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Fall 2007

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Recommended Citation
Calkins, Dian; Cunningham, James B.; Satterfield, Foad; Kolipinski, Mietek; and Ghosh, Sibdas, "Patterns of Life: Integrating Mathematics with Science, Culture, and Art" (2007). *Collected Faculty and Staff Scholarship*. 60.
https://scholar.dominican.edu/all-faculty/60

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Patterns of Life: Integrating Mathematics with Science, Culture, and Art

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Abstract

We offered undergraduate students an interdisciplinary course *Patterns of Life* that develops mathematical reasoning strategies to solve complex problems. In its most essential form, mathematics is the study of patterns; and mathematical (patterned) reasoning is the ability to think with a plan and a purpose. Students personally experience and use patterns of reasoning in diverse disciplines, and then work in groups to form a valid strategy for solving a selected problem. *Patterns of Life* is designed as guided, on-site, active-learning experiences, in cooperation with local scientific, cultural and fine arts communities. Course goals for students include: (1) to increase mathematical understanding, find mathematical thinking more relevant to their own programs and build mathematical perspectives and strategies to become more confident problem-solvers, and (2) to develop a life-long ability to reason more effectively on a wider variety of problems, including those that may be unfamiliar or seem to have no answer. The following four activities were an integral part of *Patterns of Life*: (1) biologists at the Golden Gate Raptor Observatory engaged students in the study of the raptor population crossing the Golden Gate section of the Western Flyway; (2) National Park Service scientists, students and instructors studied ecological, environmental and cultural patterns in Yosemite National Park; (3) students studied structure and vitality of traditional human cultures through their use of mathematical patterns: model and map-making, navigation, time, recording devices, networks, linear programming, probability, geometric growth rates, binary codes, fair division and appointment, measurement and systems of influence and power; and (4) with members of the San Francisco Bay Area Fine Arts Community, students discovered patterns in artistic expression, including symmetry, balance, scale, repetition of motif, and geometry in visual arts and architecture.

Introduction

The information and technology age is influencing design of undergraduate education even more than content. There is dramatic change in all the ways education works: how lectures are given, how students study, how research is done, how information is saved, and how students present their final projects. Accessing historical data or current research takes students only seconds, and even a beginner's search can be far more exhaustive than was possible just a few years ago. This development in technology dictates a radical shift in the goals of an undergraduate education. Students cannot be prepared to solve the problems of the 21st century by requiring them to "be responsible for" a certain amount of proscribed information in a variety of categories. Memorization and its related study-skills of outlining and summarizing have diminished importance as an end result, and are giving way to skills that have less to do with remembering information and more impact on building the quality of students' thinking skills. As many universities are discovering today, we need to redesign the library and research experience, based on our rapidly growing access to information.

In this paper we describe *Patterns of Life*, a series of three integrated courses at Dominican University of California designed to engage students in understanding and solving real problems through recognition of patterns. The primary value of the series is in its process more than its content; students from various departments gather and model data together, and instructors learn with students. On-site, direct contact with professional scientists and artists creates an active, cooperative learning community. Patterns are integral to the practice and growth of all professions. They form the anatomy of the investigation and learning process.

Thoughts and conclusions are the product of the mental process of arrangement. When we organize facts or ideas with the help of mental or physical symbols, when we chart a course, determine our preferences, weigh our alternatives, or recognize balance and symmetry, we are processing information into patterns that facilitate understanding. When we categorize, connect abstraction to meaning, plot a chain of events, create tactics or devise a strategy, we are thinking mathematically.

Patterns of Life is a practicum course, designed to promote student input toward learning the mathematical skill of analytic, patterned reasoning. Students investigated how patterns are discovered and used to solve problems. They explored and invented patterns themselves. Students learned analytic thinking skills by thinking analytically. Mathematics served as both the wind and the sail.

History and Design

Patterns of Life was born in the belief that mathematical patterns are fundamental to all aspects of nature, human life and the human condition. The strength, sustaining power and vitality of all cultures lie in the recognition, generation and adaptation of mathematical, analytic reasoning patterns. This project began in 2002 as a joint lecture and discussion for students enrolled in mathematics and art classes. Participating instructors encouraged students to form connections between academic studies and concepts learned in one discipline, and the questions and challenges presented in other areas.

Patterns of Life was supported by Dominican University of California and by the SENCER Summer Institute (Science Education for New Civic Engagement and Responsibilities.) Throughout all stages of development, *Patterns of*

Life was guided by the technological and quantitative literacy goals of the New Liberal Arts Program of the Alfred P. Sloan Foundation.[1] We delivered *Patterns of Life* to infuse and promote quantification, analytic reasoning and application of technology throughout the curriculum. Mathematics becomes much more than calculation; it becomes a way to analyze and strategize, to expand perspective and facilitate problem-solving.[1]

In addition, the course directly reflects ideas found in *Implication of Learning Research for Teaching Science to Non-Science Majors*[2] and design elements and goals that are components of *Mathematics Across the Curriculum at Dartmouth College*[3]. Instructors also used ideas from *Team Teaching Methods*[4] and from *Models for Undergraduate Instruction: The Potential of Modeling and Visualization Technology in Science and Math Education*[5].

Components of *Patterns of Life*

Patterns of Life is a true hybrid composed of three courses: *Patterns in the Natural World, Patterns in Cultural Organization,* and *Patterns in Artistic Expression.* *Patterns of Life* uses many of the principles of the discovery learning philosophy that have been successful in elementary education: learning is regarded as both a product and a process; each course emphasizes active, hands-on involvement and use of scientific and computer technology; and it is a common goal that students discover the structure, power and beauty of mathematics through direct connection with current research and fine arts projects. Each course contains cooperative, intensive, extended learning experiences designed for deeper understanding of the environment, artistic expression, and cultural heritage through the study of mathematical reasoning strategies.

We believe the course helps prepare students for the modern world. Problems are solved by the courage and inventiveness of individuals who think carefully and analytically, and who dare to take huge leaps of imagination. *Patterns of Life* is designed to foster this kind of thinking and this kind of mental ability.

In works of art of all kinds, there is often what is termed a "dialogue" between form and content. The structure and physicality of an object relates intimately to its impact or purpose. Both form and content of *Patterns of Life* are unique and contribute specifically to the goals of the course.

In *Patterns of Life*, students work on-site with scientists and members of the professional fine arts community. The combination of student and professional is a natural one: it provides students a first-hand view of problem-solving strategies and offers professionals a dialogue with students of varying perspectives.

The course serves to humanize students' views of mathematics, to widen the scope of their academic investigations, and to foster insight and creativity, generating responsible citizens who make sound decisions. Students develop perception, critical thinking skills and problem-solving strategies that are applicable in any discipline. They learn to think more mathematically and to expand the concept of what is mathematical; and they improve their overall academic performance by enhancing their ability to visualize the mathematical component of other studies.

The vision and guiding principle of the course is that it must be organic: work must be closely tied to the natural and cultural world, and student involvement and contributions must cause the course itself to expand in complexity and practicality. National Park Service scientists and members of the San Francisco professional fine arts community engaged our students in genuine, guided scientific research and creation of art. Course instructors and invited members of the Dominican faculty and administration worked with them.

All course activities have a double focus: student work is on-site and original; and student work is ultimately personal, helping to build valuable thinking skills. Students study reasoning strategies by participating in scientific investigation. They construct models and replicate mathematical devices that contain, symbolize or transmit a culture's knowledge or beliefs. They create art, and they use technology to interpret and present data.

They learn to ask analytical questions, to gather quantitative information, to contribute to group work and to value the contributions of others. Students discover adaptability and versatility of problem-solving strategies in a variety of disciplines. As they work alongside their instructors and members of the university, students witness the academic intent of life-long learning. Unique skills and background give every student a separate status within the group. Working together as representatives from various parts of the campus community generates high energy and a cooperative spirit that is greatly valued at Dominican.

Students are challenged to keep mentally agile and flexible, to develop an analytic focus, and to cross-reference with each other. Course activities build students' ability to use and invent strategies by which problems are analyzed and solved in the world of constant motion and process. Each student will confront Johann Kepler's realization that "everything is shown us, and nothing is explained." The mathematics in the world is not so much applied as it is illustrated, in a continuum that contains our history and all our hopes for understanding the intellectual tenor of our times.

Challenging the Students

All components of this course place unfamiliar demands on students. Academic skills conventionally honed during the undergraduate experience such as note-taking during lectures, recall of a given body of information, writing assignments from a textbook and studying for exams are all minimal or nonexistent. Working in the field is a unique way to learn, and students who are confident and successful in a traditional classroom situation can feel less secure. Also, it can be daunting for students to be working with classmates they do not know and who do not share the same interests. Serving as the representatives of their own discipline, students engaged in each learning project from their unique perspective. As the course progressed, student participation on site and in class discussions became increasingly more aligned with their own major fields of study.

Student Success

There were multiple components of success in *Patterns of Life*. The course required an unusual commitment of energy.

Mental energy was needed "in the moment" while working on site and in group discussion and presentations. Physical energy was necessary at every active-learning site. Students climbed, hiked, hauled, waded, cleaned gear, released nets from a boat, made campfires, carried boxes of food, sleeping bags and cameras, and cleaned up the group campsite. Off-campus activities in unfamiliar surroundings and conditions call for a high level of emotional energy in the form of patience, consideration and accommodation to others. Netting fish and sleeping out under the stars were easily accomplished and easily enjoyed by some students; for others they were a significant challenge and a very satisfying accomplishment.

During the course students became more active participants in their own learning. Their field book entries expanded to contain group meeting notes, lists of quantitative questions on various topics, statistical analysis assignments, outlines for research proposals, results of on-site group work, and copies of databases accessed. In the art class, students kept a sketchbook of assignments and also completed several large drawing or painting projects, evaluated by the teaching faculty.

As a final project, *Patterns of Life* students presented group proposals that applied the research process to a problem of current national or global concern. Instructors and students completed a Listeners' Response form, giving comments on the use of technology, the discussion of the problem and the clarity of the statistical analysis. This response form also asked student listeners to write as clearly as possible, the research question and the conclusions presented by the group, as a method of confirming that the question and results were presented distinctly.

Specific skills graded by the instructors also include: method of data collection, access of scientific literature through the World Wide Web, access of relevant databases (some sites were provided), appropriate statistical analyses, use of graphs, formulation of hypotheses, and valid construction of the research process.

Specific presentation criteria were also evaluated and graded, such as participation by every member, speaking loudly and clearly enough, and directing the explanation toward the listeners rather than toward other group members. During the second series of presentations, instructors and student listeners noted improvement in these skills for every group. Also, listeners' response pages showed students were better able to correctly and concisely state each group's research question and results.

Students were directed to read less of their presentation; they were asked to reserve the slides for pictures, graphs and statistical analyses and not to make slides full of written information.

However, every group continued to display written information, which they then read.

Technology Week: Tools and Skills for the Course

Patterns of Life had the good fortune to connect with two generous faculty members from other departments and facilities on campus, who agreed to help our students solidify the foundational skills necessary to blend statistics and technology into their research.

For the first week of the semester, students worked together to learn how to transfer information between word processing and spreadsheet software. For our Liberal Arts, Communications, History, English, Nursing, Teacher Preparation and Music majors, it was a less familiar experience to present patterns of data found through original research. Biology majors were more capable in these skills, and they were asked to help students who were less familiar with organizing data. Throughout the course, the guidance and instruction shared between students became a very valuable interaction. Students in *Patterns of Life* created interdepartmental connections that greatly enlarged the experience for everyone.

***Patterns in the Natural World*: Fish, Frogs, Raptors and the Pine Forest**

The San Francisco Bay Area is home to many outstanding natural science and environmental study opportunities. During the Natural World component of the course, our students climbed Hawk Hill overlook at the Golden Gate Bridge to view raptor migration, studied wildlife and fire management in Yosemite National Park, and dragged nets and trapped fish at Tomalas Bay in the Point Reyes National Seashore.

The Raptor Observatory in the Golden Gate National Recreation Area monitors and studies birds of prey in the Marin headlands section of the Western Flyway. Scientists helped Dominican students learn the distinguishing characteristics of the raptors' appearance and flight patterns and explained raptor observation, banding and release activities (Figure 1). The Observatory also gave our students access to data covering several years of observation, banding and tracking work.

The students learned the process of "data mining" to search for patterns in the life and movement of these raptors. Working in groups, they formed hypotheses in a chosen area of investigation, analyzed morphometric data, used statistical analysis and graphic components to explain and test it, and designed a PowerPoint presentation to share results (Figure 2). Before working at the Raptor Observatory, students learned to gather information in relation to specific, quantitative questions. Generalized questions such as "How difficult is it for a raptor to cross the Golden Gate?" can best be investigated by defining specific questions concerning the species, the distance it has traveled to reach the overlook, the method of flight, the amount of wind, and how many attempts the bird may have made recently. To keep the work focused, students were encouraged to begin their presentations with "Our investigation is directed toward answering the question…" or "Our presentation focused on the question…"

At the Point Reyes National Seashore a marine biologist helped students gather samples of fish life in a small bay by hauling nets. Students released nets from the back of a boat while others in waders caught and dragged the nets toward shore, and others collected the trapped fish in buckets. Back on campus, students used Simpson's Diversity Index and a rarefaction curve to approximate the number and type of marine life in the bay.

Patterns of Life students, instructors and faculty guests spent a fall weekend camping and studying in Yosemite National Park. We hiked to high-elevation waterfalls, learned to build a campfire and slept out under the stars. We met with National Park Service scientists to study bear management, meadow restoration, non-native frog populations and wildfire ecology. A Federal scientist with 40 years of experience as a fire ecologist conducting research in the park explained forest ecosystem processes. The students visited a location untouched by fire for over fifty years, another that burned about 10 years ago and one that burned just last year. They learned that variations and growth patterns in plant species contribute to or determine the type of fire that will occur in each area, and that burn areas continue for many years to evidence the type of fire that occurred there, as well as provide clues for future fire-ignition risk. Each group of students worked in a roped-off section of forest or meadow and collected information on species, spacing, growth patterns and the amount of dead material on the ground and in the trees. Back on campus, each group analyzed the impact of previous fires on the forest structure and composition in their section.

At every field site, professional scientists guided the work, and two leading ideas structured the experience: every student actively participates in the research experience; and as the students learn about the project, they learn procedures and format of scientific investigations. A National Park Senior Scientist consulting and working in cooperation with Dominican kept the work focused and valid. The double impact of scientific progress is to increase both our understanding of the world and also our capability for influence. Knowledge of the world's natural patterns may allow us to take full advantage of the human possibilities for exploration, to learn about earth's history and future, to fight disease, to enhance our environment, to predict the consequences of our actions, and perhaps to save us from ourselves.

Ethnomathematics: Culture held in Human Constructs

Students concurrently enrolled in *Patterns in Cultural Organization*. Mathematical patterns are integral to all parts of human organization and human endeavor. Patterns found within the structure and operation of any society, provide safety and definition, and allow an openness and freedom for people who live together. The readings and constructions of this course were chosen to add complexity and texture to students' understanding of the ways cultures define themselves and provide for continuity and prosperity. Students studied structure and energy as maintained and preserved in the strategies and devices of a cultural group. The course presented a multi-cultural view, and emphasized the seminal nature and importance of mathematic concepts in all cultures.

Mathematical patterns studied in each section were related to Western mathematical concepts. When studying the Tamil Nadu[6] people in southern India, they recreated the sand drawings called kolam that reflect the culture's values, rituals and philosophy. Geometry is currently a burgeoning part of mathematical studies in our own culture due to its facility for representing flow and network connections, and students analyzed kolam designs in terms of Eulerian paths, fractal design, Sierpinski and FASS Curves, and edges and degrees of each vertex. The Tamil Nadu use of units and subunits in recursive patterns was the basis of class activities drawing "turtle graphics" such as those used to introduce children to computer language, and samples of original array languages, in which final symbolic meaning is built up through successive patterns or according to specific rules of formation.

The Navajo and Sioux[7] are Native American people who hold unique views of the dynamic nature of the universe. The class studied the idea that nature moves and develops in circles, and that human life well-lived will result in accomplishment of an individual's goals and will show evidence of circular patterns. In Western mathematics, the Jordan Curve Theorem delineates a simple closed planar curve that determines two regions of which it is the common boundary. Following is an example of a student response to a class activity, illustrating the course of a man's lifetime and reflecting the Sioux nation's belief that the power of the world works in circles (Figure 3). Students used a variation of a Jordan curve to map a lifetime. The darkened circles within each curve represent the aspects of the individual's life; his many accomplishments are grouped within a separate curve, his family and friends in another, and the many plans, wishes and dreams he had in another. Hopefully his life would continue through turns and circumstances that would give rise to more curves full of circles indicating richness and satisfaction. But his life ended within a circle, and only the potential for such a growth of new curves is shown. The life was over before they could develop.

The culture of the Incas in South America was a primary choice of study for this course because of its complexity, success and place in history. Although the Inca culture flourished over 600 years ago, their society of approximately 4 million people was highly organized. They were intense data keepers and sent many messages and records throughout their vast empire concerning the governing system, work force, taxes, population count, resource allocation, peace negotiations, laws and history. They had no written language. All records were encoded on arrays of colored knotted cords called quipu.[7]

Students studied the quipu construction and method of communication and also its similarity to modern day practice of using numbers as both labels and quantifiers. Number labels such as social security numbers, ISBN book identifiers and product codes are common in our society and will increase as we continue to use computers to store and process numeric information. Quipu were not calculating devices; they served the Inca in the way the record-keeping aspect of a computer serves our society today. Because cotton was abundant, the Inca used cotton cord for this logical-numerical recording. Students in *Patterns in Cultural Organization* used cotton rope and cord to construct messages in the manner of those that were sent throughout the Inca Empire. Each group used the color and length, the connection of the rope, the placement of each piece of rope, the spaces between cords, the types of knots and the placement of each knot to construct an 8-foot long quipu with encoded information.

Students developed a more complex understanding of mathematics, an appreciation for the inventiveness of the Inca and an understanding of how numbers used as labels are increasing our ability to store and relate data in the Communication and Information Age. Ultimately the course goal was to open students' awareness to the fundamental and powerful nature of mathematical ideas in any culture.

The existence and success of traditional and complex cultures alike depends on mathematical ideas such as cooperation, communication, cosmology, divination, time and continuity, and systems of influence, justice, and power. It is a primary goal of this course that Dominican students recognize the structures and processes inherent in other cultures' systems that can be modeled and perhaps redefined and reinvented to serve us.

Patterns in Art: The Web in Which Every River Flows and Every Life is Lived

Led by a fine arts professor at Dominican, *Patterns in Artistic Expression* combines study and creation of art with access to artists of diverse media and creative methods. Students have direct access to professionals in the visual and performing arts. They study evidence of process, motion, symmetry, opposition, balance and weight in varied art forms, and learn the relationship of form and content. They discover that in the creation of art, artists often use the systems, theories and historical models of mathematics as a starting point; and that measurement, proportion, patterning, iteration and geometry are equally instinctual to other more recognized artistic sensibilities, and incredibly rich as grounds for artistic production.[8]

Artistic expression can make a pattern easier to understand. In this course students relate the concepts of motif and abstraction to patterns constructed in various materials. At an exhibit of sculpture in natural materials, students talked with the artist about motion and representation of the cycle of life in materials and forms that are usually considered stable or permanent such as rocks and mountains; students then created a series of drawings that were representative of forces of change they recognized in their own life, life of a culture, or that related to their own field of study. In the initial offering of *Patterns of Life* students also toured the campus grounds with the Director of Environmental Landscaping at the University. They learned how the present requirements and growth of the university affect the property, and how the form and function of the land interrelate. By incorporating natural forms into their art, studying art of other cultures, and meeting art in many forms, students learn that mathematical thinking can be applied in domains other than numeric. The course could be extended into the literary arts, guiding students to analyze patterns of rational argument and identify the pathways along which valid reasoning formed.

Assessment: Looking Back One Year

Patterns of Life was delivered as a series of discovery-learning situations. The activities, requirements, challenges, and partnerships built into the course can place students on unfamiliar ground. Future offerings of the course need additional class time built into the schedule to more thoroughly delineate what the students will see and how they will participate. This will also allow more opportunity for students to discuss and help each other prepare for situations such as wading in moderately deep water, hiking, and camping without tents.

Many students are unfamiliar with active research participation. Students proficient at taking notes from a text are not equally comfortable taking notes in the field, and they may be unclear about what to write. Instructors suggest that in addition to the prepared student guides and outlines of the research process, it might also be helpful to students if instructors worked on an aspect of the research at the same time. A useful class activity during the first week specifically addressed the formation of scientific questions, which helped keep students' field notes focused.

In assessment survey responses at the conclusion of *Patterns of Life*, every participant replied positively concerning on-site work at research locations, talking with scientists and artists and working together in small groups. Also many students considered the tech-week meetings in the labs to be helpful; some students considered these sessions to be absolutely necessary and to have greatly increased their ability to participate in the course activities.

Several factors presented complications. Some students had difficulty clearing their schedules for full participation in off-campus events and group meetings. For students not returning home before the trip at the end of September, the course required preliminary preparation for clothing and equipment to be brought to Dominican in August. Several students needed to borrow appropriate camping gear to bring. Any time students assemble off campus, there are logistical complications that need to be addressed and resolved ahead of time. Students involved in a course clearly outside the parameters of regular campus life can feel apprehensive about leaving the routine of lectures, cafeteria dining, textbook reading assignments and studying for tests.

These reservations tended to fall away as students began to enjoy the work and community. Students whose paths might not have crossed, became friends. Instructors worked with students who would not have been in their classes or departments. Scientists and artists noted the energy in the group, and students who had been introduced to an area of study they would like to investigate further—art, marine biology and wildlife management— took the opportunity to ask about professional preparation and summer internship or volunteer positions.

Final research proposal presentation days had a seminar-conference atmosphere that instructors felt held moments of high-level community learning. Students suggested there be only one presentation a day instead of two as scheduled, allowing more time for questions and discussion.

Two main concerns in the presentation of the course are the number of students, and the students' preparation prior to the start of the course. *Patterns of Life* was presented as a practicum; larger student enrollment can result in less individual involvement. Also because there are equipment and clothing requirements, the class list must be established early and finalized, so that course information can be mailed during the summer to all members. The instructors recommend the class be limited to 20 students, as compared to the 33 that registered.

Everyone considered having a diverse group of disciplines represented in the student registration a positive aspect of the course. At the heart of every learning experience in *Patterns of Life*, there was a strong reliance and dependability factor intended. Participating students' diverse talents and learning styles magnify the experience for others. Every individual's varied perspective and questions serve to increase every other member's mental landscape.

Tracking Student Skills

As part of the course plan, the Instructors chose the following skills and abilities as indicators of student success. They encompass the product and process of student participation in the learning activities presented in *Patterns of Life.*

Development of Mathematical Literacy and Technology Skills: Students were very successful in gathering and sorting numeric information; throughout the course, they showed increased ability to represent data in statistical form, and to write quantitative questions. Recognizing trends and using equations to model process and change are more complex skills that continue to develop with increased experience. Students were very successful with basic statistics such as taking a biodiversity quotient for a section of San Francisco Bay, but were less capable when trying to interpret information that may or may not be significant enough to indicate a pattern. Students recognized that valuable information or conclusions can also be formed when information does not support an initial hypothesis. Formation of hypotheses was an area that showed major improvement, and because it is so integral to analytical reasoning, all instructors considered student improvement in this skill fundamentally valuable.

Instructors discovered that some of the strongest thinking skills developed in *Patterns of Life* were the ones most easily translated throughout all disciplines, and we are gratified that student work in any field may be stronger or more productive as a result of this experience. Students practiced the skill of looking closely and carefully by separating sections of information or by drawing what they are looking at; they learned to ask quantitative questions by writing and rewriting questions in valid analytic form; and they learned techniques for analyzing hypotheses that will help them solve problems in any subject area.

Technology skills also increased: students accessed databases, gathered previous research, created charts and diagrams with their own research results, read and translated numeric information, and used computer programs to design their own presentations. Many of the photographs embedded in the presentations were taken by the students on location.

Participation: Students represented departments of business, communications, nursing, psychology, history, music, biology, and teacher preparation. Within each group, students relied on each other and learned by cooperation rather than competition. Instructors saw evidence of diverse input in the final proposals, and considered the blending of research into traditionally "under-represented" major study areas to be a very positive aspect of the program.

Understanding Quantitative Reasoning Strategies: Students wrote outlines that followed valid, recognized components and process of research; they accurately calculated statistical analyses; they worked with a plan and under the guidance of the National Park Service scientist working cooperatively with Dominican; and they wrote proposals in the same format used by national park service scientists. In the Art class, students' work showed real understanding of motif, pattern and perspective, and the connection of these concepts with mathematical reasoning.

Understanding Mathematical Ideas of Other Cultures: Students were inventive and drew a wide range of maps, charts and models. Instructors especially valued mathematical representations drawn from the student's own life or major area of study, such as a student picture graph using the Jordan Curve theorem to illustrate the structure and living arrangement of the family unit of the Masi people in her homeland of Tanzania (Figure 4). The student explained that Masi consider any land they move across to be Masi Land. Each of the wives builds a shelter for herself and her children; the homes cluster together in a roughly circular formation. The man moves throughout the group of homes, staying at night in whichever one he chooses. The interior space in the cluster is reserved for cows. Cows are of primary importance to the Masi; her explanation included the common belief that if you have no cows, you have nothing. The cows in the center are the property of the man whose cluster of homes encloses them. If they wander off or are taken by someone else to another cluster, they become the property of the finder. The circle of homes is convenient for the husband, it helps secure the cows at night, and it marks the boundary of his wealth and authority.

Using Mathematical Problem-Solving Strategies: Final research proposals showed students had increased skills in collecting valid data, interpreting data and forming hypotheses. Student research and statistical analysis were well done and were understood by the student audience. Instructors felt the logistics and effect of the proposed solution needed more thorough explanation and development, in every presentation. Social programs were suggested without enough implementation strategy. During the following discussions, listeners raised reasonable questions that had not been addressed by the group's strategy. In all group projects, students' analysis of the problem was more thoroughly and clearly represented than the proposal for solving, perhaps because the analysis aspect more closely aligned with other more familiar assignments throughout their curriculum.

Conclusions

Effective, life-long learning is an active, constructive process. The "Cognitive Revolution" asks that learners be able to apply past experiences toward the understanding of new situations and problems. Hands-on, primary learning experiences encourage each student to participate from their own previous knowledge and skills, constituting a very positive aspect of the learning experience. Learning is a process of constructing frameworks of information blended with experiences. This scaffolding is constantly being constructed, demolished and reconstructed by the brain. Human beings have an ability to gather knowledge about specifics and construct frameworks that encompass general understandings. These understandings are very individual and unique; they evolve from personally selected specifics and the resulting constructions are personally meaningful and satisfying. Cross-disciplinary, constructed learning builds knowledge that is inwardly born and results in students becoming more effective thinkers on a wider variety of problems. The more clearly a student confronts a problem and has participated in finding a pattern contributing to understanding or resolution, the more effective will be his or her thinking on other problems. Also, scientific advancements often mark the intellectual climate of an era, and citizens who have limited analytic reasoning skills can be cut off from the intellectual tenor of their times much the same as a person who cannot read.

We offered *Patterns of Life* as an adventure, an experience and a challenge to every student, to build a personal view of the world that provides intellectual and aesthetic satisfaction, and to become a citizen prepared to help solve public issues that require mathematical literacy, in order to more responsibly participate in keeping the democratic process alive. Throughout *Patterns of Life*, course activities are designed to show the strength of humanity in our diversity of interests and strengths, and to acknowledge and appreciate all that cultures have in common. The means by which societies establish themselves and become successful are of value to all people dedicated to the goal of knowledge in service to human rights and human progress.

Acknowledgments

The work was supported by grants from SENCER (Science Education for New Civic Engagement) and from Dominican University of California to Sibdas Ghosh and Dian Calkins. We thank Professor Grace Grant and Professor Virginia Darney for their advice on assessment throughout this project and all scientists of Point Reyes National Seashore, Golden Gate National Recreation Area, and Yosemite National Park who worked with us in "Patterns of Life".

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Figure 1: ***Red-tail Hawk in flight***

Figure 2: ***Hawk Sightings of 2004***

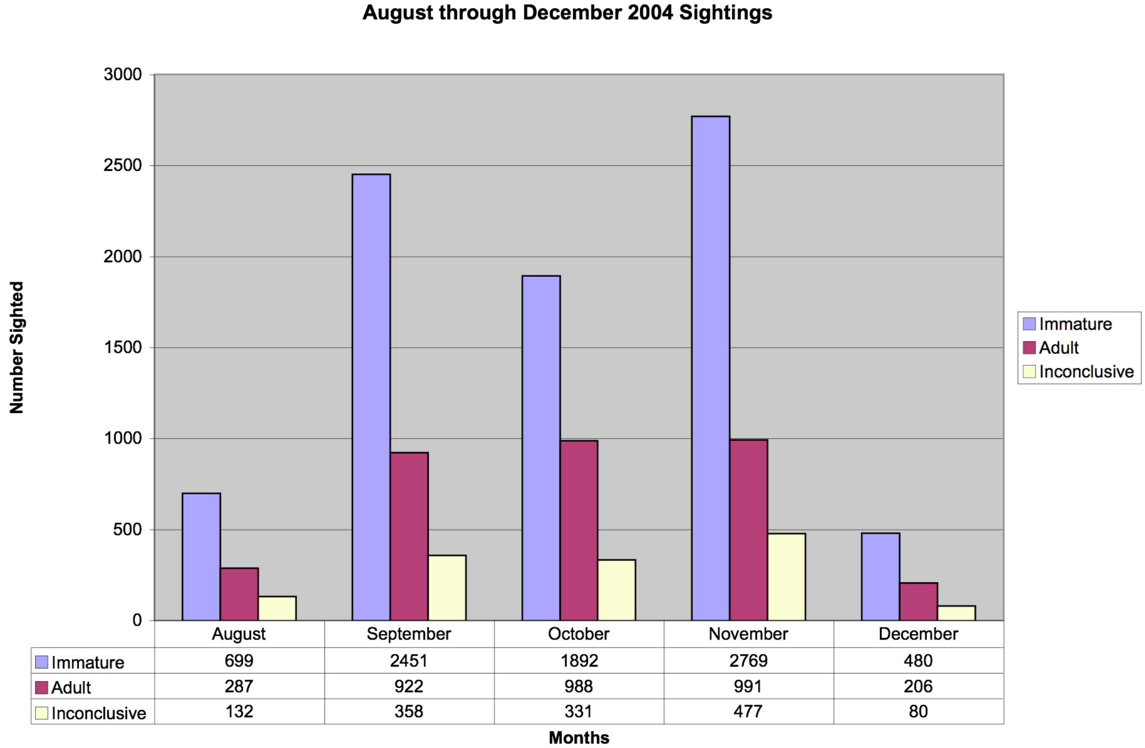

Figure 3: ***Jordan Curve Mapping of a Lifetime***

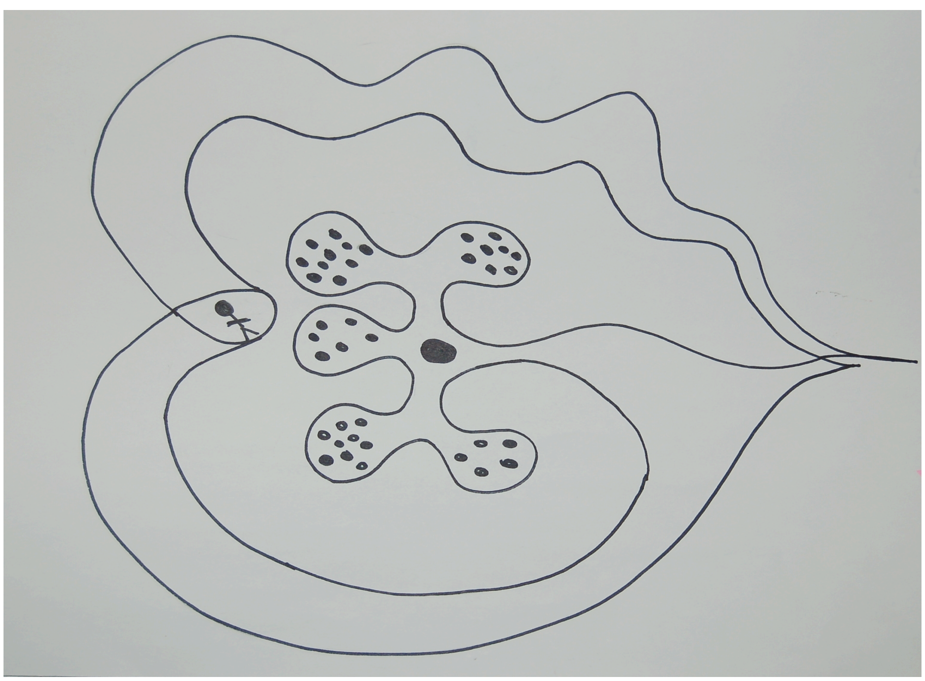

Figure 4: *Jordan Curve Mapping of Masi Homes*