationalization indicates. With his book on dwarfism about half finished, Sean hesitated, abandoned it and turned to the safe and traditional design solution: the Logo or Corporate ID. He pursued this possibility only briefly; long enough to realize that he was actually closer to a solution with the book on dwarfism, and that the logo solution would take too long to complete. Thus his re-evaluation was combined with a simultaneous elaboration of his Logo design. The process of creativity that Sean’s project took was not linear, nor did it strictly fall into the traditional creative steps. These deviations from the expected process will be discussed at length at the conclusion of this paper.

The researchers were also interested in the design students’ attitude and experience with science before and after their “Livermore experience” as their instructor referred to the project. Sean, in response to questions about his attitude toward science before the project began, said,

> “It seemed very different from everything else. It seemed like a completely different world. . . I did like the math, figuring out puzzles and stuff, but it just seemed so repetitive. The same thing.”

This quality of science seeming to art students to be remote from not just their interests, but from their lives, was mentioned by two of the five participants.

When asked why he had volunteered to be a part of the study, Sean answered, "I'd say half pressured." The researchers asked by whom he'd felt pressured, and he replied that he felt the pressure came from his instructor and from the class too; although, as he acknowledged, he was told that he could withdraw from the study at any time. He also acknowledged, "I usually try to help people, I guess."

Sean had volunteered for the creativity project to help his instructor, and perhaps the researchers. His creative process was clouded by his concern about remaining objective and being careful not to offend. His creative product had been an effort to educate the public about dwarfism, as his title page clearly states, “This book is dedicated to the education of dwarfism." Education was Sean’s intention.

DENNIS

Dennis' creative product was a book entitled The rebirth of the lab. The first page of the book explains the student's intentions:

> "This is a book of ideas about relating Lawrence Livermore National Laboratory to the mandala. It is full of quotations, ideas, solutions, and connections. I have assembled all of my knowledge gained through this project and applied it to help make Lawrence Livermore National Laboratory a more humanistic place. Instead of creating a logo for the lab, I have created an image to unify the lab, the mandala...The mandala is based on the circle, everything in the universe goes in cycles. Therefore this book is meant to be fanned out into a circle. The pages of this book can be read in any order, all the information interrelates and creates one big circle.
>
> "My original idea was to use the mandala to organize the lab in a visual manner. As I progressed it went much deeper than that, it became a way to make the lab more unified, the mandala could quite possibly give the lab a soul."

Dennis' book is over one hundred pages long, and constructed of pages connected by a single grommet in the upper left corner. This construction allows the pages can out around the grommet, forming a mandala (see Figure 6). The pages contain quotations from eminent scientists, psychologists, and philosophers; reproductions of mandalas; patterns for mandalas; a mandala purchased during the project from a street artist in Pasadena; site plans; and an aerial view of the Laboratory overlaid with Dennis' design for the installation of information kiosks.

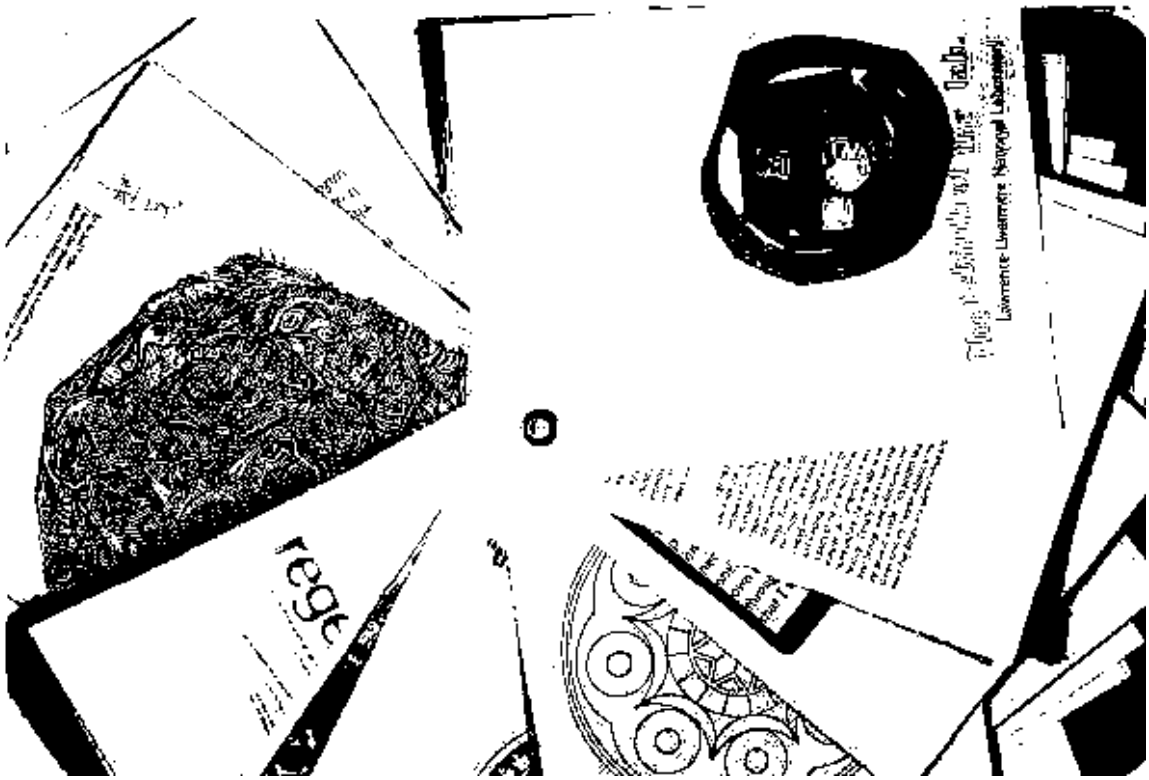

Figure 6. Dennis' book fanned out into the shape of a mandala.

As a part of his project, Dennis designed information kiosks, in the shape of mandalas, to be placed around the grounds of the Lab. These hubs of information were intended to bring together the different departments at the Laboratory and the public. The scientists, staff, and public were to share these meeting places designed with walkways and benches, provided within circular flower gardens, and covered with a translucent fabric (see Figure 7).

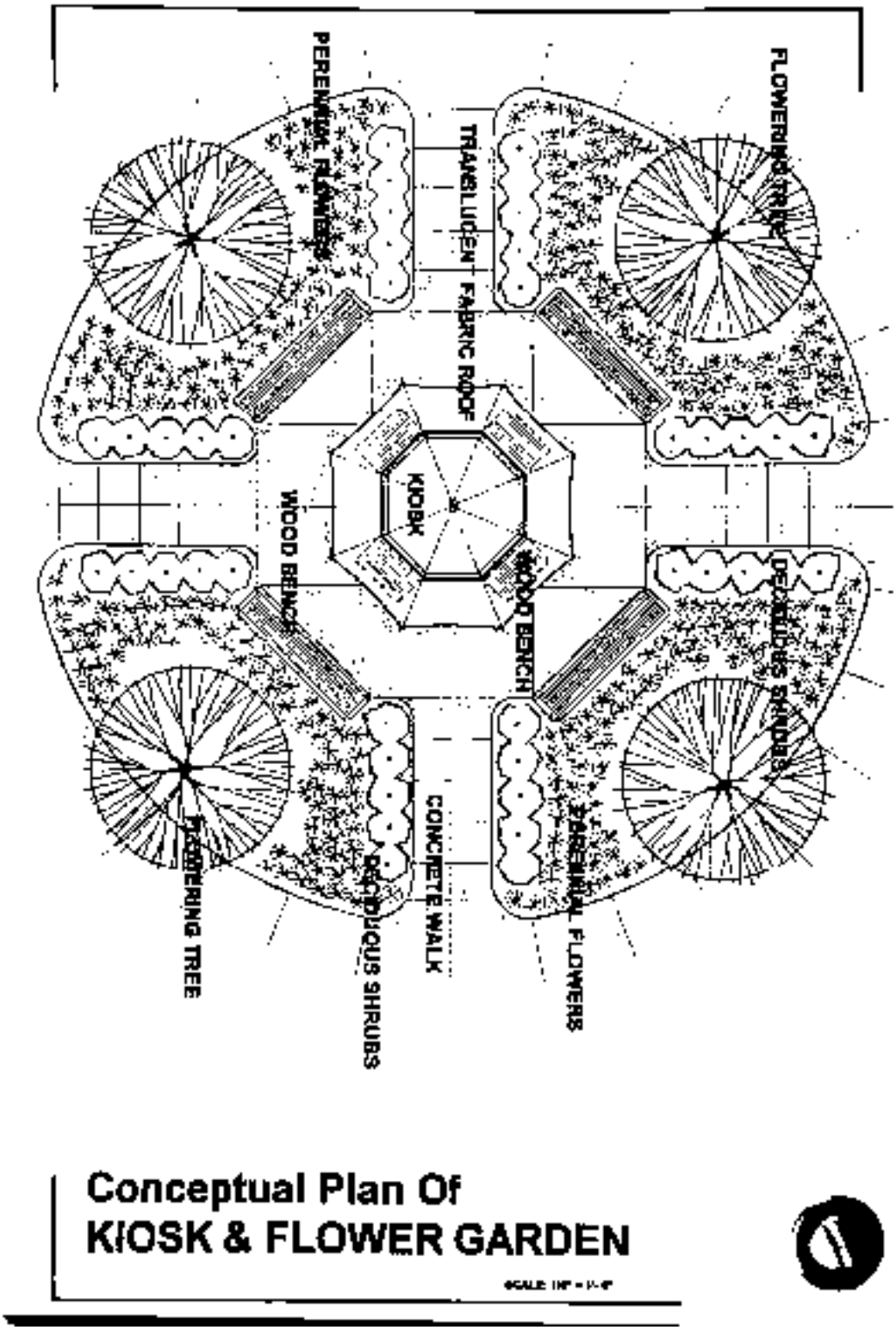

Figure 7. Conceptual plan of information kiosk and flower garden

When asked where the first bit of the idea for his project came from, Dennis replied that he had learned about the mandala in a previous class, and knew it to be a non-linear way to form a story, and "it just came back into my head as I was doing this" and, "I went with it," but "I didn't know what form the final piece was going to take." The project "evolved" into the book. The actual mandala shape of the book came about when Dennis was searching for a way to compile the visual research paper he had done.

Dennis told us he thought his concept for mandala-shaped kiosks, which would serve as meeting places for the different departments and the public, was sparked by seeing an aerial photograph of the Laboratory in the Art Center library.

Research for his project was begun by reading books on mandalas, which he found in the college book store. These books, in turn, led him to research Buckminster Fuller and Jung, both of whom wrote about mandalas.

> "[Jung] used mandalas a lot and was using them in psychology. They mentioned him in the mandala book, so I read a little of his book and got a couple of things. It was just the whole [project] thing created a big circle, which is what it was all about."

The books on mandalas, and on Jung and Buckminster Fuller, rewarded him with a great many notes and quotes, and in an effort to organize these he came to utilize the very shape of the process he was researching. Dennis seemed to trust the process of creativity, and allow his project to evolve as it would. The "circularity" of the process he mentions above seemed to justify his trust. Many of the quotations Dennis used came from Jung and Buckminster Fuller. One of the pages in the book follows:

> Jung circle and square
> the circle symbolizes essentially the process of nature or the cosmos as a whole
> while the square refers to the universe as conceived and projected by man
> circle = subconscious and superconscious aspects of nature
> square = conscious rational aspects
>
> integration of both represents a holistic world view
>
> lab has lots of squares needs the other organic circular part

When asked if the project evolved in his mind while he drew, Dennis answered that he really didn't draw that much, but the concept evolved as he "wrote words down." His notes confirm this statement. His four pages of notes are nearly devoid of drawings, with the exception of two stars radiating what looks to be light, and three ovals on one page of written notes. "Change" as a concept seems to run throughout his four pages of notes,

> "FUTURE IS UNKNOWN. CHANGE. NOBODY knows what the lab is going to do in the ...CONSTANTLY CHANGING EMPHASIS. (SOUNDS LIKE) LLNL IS TOO DIVERSE TO BE LABELED.- JUST LIKE PEOPLE. . . Process based, see what happens."

While considering a medium in which to work, Dennis acknowledged to us he wasn't very interested in "sitting in front of a computer all day," because he likes to work with his hands:

> "I like the old cut and paste, have fun and see what happens, [the] chance method. How the whole book came about was just chance. I don't really know how it comes into my head, it just does."

When he was asked where and when his creative ideas come to him, he told us "It's usually in the most random place. . . In the shower, at breakfast or before class. [At] Lunch. It magically happens."

How much time he had put into his project was hard for Dennis to gauge. He said it was difficult to estimate because the idea of the project would come to him, "When I wasn't really thinking of it. I would just think of it randomly at times, and its hard to add up those minutes and figure up the time."

He denied being emotionally involved with his project, he said he was really "interested" in it, but seemed cautious about any emotional involvement. He explained to the researchers:

> "I think the whole thing about being a designer is you try not to become too emotionally involved with your work. You try to be as subjective [sic] as you can because people are going to talk about it and you go to class and try to look at it with an objective view. . . If you get too attached to it and someone says something bad about it--or critical, not bad--and you take offense to it. You try not to get emotionally attached."

Dennis' experiences with the creation of his project do not fit perfectly within the given framework. His trip to the Laboratory, writing down words, and researching in the Art Center library are obviously Wallas', and the traditional stage of preparation. In his case, incubation and preparation seem to be simultaneous. He researched the mandala, compiled a stack of notes, and needed some way to organize them. One illumination step can be assigned to the moment when Dennis saw the aerial photograph of the Laboratory and visualized the information kiosks designed in the shape of mandalas, placed around the grounds of the Lab.

But he seemed adamant about the project having "evolved," rather than appearing in the traditional insight, "Aha!" step. During his evaluation stage, he eliminated some twenty pages. About this reduction he said, "I could have gone on forever, but finally just had to stop." Again, elaboration

could be the finished project or product: the book on mandalas, in the shape of a circle.

In his responses to the science education questions, Dennis made it clear that in high school and college, he'd had an attitude about science: "I've had a bad attitude about it, I've never really liked it." When asked if he referred to chemistry or science, he replied:

> "All of them. I never really felt a close connection with any of my teachers. I don't know if it was that or the fact that I wasn't interested in it. It was just confusing, all those formulas and equations, and I just wasn't interested. I didn't like it. I didn't see the connection it had with anything I was interested in."

Dennis allowed that his attitude toward science changed after taking the "Visual Synergy of Science" class at the Art Center, he stated, "I found a portion of science I was interested in." When the interviewer asked what portion he had found, he stated:

> "Kind of the more spiritual, mystic, like Jung and mandalas and Buckminster Fuller...I'm sure there would be people who would say that this isn't science because it's not as solid as equations, and lasers, and labs. It's a little bit more what I like. But it made me realize that there is a connection between it. [Science and art]"

When asked to describe what he had learned about science as a result of the class Dennis seemed happy to realize that science wasn't all formulæ and equations, but as he had written in his very first notes about the Laboratory, "It seems like a lot of the things the lab discovered are discovered by chance. . . they randomly discover. It's exactly pretty much the same way I came up with the book." The process of discovery at the Laboratory is the same as it is in life and art: random.

Mathematics was not Dennis' strong suit in school, as he readily acknowledged, "I didn't really enjoy it that much." When asked what he thought of geometry, he replied,

> "I think out of all the math, that was the most interesting, [be]cause it was about shapes. It had a visual to go along with the words so you could see it."

Dennis told us he had assisted in a geometry class at a local high school during the previous quarter as part of a work-study program through the Art Center:

> "They're doing a program with Art Center, in math. It's basically a geometry class where they're doing a lot of what Escher did. . . a whole math program for the people that are like us, visual people

that don't get it. And it kind of keeps them stimulated, in that they kind of combine art and math, and maybe a little of science."

Dennis said that Art Center was attempting to show the high school students that art is a viable profession. The high school is offering a math program for visual students who are having problems relating to the usual verbal/symbolic math teaching methods. Students are taught mathematics in a way that corresponds to their learning strengths and preferences. And, not least in importance, these high school students can observe that Dennis is actively pursuing his vocation of graphic design at the Art Center College of Design. Art, therefore, becomes an option:

"These kids want to do art, and their parents aren't encouraging. They [the kids] see us, that we're doing these things [art/graphics] and they know, 'I can do this if I want.' It's an option."

Dennis used a metaphor to describe how he was able to correlate the Laboratory with the mandala. The making of a mandala is done more for the process of creation than to make or preserve a material object. After the mandala has served its purpose, it is destroyed.

"There is a mandala being built in Pasadena right now. It's in the big Asian museum. They've been building it for a long time and the Dalai Lama is supposed to come, and I don't know what they do, they bless it or something like that. And he looks at it, and they're [the mandala is] destroyed. . . You don't have to destroy it but it's a symbolic process that you go through, and then it's reborn, or you're reborn."

"And how did that relate to the Laboratory?" asked the science half of the research team.

"The fact that of the '70's and that were [the years of] its prime. And it did really well and then it has a really negative image attachment that the image of the lab wanted to be improved, and I thought, 'The lab has gone through these processes that the mandala has gone through, that goes through, each time it's built.' It's kind of like a person. It's gone through good times, bad times, and what not, and maybe it was destroyed and maybe it's going to be reborn and have new interests."

Curiosity concerning his newly discovered science-art connection and a personal interest in the creativity process were part of the reason Dennis volunteered, but he also had an important additional reason for participating in our study about how art students conceive of science:

"Maybe this would benefit the kids that are in school now and having problems with science. It needs to be changed. It's ridiculous. And the fact that the first programs to be cut are always the art programs, which are the best ones. I don't understand that. That's important."

Dennis, like Sean, produced a project that focuses on circles, but in a different way. Sean had used circles and ellipses as an organizing element in his book about dwarfism. Dennis chose the circle as the very subject of his research. He mentions the circularity of his project, and his metaphor of the Laboratory and the mandala focuses on the circle of life: the cycle of birth, death and rebirth.

HENRICH AND ERIK

Henrich and Erik worked on their project as a team. They produced two products, a book entitled, planet livermore one: a quarterly publication of the ethical consultant department at lawrence livermore national laboratories, and a multimedia computer program about the Laboratory, entitled, livermore two.

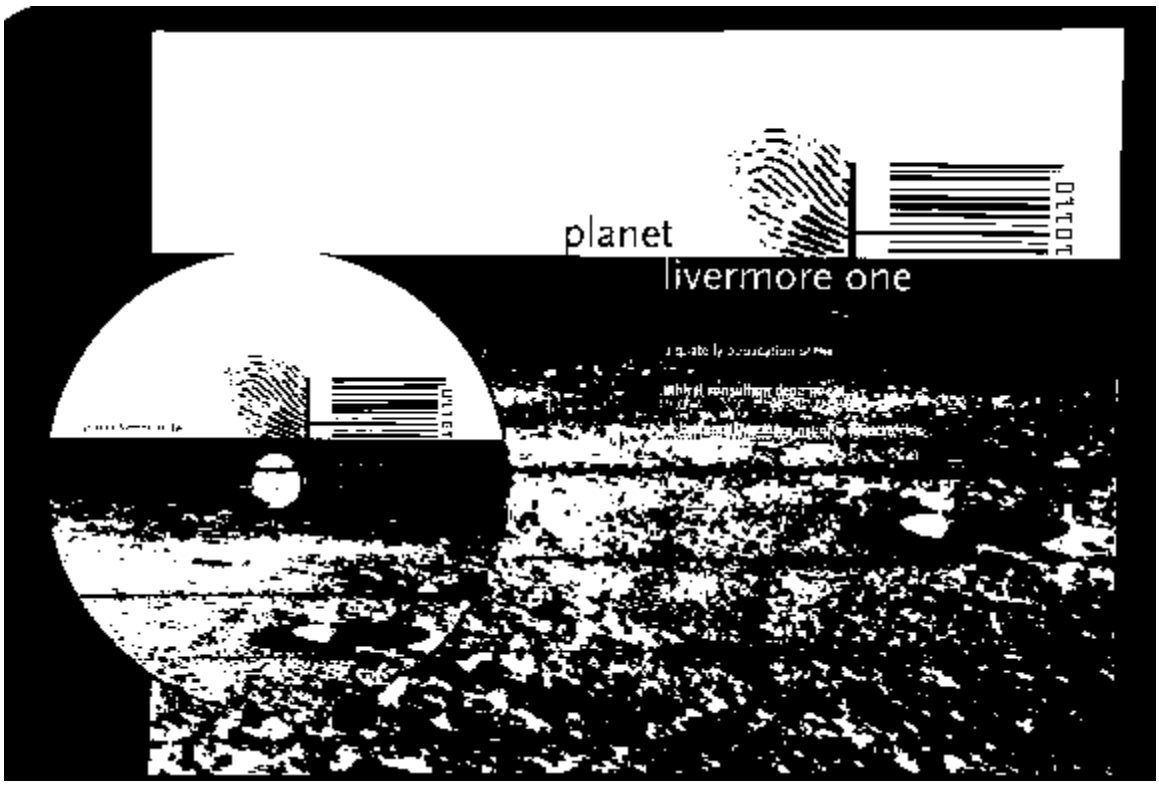

Figure 8. Cover for planet livermore one and the livermore two CD.

The student team was interviewed together. In reply to the question concerning where the germ, the first bit of the idea for the project came from, both students agreed it was an over-all synthesis, and did not occur as an "Aha!" "It was everything, together, I think. It was the whole trip there and back, and what my mind made overnight of it," was Henrich's reply. Erik said that he'd had "kind of an idea" coming out of the Nova Laser building, but, "It was the whole sequence of the tour, and the whole impression of the Lab that kind of made me think of the human and science side[s] of this whole thing."

When asked if the book and the multimedia production were separate ideas, Henrich answered, "I think they were just one idea in the beginning. . . Then we said, `OK, let's separate text from images.'" And the text became the book, and the multimedia became the images.

Erik answered in the affirmative to the question concerning whether the project evolved for them as they drew. He mentioned that he had drawn a mind map about the subject of science on his return from the tour of the Laboratory, before beginning the project (see Figure 9).

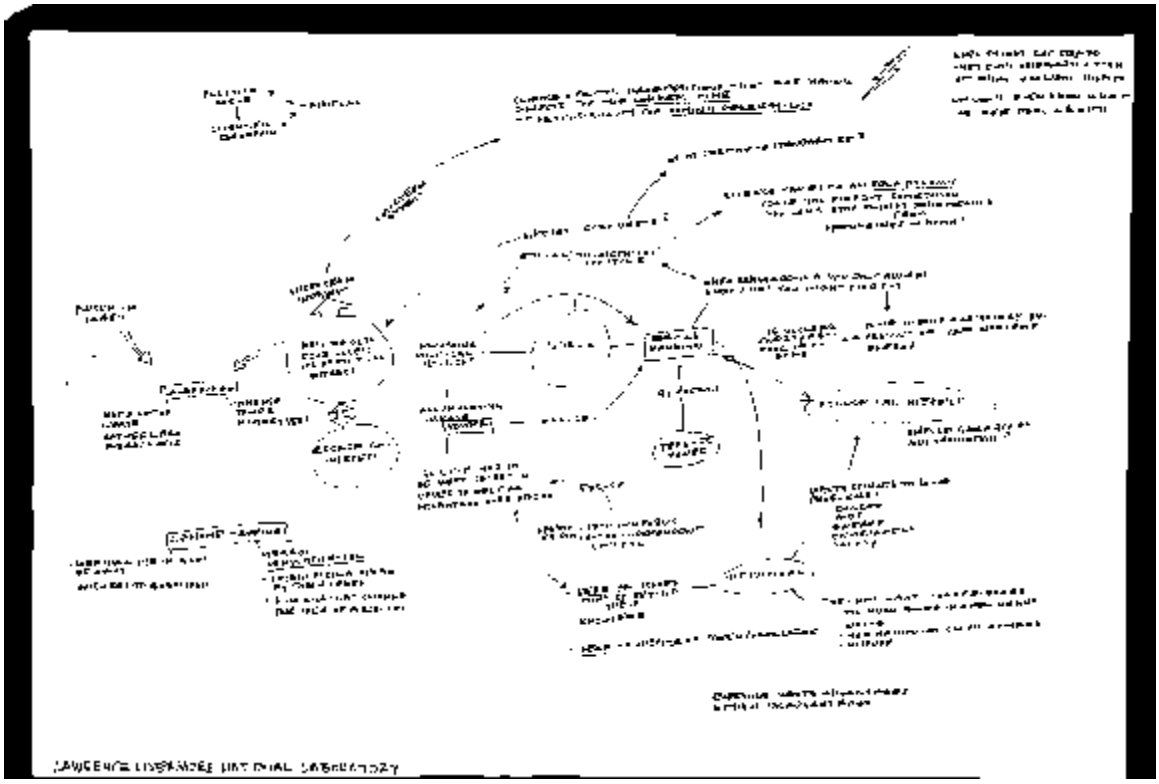

Figure 9. Erik's mind map.

Erik said of his mind map, "I think I got a lot of thinking out of that and a lot of direction in which I wanted to go with this thing."

When asked whether the physical act of drawing helped the concept for the project to evolve, Henrich admitted to beginning his project with

drawing, but seemed to want to make it clear that he didn't know what his product was going to look like until the very end. Part of the creative process, for him, was to “keep my things open to the last minute, until they're finished.” He was very interested in the element of “randomness or accidents of some sort, which also get into the project.”

The question about where and when creative ideas presented themselves got a very specific location from Erik, "Actually, I got a pretty good thought on the toilet, while we were working." Both students agreed that creative ideas came to them when they were not consciously trying to find solutions. Erik was aware that a specific time for him was when he was in bed, "I'm half conscious and half unconscious, and a lot of stuff just forms in that period of time."

Henrich gave this suggestion, "You really have to think of something completely else. All of a sudden if you think once again over the same thing, there's the idea." He also specified that creative thinking doesn't happen when he is under stress.

The team said their research for the project was basically reading. They went to the library and scanned through “lots of books” and took some of them out. One critical piece of the project was from “Wired” magazine; an article about computer viruses. Both team members had read the article prior to the class, “years ago.” They recalled that it could be a good text for their project, and were able to find it in the Art Center library. They incorporated the thesis of the article, that computer viruses lie somewhere between protoplasm and mechanical electronic impulses (organismic and mechanistic) on the evolutionary ladder.

To the question, "What shape or form did the development of the project take?" Both students considered the decision to work as a team to be a crucial part of the development of the project. Erik spoke for them both when he said:

> “At first I thought it [the project] was going to be a little bit boring. Then I kind of saw the possibilities, and also working with Henrich, I think it went really further than I had thought it would. And I think that [teaming up] made it a lot more fun and a lot more exciting than I thought it would [be].”

When asked how long their project took them, Erik replied, "Wednesday night for six or seven hours, for 14 weeks." and his partner added, "I’d say about five [hours] on the side. That would be 12 [hours] a week times 14." [Times two participants.]

Emotional involvement with the project was affirmed by Henrich who said that he did "like" the project, partly because they had produced it together. He continued by saying, “The project itself was really interesting, so I have a good feeling about it that way, and I would like to do something like this again."

Erik's reply to the emotional involvement question, was that it was personal:

> "I think it came out as a very personal piece in a way. Something that's taken out so far that the only people that really understand it are just the two of us, so I think it's a really close kind of project."

When asked how their thoughts came to them, the student team was able to accurately describe a very individual experience, metacognition. The interviewer's words were, "How do your thoughts come to you? In words, in pictures, colors, forms, music, shapes, or in some other way? To which Henrich replied,

> "All of the above I guess. First I get an idea about what I want to do, what I would say is verbal, verbalized by 'OK, I'm going to do now a book.' And that gives me the recognition of letters and so on. And then I have a visual image of something--what it's going to look like--but then I think I have to force myself to go back to what the concept is about; back to a verbal thing, and from there on it's kind of a back and forth, I would say."

This back and forth process of creative thinking is not unusual. The schematic of creative thinking is linear but the actual mental process is not. Erik believed his thoughts came to him in images, but not easily recognizable photographic pictures. He also hinted at another part of the creative process, feelings. His reply to the question, "How do your thoughts come to you?" was:

> "I don't know, I think it's images. It's something visual, but it's very blurry in the start, I can't really. . .I kind of know what the feel should be like, but I don't really see it. But it's not a word either, it's a, I don't know"

When prompted by the interviewer to explain what he meant by his use of the word "feel," Erik continued:

> "A thing [project] should say something, or make me feel in a certain way. And I kind of know what that feeling should be, and sometimes there is like a more or less clear image there too. But that image gets better and better as I go along, I just try out what I thought it should look like"

This particular experience felt by Erik may be analogous to the "tension" spoken of by creative people. The resolution of this conflict,

sometimes felt as a tension, is a sense of satisfaction felt by the creator. (Csikszentmihalyi, 1996; Gruber, 1989; Shaw, 1989).

An important stimulus to his creative thinking was Henrich's reaction to the warning signs he saw on the tour of the Laboratory. He began by sketching what he thought was to be a logo, but the concept very quickly developed beyond that. He explained some of his sketches of proposed signs, "I was really impressed by all the warning signs you see at Livermore. And so I was thinking why these warning signs which have to be like this: inhuman." The signs about which Henrich spoke were schematic: symbols used to represent people, but in a visual shorthand, a symbolic representation. Mankind reduced to symbols (see Figure 10).

Figure 10. This yield sign containing a human figure illustrates a quote by Isaac Asimov. The figure is superimposed over DNA banding.

During the trip to the Laboratory Erik spoke of both partners being very impressed with a contrast between "human" and "science."

> "We both saw a lot, that there's a really strong opposite of this human part, and of the science part. And in the mind of people, that's a really different way of thinking: A human way of thinking, and the scientific way of thinking. There always seem to be those two poles of thinking that are far from each other."

Henrich and Erik attempted to focus their project to address what they saw as a credibility problem stemming from these two "poles" of thinking. They felt that the public, human side, was uninformed about science, and this

lack of knowledge bred distrust. The concept of their project became to enhance public understanding about science in general, and Lawrence Livermore National Laboratory, specifically.

They proposed a new division of the Laboratory to deal with ethical questions, the "Ethical Consultant Department." This department would serve both the scientists and the public by considering ethical problems facing science. The idea was not to change people's thinking, but to start them thinking. Erik seemed balanced in his desire to inform both the public and the scientists themselves.

> "How can you be honest, or how can you tell people something without them thinking, "Oh, they're government, they're a lab, they're not going to tell us the truth." So I thought it would be really good to have a thing [a publication] that talked about science and about the moral things that go on, about the ethical things that go on when you deal with science."

The first page of the booklet talks about the new department, it reads: "No one needs to love their lab, but it would be of much more benefit if everyone understood it." They used quotes in their text by Lewis Wolpert, Hegel, Oppenheimer, William Blake, and Asimov.

A new logo designed by Henrich and Erik for use in the new Ethical Consultant Department publication, represented the combination of a human thumb print and an electronic bar-code, artistically rendered (see Figure 11).

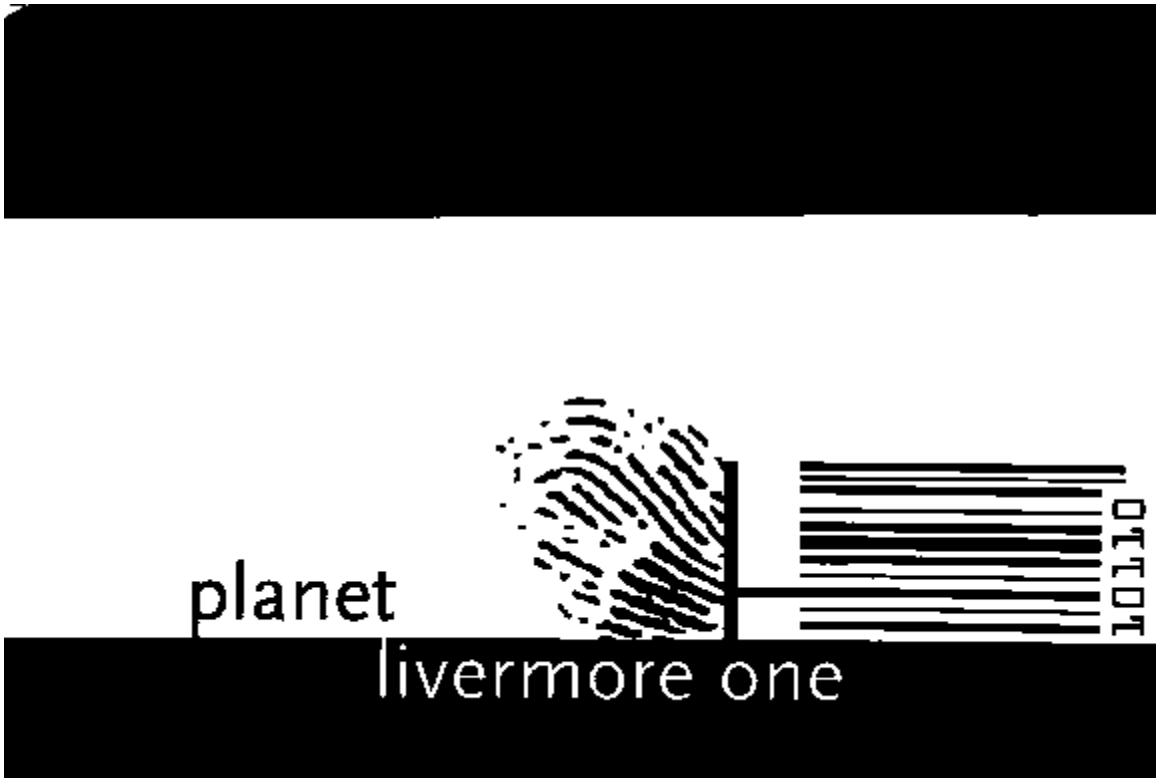

Figure 11. This logo appears on the cover of “planet livermore one.”

Henrich explained how he came up with this concept,

> “I went into the idea of the computerized human or what ever. I mean you have these bar codes all over the place in our modern world of today. Nobody can read it, but it means something.”

Both Henrich and Erik were aware of their creative thinking processes. The traditional creative stage of preparation included their introduction to the class, the trip to the Laboratory, and their initial research. One possible point of illumination, while not the “Aha!” step, was Henrich’s focus on the warning signs he saw at the Laboratory.

It seems that the “Aha!” from their point of view was the decision to work together on the project. The evaluation and elaboration steps for this team were quite rigorous, and required several hundred hours.

Erik and Henrich used metaphors to describe the Laboratory, as Dennis had earlier. Henrich said of the physical layout of the Laboratory, "You could take the science out of there and look at the structure. It has a feel to it. It's like a big piece of art work." Erik elaborated on this idea, "It's kind of an evolving colorful patchwork of different structures." Henrich added, "It's more like a culture, let's say, than like an object. Like a science culture in a way, like a culture, like society."

Both Henrich and Erik expressed personal reasons for volunteering for the study, citing curiosity about creativity. They had, however, in their project, evidenced a deep belief in openness, integrity, honesty, morals and ethics. In fact, truth and honesty were to be the basis of a new and developing trust between the public or the "human side," and the government or the "science side."

Although we cannot turn to Henrich and Erik for suggestions about creative education, because they were both educated in Europe, Henrich described personal knowledge with a computer metaphor:

> "I think I see it as a general data base that you have. And you're dealing with science, and art, but both of these data bases are just a part of your life, your self, and you are somewhere in between. Maybe there's also a third data base, or a fifth, and it can continue with everything that you learn. As long as you have this possibility to go back to this data base, and use it for yourself, adapt it to another one, and shift things in between those, it just helps you."

Using this metaphor for knowledge, it seems that the more extensive and elaborate a person's data base becomes, the better integrated a person would, in turn, become.

RYAN

Ryan's project was a book of images with a rather esoteric text. His book opens from the center. Appearing on the left front cover is a Renaissance drawing by da Vinci; the perfect man. This drawing is da Vinci's effort at providing the canon of perfection of the human form. It is an ideally proportioned, exceedingly elegant, nude male, standing in the middle of a circle: "man as the measure of all things." This image is split down the middle and juxtaposed against a black and red elemental male figure painted on what looks to be a circular ritual drum or shield. This second figure is painted as though clothed in a striped garment and the drum or shield is decorated with black, red, and white feathers.

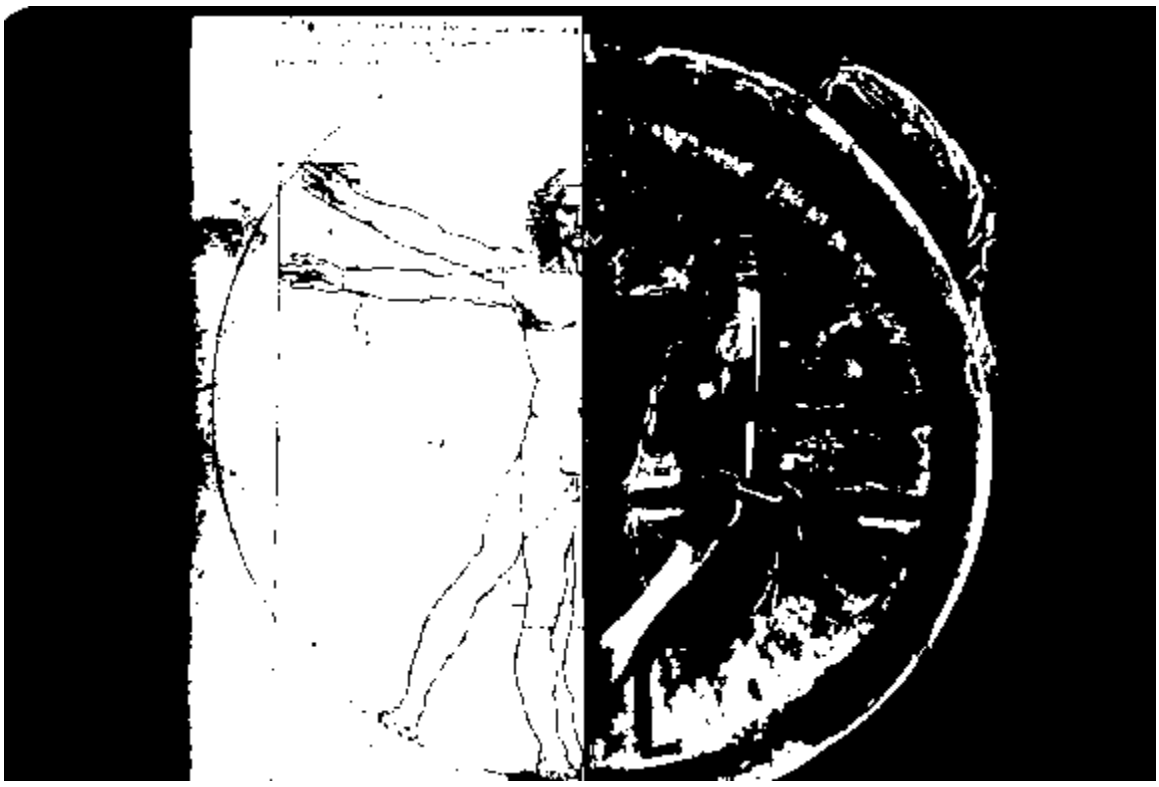

Figure 12. Ryan's book cover.

The book is twice as wide as it is high, approximately 16 inches wide by 8 inches high. When opened, it expands to 32 inches wide. Each of the four images thus displayed is eight inches square.

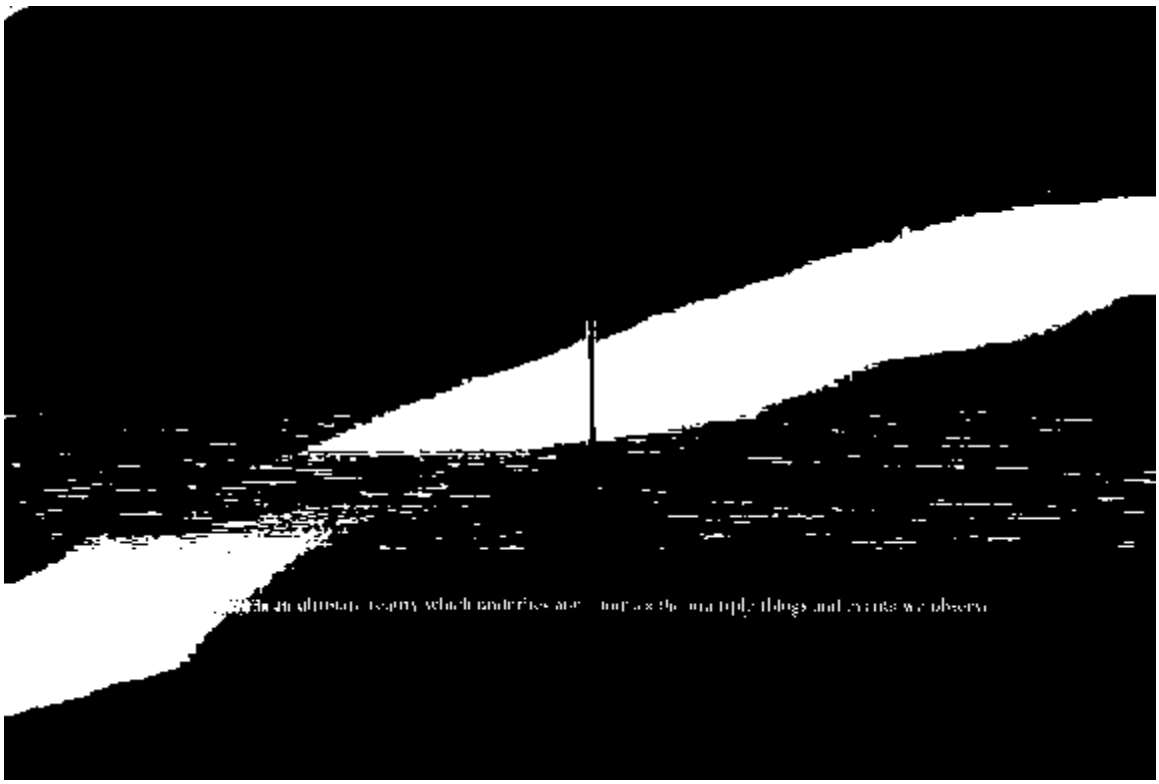

Figure 13. Ryan's book opened to show the center two of four images.

The first image, on the inside cover is quite striking (see Figure 13). The text reads, "There is an ultimate reality which underlies and unifies the multiple things and events we observe." The following four images (figure 14) are all circular in form and consist of, left to right, what looks to be a supernova, a circle of hands holding arms, a photograph of the earth from space, and a fetus with its amniotic sac floating in darkness.

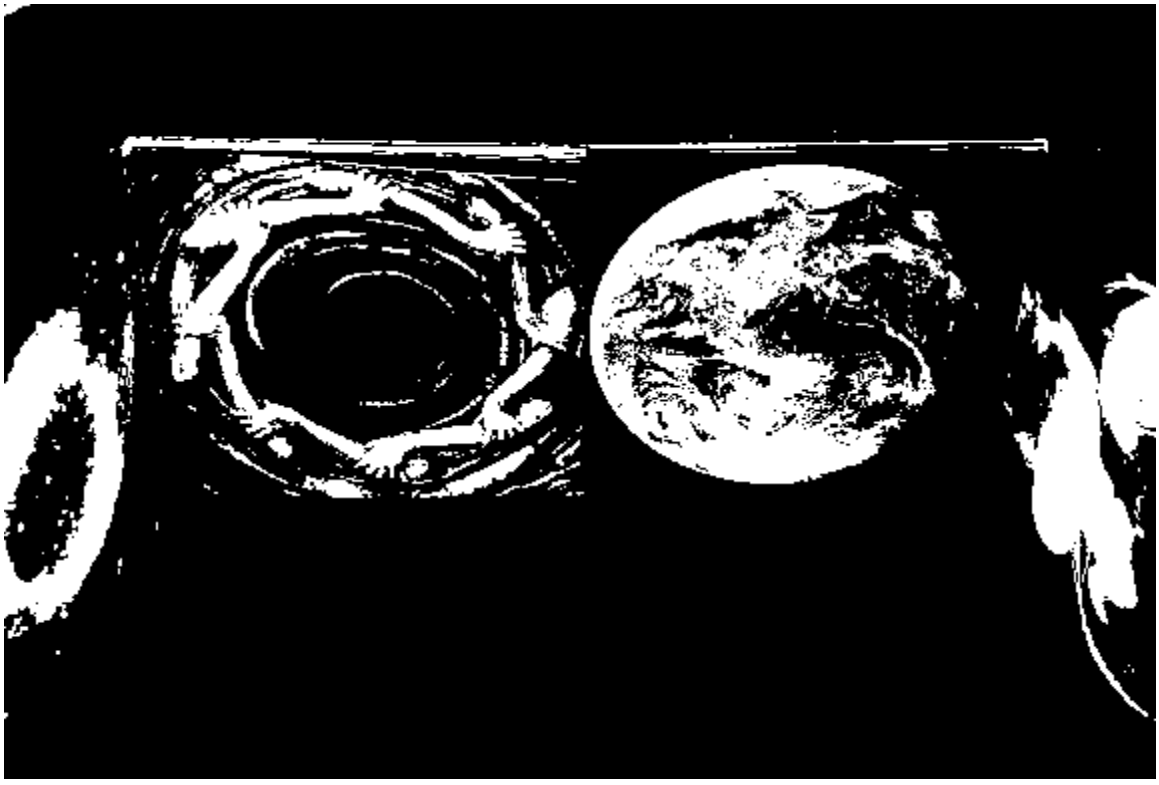

Figure 14. The second page of Ryan's book.

The third page has the Buddha in the far left square, a rose window depicting Christ arisen in the far right square, and this quotation in the middle two squares:

> "It seems most paradoxical to us that experiences and values which we had always believed to be contrary should be, after all, aspects of the same thing.
>
> "We speak about this sense of belonging."

The book continues with images alternating with recondite text, in small subtle print: 14 double openings, 56 pages, 36 images, all of which are circles. A stone carved wheel, a vortex of winged angels, a human ovum besieged by sperm, a mandala. There is no mandatory page to start or to end on, because the text on any given page will correlate with the image on any other page. It is created as a unity. Each image is discrete and perfect within itself and the images combine as the viewer turns the pages. They flow in a continuous visual communion. The viewer is made to feel a part of this flow. All of these images dissolve together to form a synergy.

The motivation for Ryan's visual synergy of science seemed to derive from his bias against the project. Ryan explained that he had been biased about the Laboratory project from the beginning of the class, actually even

before the class started. He said that the tour of the Laboratory made him ask himself, “Are they just giving me a PR rap?

Although Ryan explained to us the job of the Art Center was to provide a "visual appearance" for the corporate world, he seemed suspicious that the Laboratory was seeking a new logo, and deduced that there was an undisclosed agenda on the part of the Laboratory concerning their history of involvement in nuclear energy. He said,

> “So this is what went through my mind: "Is Livermore coming to the Art Center to try [an] experiment. . .[to] see if a student Art Center could give them a visual representation that would get people to not react critically to what they've done in the past?”

Ryan seemed vitally concerned about truth, honesty, ecology, the world community, the economy, futurism, nuclear weapons, alternative energy, and the ultimate questions: "Where are we going, and where are we from, and where have we been?" He was focused on eschatology, and seemed to be trying to garner answers to these questions from the present project: A Visual Synergy of Science.

When asked where the first germ of his idea for his project came from, Ryan mentioned talking with one of the scientists at the Laboratory about nuclear testing, which seemed counter productive to him, since we were about to be one world, “one gigantic culture a couple of generations down. If that happens, then what’s the point of having nuclear weapons? I don’t know. So that’s kind of how the book started.” His book is designed to visually represent his one-world concept of the present and the future.

Ryan’s book represents his “mission” as he phrased it, which is to hit his audience over the head with images, and get them to really see. He wants his reader and viewer to “Get it!” Ryan’s project presents what he calls his “opinions” visually.

To the question, "Did your project evolve in your mind as you drew?" Ryan answered in the affirmative, and added,

> "...but it's not like writing a paper, it's totally abstract. If I were to build or draw what's in my head, it would be like a galaxy. All you'd see are just stars everywhere. . . .Drawing is just that one part that helps you make sense."

Ryan’s notes, in contrast to Dennis’ written ones, contain very little text. They are all drawings, moving from one sketch to the other with occasional two word notes. They actually look like his description above, of what is “in his head.”

To our inquiry, "How did you research your original idea, what kind of research did you do? He replied that his research began with him asking himself rhetorical questions. Then he answered with a physical location: "I went to India, I guess. I wish I could of gone there physically but I went to the

book store literally." He began his research by reading about religion, which gave him answers, but perhaps not all the answers he was seeking,

> "So I started reading a lot about Hindu religion, and Zen Buddhism, and Zen and I guess I was probing for answers, but the only answers that they gave me were that you have them all inside you. So, OK, I guess that's what's going to have to go into my book. Perhaps in the future I will come up with other answers, but I haven't. [Pause] Maybe I have."

When one of us commented to Ryan, "I'm not sure what led you to a religious answer to the questions you were asking regarding the science?" Ryan answered in an almost anguished tone,

> "Who else am I to look to? The scientists don't know--they're trying to find out--but these guys [Tibetan mystics, Zen Buddhists] have known forever. They just aren't into doing it mathematically, they're into doing it more intuitively."

As part of his research Ryan went to a Zen temple and to a friend's house, where he participated in a Hindu ceremony containing singing, chanting and drum beating.

His method for discovering the appropriate images for his project was to ask himself more questions. Ryan desired that the viewer of his project learn something from it. He wanted the viewer to be inspired to ask themselves the ultimate questions: "Who are we? Where have we been? Where are we going? All that kind of thing."

Requesting an estimate of the time Ryan had spent on his project received a very direct answer, "24 hours a day." He further elaborated on his answer, which anticipated the question to follow:

> "Even though I might not be thinking about it in my head, it's still, the gears are still spinning, the ones underneath the plane of consciousness. 'Cause how else could that be happening? When you wake up in the morning, you've got an idea. You know? Like this morning, it happened. I had to go scrounging around for a pencil--I had to find a pencil quickly--before I forgot it."

The question, "Do a lot of your ideas come to you when you first wake up?" elicited the answer that a lot of ideas appear to him when he first wakes up, and that he wakes up in the middle of his sleep with ideas too. But a lot of his ideas come to him while casually brain storming with friends. They participate in these sessions not for any particular purpose, but because they all enjoy playing with ideas, tossing them about, embellishing them, and seeing who can come up with the most profound idea.

Ryan claimed neutrality when asked if he was emotionally involved with his project in any way. "With the work I did here at school, it's done." Then he asked himself a rhetorical question: "What did you learn?" and answered at length about humanity and compassion, and the future of mankind. World over-population, poverty, and the dissemination of questionable values throughout the world by way of American television, were of great concern to him. He proffered solutions that contained ideas for ecological preservation.

When asked how various thoughts and ideas came to him, he answered by contrasting the way he thinks with the way others in his classes think.

> "One of my friends is very verbal and all of his stuff comes out written, and all of a sudden you can see that in your head when you read his little paragraphs. That's good. That's advertising class--good copy writing. You've got to have it, but this is what I struggle with. Because the majority of people are that type in terms of creativity."

Ryan is not a verbal thinker, but he is surrounded with friends who are verbal thinkers and teachers who also think verbally. He makes his struggle to communicate in his own way--visually--very real:

> "Me? I've realized I'm a visual person, I can do the exact same thing, but with pictures. And in class when I'd show up with pictures, and of course they weren't there all the way, [fully developed] and I'd fail, flat on my face. I had a really hard time because the teacher would always try to get me to solve the problem verbally. I'd be [saying] "I don't know, I'd rather do it this way." And it still happens in class because the teachers [here] don't understand what I'm talking about, 'cause they're verbal also."

Despite being a visual thinker in a verbal world, Ryan knows his visual way of problem solving works, and works very well:

> "But I've realized that when I <u>do</u> finally solve this problem visually, it's like, "Whoa! that's cool!" So I know it works. And there are a couple, at least a handful of people [who think] like me in the school."

Another problem Ryan felt was critical in education was that schools and teachers seem to have a vested interest in following the text book when teaching subjects such as history. He seemed to feel as though he had been disadvantaged, even lied to by his teachers. He wanted the truth, the whole truth about history, not the glossed-over text-book history.

He used Christopher Columbus as an example, "If they'd told me that his main role was to capture all the Indians and make them slaves, I'd have gone, "Whoa! My God! If this is what history is all about, I want to learn!

But no-no-no they make you learn dates, things that are not really that relevant." He felt that memorizing dates wasn't what he wanted to learn. He continued,

> "And there's that saying that they always say, "If you don't know history, you're bound to repeat it." Well, Jesus Christ! We weren't taught it [right] in the first place! If you would have taught history to me [correctly] in the first place, believe me, I'd be a different person. And if schools are even willing to do that I think that children would just be a lot more motivated to go to school and be educated."

Ryan was much concerned about the truth. He wanted the truth taught in school, even ugly truths, and believed his lack of interest in learning had been partly caused by being taught bland untruths.

> "I'd go home and say, 'Mom, this stuff is just bullshit,' and they even understand. Now I go home and say, 'Hey, look at this stuff I'm learning, and how come I didn't learn this [in high school] when I was supposed to?'"

One of us remarked that some of the best scientists in the world have been visual thinkers, Einstein for example, and that many mathematicians were visual too, they did mathematics for the "beauty" and "elegance" of the equations, because they were seeing math visually. Ryan seemed moved by the possibility of visual mathematics:

> "Imagine if there was a teacher like that in my high school that talked about math that way! I'd probably have become a mathematician just because I was exposed to that early in life."

When asked, "What did you understand about the science at the laboratory, in general--generically?" Ryan replied, "That scientists are like me." When asked to elaborate, he was able to cite an example which he had noted on the tour to the Laboratory:

> "One of the scientists came out and was talking about the laser, and he was sitting there explaining. He was answering one of his questions and he was talking and I'm thinking, 'Wow, this guy is a visual guy!' I didn't really probe his mind, but I could just hear by the way he was talking and his hands, what he was seeing in front of him. And again, Wow! 'Cause scientists don't know what they're doing--they're just sort of guessing--just like we are."

One of the final questions was, "Why did you decide to volunteer for this project?" to which Ryan immediately answered, "'Cause I'm going to analyze what you guys come up with and see if you're right or wrong."

Ryan was interested in and curious about a wide range of subjects. He was motivated by truth and honesty. These are two important characteristics of creative people noted by Csikszentmihalyi (1996). Ryan was equally frustrated and angered by what he considered half-truths or untruths, "a PR rap." He used his creative energy in an attempt to counteract these untruths: he chose to educate the people at the Laboratory with his Visual Synergy of Science project.

This student was a visual learner, a visual thinker, and a visual problem solver. He had experienced on-going learning problems in school because his teachers had tried to get him to work his solutions out in a verbal medium, a medium that was alien to his thinking. He remarked that even at the Art Center, the teachers and students were mostly verbal thinkers and learners. He was correct about his ability to create visual solutions to problems. His visual synergy of science was the solution to the problem of representing "big science" in images.

The last page of Ryan's project is four squares across (Figure 15). The far left square has this statement in it:

> "Science and technology could be regarded as interacting approaches to the same reality, namely human experience. As conventional wisdom has it, science asks for the *how* and theology asks for the *why*."

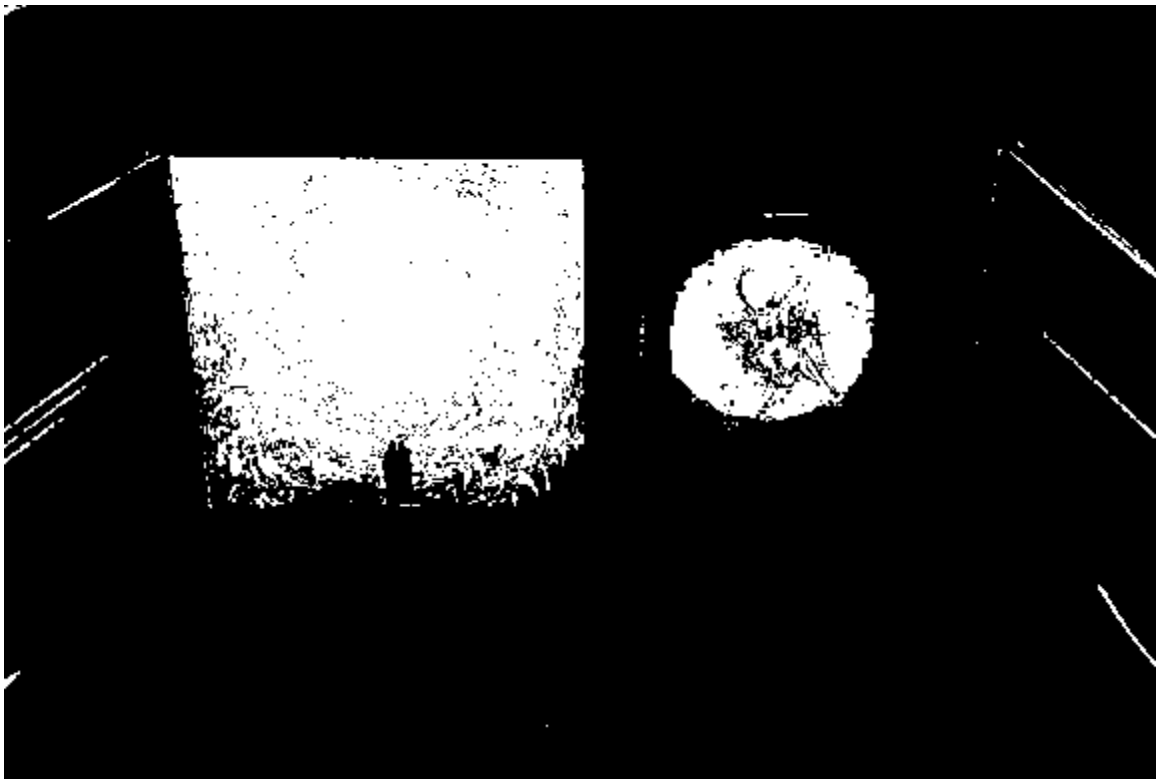

Figure 15. The last page of Ryan's Visual Synergy of Science.

The near left page holds a picture of all white angels arranged in a spiral vortex, getting smaller and smaller toward the center, and finally receding into infinity. There are two figures in silhouette standing in the foreground before them. In the near right square is a poured painting resembling an atom or a universe in action, either being formed, or blowing itself into bits. In the far right square, appears this question:

> "Are *you* interested in intuitive wisdom, rather than in rational knowledge?"

Ryan's preparation stage consisted of the research he conducted about the Laboratory, the trip to the Lab, which "increased" his pre-existing bias, and asking himself questions concerning the meaning of life.

His incubation stage probably coincided with his active search of readings about Hinduism, Zen Buddhism and Zen, attending a Hindu ritual at a friend's house, and visiting the Zen temple. His insight, although not an "Aha!" consisted of the realization that the masters he had been reading revealed that the answers to his questions all existed inside him.

His evaluation stage was once again asking himself questions, and critically; locating the precise images that would induce his reader-viewer to ask of themselves the same ultimate questions, "Who are we? Why are we here? Where are we going?" Elaboration was the actual making of the images, choosing the text, fitting images together, and checking the validity of the project, probably by asking the questions again and determining if his visual synergy answered them. Or, alternatively, carefully examining the images he had chosen, to determine if the synergy of science elicited the ultimate questions from the viewers themselves.

Ryan's creative process, with the exception of his pre-existing bias, differed little from the traditional one. His motivation to create his synergy of science was his spurred on by his bias about the Laboratory. This sense of conflict, that something is not right, starts the creative process, (Csikszentmihalyi, 1996). His intention was to educate the client; in this case, the Laboratory.

Discussion

Four out of the five student participants' creative processes differed from the traditional schema. Sean stopped in the middle of his project and began anew on an entirely different creative product; Dennis denied having experienced an illumination stage, and combined two stages, incubation and preparation; Henrich and Erik also declined to identify an illumination stage, considering the most important part of their process their mutual decision to work together on the project; only Ryan followed what are considered to be the traditional steps of the creative process.

The following themes emerged from the data, although they were provisional for a lengthy period. For the most part, they appeared early in the coding process, and endured, sometimes slightly changed in form, to the end:

1. The spontaneous use of metaphor to describe the Laboratory;
2. A general lack of interest in "school" science and mathematics by the American students;
3. A well developed sense of conscience which manifested itself in:
    A. A search for, and respect of, truth,
    B. Concern for other people;
4. A spiritual leaning as demonstrated by their artistic products, while simultaneously denying any interest in organized religion;
5. Extensive utilization by all three American students of a single element: the circle.

The first theme, the spontaneous use of metaphor, was utilized by three of the five participants to describe the Laboratory. Dennis likened the Laboratory to a person who had gone through good times and bad times, and maybe was about to be reborn. Erik used the words "an evolving colorful patchwork of structures" to describe the Laboratory. And Henrich said it was like a "culture, . . . a science culture." Henrich also later used the computer metaphor to describe personal knowledge, seeing it as different "data bases." Ryan used a metaphor to describe his thinking processes, painting an image of his thinking as analogous to "a galaxy. All you'd see are just stars everywhere." Sean used a physics (or perhaps a surfing) metaphor when asked about his attitude toward science, "I would say [I was] interested in wave form."

A second theme was the general lack of interest in "school" science or mathematics by the American art students--even those who performed well in those subjects. One student specifically said that he did not think in the same way that science courses were taught. Two out of three of the American art students said that they found "school" mathematics and science repetitive and boring. This contrasts sharply with the European students who had much broader scientific backgrounds. They advised embarking upon an immediate dialogue leading to a reciprocal moral and ethical education between scientists and the public. The Europeans felt science and technology were "driving the country," and required our direct and on-going ethical and moral stewardship. They felt, "The people have to understand science better in order to gain more control."

A third theme was the well developed sense of conscience exhibited by the art students. This manifested itself in two interconnecting ways: a belief in the truth, and a concern for others. The students seemed to hold a deeply felt interest in the truth, honesty, ethics, and a need to communicate these qualities to others. Four out of five of the art students spoke spontaneously about truth or honesty. Ryan was the most vociferous, his search for truth and concern for others seemed to be the driving force of his life. Henrich and

Eric based their entire project around a new division of the Laboratory to be entitled, "The Ethical Consultant Department," in an attempt to wed ethics and morals to science. Dennis speaks to us through his mandala book: it represents a unifying, healing, centering element. He joined the study partly in the hope of helping the visual thinking high school students he had worked with in Pasadena. Sean hopes to educate people about dwarfism. He joined the study partly because he likes to help people. This group of creative students is altruistic. Carlozzi, et al., (1995), found a positive relationship between affective sensitivity and creativity.

A fourth theme was a spiritual inclination. Dennis attempted to utilize the mandala to heal and revivify the Laboratory, to give it a soul. Ryan researched his project through wisdom writings, Hindu ritual, and asking himself the ultimate questions. Ryan hopes, with his project, to educate the Laboratory about the unity of all life. All five students demonstrated an altruistic or spiritual bent, while uniformly rejecting organized religion (see below).

A fifth theme was the extensive utilization of the circle in all three American students' projects. Sean's attraction for circles and ellipses manifested itself in his use of this shape on practically every page of his book. Whether his use was a conscious artistic device or a subconscious one does not concern us. Ryan's entire book consists of pictures of circles interspersed very sparsely with text. Dennis' mandala book is circular in shape and contains over 100 pages of pictures and text relating to circles. All three books are designed using both circular and square shapes, and while this may stem partly from the fact that books in general are square or rectangular in form, the inherent symbolism of placing a circle within a square is not, thereby, nullified.

The researchers believe a connection exists between the spiritual inclination exhibited by the art students, and their production of three artistic projects marked by a preponderance of circles and squares. Recall the quote from Dennis' mandala book: "the circle symbolizes the process of nature or the cosmos as a whole, while the square refers to the universe as conceived and projected by man. . . "

In this project we have three students using the same symbolism, circles placed within a square or rectangular format. Ryan's usage is the most arresting. Ryan has placed circles within squares 36 times. The cover of his book is a melding of primitive man and Renaissance man. Circles within squares. He has, indeed, hit us over the head with his message. The squared circle represents wholeness and the union of opposites.

The three students have visually, symbolically, married science to art. We feel that the possibility that these books would be produced by people who were not of a spiritual bent, seems very small. These five students seemed, to the investigators, to express world views much beyond their years.

In finding a theme of the spiritual in our study of creativity, we may have done the subject a disservice. Sternberg and Lubart (1996) believe that the study of creativity has been retarded by the belief that creativity is mystical

in some way, or "more of a spiritual process" (p. 679). While we hope not to have caused further delay in the study of creativity with our findings, it must be said that art has always been connected to the spiritual; as has science: since Plato wrote of Truth, Beauty, and the Ultimate Good, (Wilber, 1996).

The "spiritual inclination" theme (the fourth, listed above) inspired us to investigate this phenomenon further by asking a clarifying question, "How do you view religion?" The following list of answers was a surprise to both researchers.

Dennis:	"i dont view religion at all."
Sean:	"religion is an excuse for not believing in yourself"
Ryan:	"As a sickness of the mind."
Henrich:	"religion never played an important role for me, I would say I belief [sic] in "nature."
Erik:	"I think religion can be very helpful to cope with problems if you believe that you are not totally on your own. I think as human beings we have the need to believe in something. Personally I believe in Jesus Christ an [sic] his ethics. I dont know about the reincarnation thing. I think organized religion can be dangerous. I don't like "the church."

The sub-theme of concern for others was also put directly to the test by asking the participants directly, "Do you have a strong concern for others?" The participants E-mailed back these replies:

Dennis:	"yes"
Sean:	"I have a strong concern for people who are close to me (a very immediate social circle)
Ryan:	"yes"
Henrich:	"Yes, more for people that I really like than for others."
Erik:	"I have a very strong concern for about 7 people. As for the rest mediocer [sic] I guess.

Conclusions

This study has several limitations, which, if we are able to continue the work, or if others can replicate the study, can be mitigated.

First, we would have liked to have had more participants in our study. This study would have been particularly enhanced by the addition of one or more female students. It would also have been enhanced by having students with greater ethnic diversity. Second, due to our distance from the participants, it was not possible to observe them at work or use a long interview process as would be found in an ethnographic study. However, we feel that despite these limitations, we have been able to arrive at the following conclusions.

The student participants were visual learners and visual thinkers, with the exception of Henrich, who was able to think verbally as well as visually. Visual thinking is an important factor contributing to their sensitivity, and perhaps their altruism. Somers, (1978) states that there is an important difference in affective response between those who think visually and those who think verbally. Verbal thinkers are analytical, as opposed to visual thinkers, who are affective. He believes that our educational system, and educators themselves, are hostile to visual thinking, and consider it inferior to verbal thinking.

Eisner (1991) also sees visual thinkers as disadvantaged in our educational curriculum. Visual students, affective thinkers, are taught in an alien (verbal) modality. English is not their first language; pictures are. Their strengths and opportunities to excel in school lie in the very classes that are the first to be deleted when money is the issue, as Dennis pointed out. Gardner (1983) asserts that those who learn in visual, musical, kinesthetic, or affective modes have been neglected in contemporary education. Ryan is a perfect example of a visual/affective thinker who was frustrated by his (verbal/analytical) teacher's efforts to make him think in another mode.

Piechowski (1991) created a model of emotional development which may contribute to early identification of adolescents with the potential for outstanding moral development. He sees fantasy, sensitivity, and altruism as indicators of deep psychological potential. These affective students we have studied are not only creative, they are possibly gifted in moral development. But, many visual thinkers, perhaps the majority, give up on the system and on themselves, and drop out of school before they reach college. West (1991) believes that our educational system may eliminate the very students who are the most talented, especially if the student is a visual thinker.

When Henrich and Erik created their Ethical Consultant Department to act as a platform for discussion between the public and scientists, they presumed an interested, responsible, and informed public, one that would vote on important matters of morals and ethics, and take responsibility for learning about science. In short, they pictured the public as being much like themselves and the other participants in the study: intelligent, informed, curious, visual/affective thinkers with a well developed sense of conscious, and perhaps a spiritual leaning. Are these the students we want to eliminate from the educational process due to our inability to adjust to their learning style?

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Appendix A

E-mail questions: Set I

1. Please describe any science classes you have taken since elementary school. Be as detailed as possible.

2. Please describe what kind of science student you were. We are not looking for grades, just a general description, e.g., good, average, poor, interested, disinterested.

3. Please describe your attitude toward science during this period of time (since elementary school).

4. Please describe any reasons you can think of that may have had an effect on the answers to questions 2 and 3.

5. Based on your answer to question 3 above, was this your attitude when you entered the ACCD class that involved the science at Lawrence Livermore National Laboratory.

6. Has your attitude toward science changed since taking the class? If so, please describe in what ways it has changed? Could it be said that this change in attitude was a result of the class?

7. In a general way, please describe what you learned about science as a result of the class. Please note that this question is about content, not attitude.

E-mail Questions: Set II

1. Are you right or left handed?

2. Are you a first, second, etc., born child?

3. What is your approximate IQ? (Remember these answers are confidential)

4. Do you consider yourself an introvert or an extrovert?

5. Were you healthy or sickly as a child?

6. Are you primarily a visual or verbal learner? Visual or verbal thinker?

7. How do you view religion?

8. What kinds of extracurricular activities did you participate in when you were in high school? What do you do for recreation now?

9. In high school, were you shy and/or aloof from classmates?

10. When you were younger, were you independent of your family?

11. Do you have a strong concern for other people?

12. Have you decided on a SPECIFIC career? If so, when did you make this decision?

E-mail Questions: Set III

1. As a child, were you an avid reader? What about now?

2. Do you like movies?

3. Do you like social affairs (parties)?

4. Are you involved in political activity?

5. Is your interest in women less than moderate, moderate, more than moderate?

6. Do you do better on non-verbal or verbal tests?

7. Have you ever taken a test of your spatial abilities? Did you score high medium or low?

8. Do you score high medium or low on mathematical tests?

9. Were you rebellious as a child?

10. Was learning a high value in your family?

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