THE ROLE OF INQUIRY-DRIVEN FIELD-BASED (IDFB) ECOLOGICAL SCIENCE CLASSES IN COLLEGE STUDENTS’ DEVELOPMENT AS SCIENTISTS
Nicole L. Crane

FOREWORD

As a practicing teacher of college science (marine science in particular) for many years I have noticed the power of engaging my students directly with the material, and helping them see the relevance to their own lives, and their personal relationship with the material (whether it be an interest in a career in science, a required course they needed etc.). I have witnessed an increased ability for them to succeed academically through this kind of engagement, and an increased excitement and connection with the material. I have stressed field-work in my teaching, especially assignments whereby students develop their own projects, and interact within ‘communities’ to discuss and present their work. I have noticed in particular that many underrepresented students find new meaning and motivation in science this way. Many of them do not have the mentors, models, and support structures at home or in their communities to emphasize science (especially ecology or environmental science) as a career choice, or to help provide a vision of their role in the world of science.

My original hope with this research was to document the impact of Inquiry-Driven Field-Based (IDFB) experiences on first and second year undergraduates, and in particular on underrepresented students. I was unable to find many examples of either student group at the institutions from which my samples were drawn. Access
issues tend to limit enrollment in IDFB classes to: a) those already mostly committed to a science career; b) middle and higher income students and; c) higher achievers. There are several likely reasons for this, including access (or lack of access) to information about the programs, an understanding of their importance, an ability to participate in a program that requires extended time away from home, conflicts with work and other obligations, and access to social and institutional networks that help students navigate the college system and locate and fund important opportunities such as these. Administrative support and promotion of such programs also plays an important role in who participates in them.

Thus this study involves mostly third and fourth-year European American students from middle to upper-middle class backgrounds. However, there are a few underrepresented students in the sample, and a few first and second-year students. What is most telling and perhaps most important to this study in terms of the impact of field-based learning on college students is that all students, regardless of their backgrounds, were remarkably consistent in what they said about the experience. This study should inform science teachers and administrators about the importance of field-based programs for all students, and their potential for recruiting and retaining more students into the fields of ecology, environmental science, and geosciences.
OVERVIEW

This study investigates the role of inquiry-driven field-based (IDFB) learning in the academic and personal development of undergraduate students of ecological and marine sciences. It focuses on their development as scientists as they participate in contextualized scientific investigations, and on how their engagement in these investigations enhances their cognitive growth, personal growth, confidence, motivation, and view of their future educational and professional objectives.

For the purposes of this study, inquiry-driven field-based learning has two key descriptors: 1) inquiry driven: students participate in an entire investigation (or investigations), and are responsible for asking scientific questions, designing methods, collecting evidence to support their questions, and interpreting and discussing results (Ash and Wells, in press; Bowen 2000; National Research Council, 2000; Southerland, 2001; Minstrell 1999; Wells, 1999; San Francisco Exploratorium, 1998; Hammer, 1996); and 2) field-based: a learning experience that occurs in a contextualized ‘real’ setting, such as in the ocean, a forest, or a stream (Dayton, 2003; Southerland, 2001; Bowen and Roth, 2000; Fernandez-Manzanal et al, 1999; Minstrell, 1999; Hammer, 1996). For the remainder of this document, I will use the acronym IDFB to refer to inquiry–driven field–based experiences.

My study deals with students engaging in ecological (particularly marine/coastal) or related biological/environmental studies. Throughout this document when I refer to students of science, the field of science, or science curriculum, I am using the word ‘science’ to describe biology primarily, and even
more specifically ecology, environmental science, and related fields. In particular, this study focuses on how participation in IDFB experiences leads to the acquisition of skills and factual, theoretical, and applied knowledge (cognitive development), and leads to students’ increased confidence in their ability to ‘do’ science, their motivation as students of science, their understanding of their role in science (their future educational and career pathways), and their personal growth (affective development) (Rogoff, 1998). The growth they experience as a result of engaging in IDFBs and ‘doing’ science leads to their development as scientists. This study provides evidence to document students’ cognitive and affective growth, and how that growth helps them develop as scientists; allowing them to ‘be’ scientists and think like scientists.

I will begin by providing background on inquiry and field-based learning in both a general context and specific to learning science. I will focus on the importance of inquiry as a learning strategy and on how incorporating inquiry into pedagogy helps connect students to one another, to the material, and to their own motivation. I will then provide some background on methodology and elaborate on the theoretical underpinnings of the qualitative methods used in this study. The second section will outline the methods used, both in data collection and data analysis, and will introduce the study participants. In the third through fifth sections I will present the results, provide an interpretation of them, and place them in the larger context of science education.
SECTION 1: Introduction

Science is a process, not the mere acquisition of facts or memorization of theories. Students of science must learn to apply theories, design studies, ask relevant questions of the natural environment, interpret data, and think critically, among other skill sets. The application of these skills requires knowledge, but it also requires practice, and engagement in the process. Through engagement and practice students master important knowledge and skills, and they find the motivation and meaning so important to helping them discover their relationship with the process of science and their future career and educational goals. If we are to produce scientists capable of succeeding, it is certainly in our interest (and in the students' interests) to create educational opportunities that help them appreciate fully all that is involved in doing science and being a scientist (Dayton, 2003; Dayton and Sala, 2001; Southerland, 2001).

A. Inquiry and field-based learning–background and evidence for success

Teachers have long understood that getting students ‘involved’ in their work helps them learn and enjoy it. French psychologist Jean Piaget created a model outlining the stages of developing childrens knowledge systems based on their age (Piaget, 1970), and the importance of engagement of children in inquiry-based learning involving ‘doing’ as well as ‘thinking’ (Ash &Wells in press; Piaget,1970 & 1952). Vygotsky (1978) pioneered the concept of the zone of proximal development
(ZPD) and the sociocultural nature of learning. He emphasized that knowledge is acquired and applied through collaborative engagement in activity by learners of different maturity levels, allowing each to explore their ZPD (Vygotsky 1978).

Inquiry-based learning can occur in a variety of contexts, and it is not solely restricted to engaging learners in a physical activity. Some researchers argue that inquiry-based learning is largely self–guided, with very little structure or direct participation on the part of the teacher (Wells, 1999; Griffin and Symington, 1997; Gallas, 1994). Others argue that inquiry can be a component of a larger, highly structured learning experience, especially in the sciences (Fernandez-Manzanal et al, 1999; Minstrell, 1999; Ryder et al, 1999; Jones, 1997; Rosebery et al, 1992). Regardless of the context, however, promoting learning through inquiry involves engaging learners in a process of exploration, investigation, and conversation, leading them to ask questions, discover meaning, and interact with the material or natural world (Ash and Wells, in press; Ash 2003; National Research Council, 2000; Wells, 1999; San Francisco Exploratorium, 1998; Smith, 1994).

Importantly, the process is driven by the learner’s own interests and desire to discover. The institute for inquiry at the San Francisco Exploratorium states on its website that “Inquiry, as it relates to science education, should mirror as closely as possible the enterprise of doing science” (San Francisco Exploratorium, 1998). IDFB experiences as described in this study are based on that premise. “The enterprise of doing science” is further defined in this study as involving learners in the entire scientific process: asking questions, designing studies, collecting and
interpreting data, and synthesizing results. In ecological and environmental studies, this is effectively done through field-based classes or opportunities where students can engage in the process of science in a contextualized setting.

Inquiry-based learning has been successfully applied since it was formally developed by educators such as Rousseau, Froebel (in the development of Kindergarten), Montessori (in the development of the Montessori system), and John Dewey (at the ‘laboratory school’ at the University of Chicago) (Smith, 1994). These educators and educational researchers believed in engaging students with learning material by having them interact with it, *experience* it. Their programs and research were based on the concept that educational materials that do not meet individual needs and abilities will fail to engage students and risk being ineffective.

Information that is not meaningful to the student, and that is compartmentalized in ways that do not make sense to individuals, will not be relevant to those individuals. When information is not relevant to individuals and cannot be tied to students’ lives, they will cease to be motivated to learn it and risk doing poorly (Smith, 1994; Dewey, 1938).

A number of studies have found correlations between students’ attitudes towards science and their achievement in science (Mattern and Schau, 2002). Both students’ perceptions of their past performance in science and their achievement motivation (how motivated they are to do well) can be predictors of future achievement in science (Rennie, 1991; Oliver and Simpson, 1988). Benjamin Bloom (1976) revised his taxonomy of cognitive development through education to include
affective measures of success in students (Bloom et. al, 1964); an endeavor that highlighted the importance of affect in student learning. Bloom included motivation as one of three variables key to learners attaining high levels of knowledge acquisition (Bloom 1976). The taxonomies indicate that creating a learning environment that is relevant to students, that engages them, and that leads to positive attitudes and motivation can be highly effective in promoting learning. This study provides evidence that IDFB opportunities help accomplish this for college undergraduate ecology/environmental science students.

Studies that document the impacts of after-school and school–support programs on student achievement and motivation also provide insights into the importance of the affective component of the learning experience. It is widely recognized that after-school programs can lead to better grades and higher persistence in school for participants (Halpern 2002; Kahne et al. 2001), but it is the nature of those programs that turns out to be so important. When these programs provide a setting where youth can engage with their peers and teachers in constructive and meaningful activities, in both a social and academic context, they gain confidence and become more motivated academically (Gibson and Bejinez, 2002; Halpern, 2002; Kahne et al. 2001; Stanton-Salazar et al 2000, Posner and Vandell, 1994). Programs that emphasize academics as well as social interaction and motivation are often the most effective (Kahne et al., 2001). What becomes clear in these and other studies is the importance of how students feel and think (affective
measures) about their learning experience, not just what they are learning (cognitive measures).

B. Inquiry-based science education

There is a growing body of evidence suggesting that science students' behavior and relationships with subject matter change or are influenced through hands-on experiences included as a part of an inquiry-based approach to teaching and learning. Several studies have documented that high school and college undergraduate students gain a deeper understanding of science and how to apply it through field-based experiences and/or designing and carrying out research projects (Bauer, 2002; Fernandez-Manzanal et al, 1999; Barron 1998; Ryder et al. 1999; Jones 1997). Other research points to the use of inquiry-based techniques, including student-directed inquiry projects, to enhance the learning of difficult science concepts (Southerland, 2001; Bowen and Roth, 2000; Minstrell, 1999; Hammer, 1996; Rosebery, 1992). These studies, however, focus on cognitive measures of success, with little attention paid to affect; the importance of increased confidence, motivation, and personal growth in students through these experiences.

The evidence presented thus far supports the argument that inquiry is important to student learning and that engagement through inquiry can lead to better understanding, motivation, and enjoyment (affect), which can lead to higher achievement. It also emphasizes the importance of the educational setting and social dynamics. In these studies, inquiry-based learning includes a broad definition
encompassing varying levels of student participation with material and in activities. Many teachers structure an ‘inquiry-based’ learning experience in a highly organized fashion, much like standard laboratory exercises in college biology classes. In this format, students follow a ‘learning map’, answering questions and filling out worksheets (common also in student field trips to museums and zoos). This is not inquiry-directed learning as I have defined it. My definition includes the student’s role in designing the learning framework; asking the questions, and thinking about why they are important (Bowen and Roth, 2000; Southerland, 2001; Bowen et al., 1999; Minstrell 1999; Hammer, 1996).

Creating this ‘real-world’ or ‘authentic’ environment in a science learning experience, where students engage in discussion and are developing and testing hypotheses, jointly analyzing results, and drawing conclusions for themselves, fosters learning and also creates the atmosphere of a science community (Southerland, 2001). This is important if we are to expect learners to apply information and practice in their own future—both in school and in the work world.

Methods in teaching field-based science often follow a non-ecological format (Dayton, 2003; Bowen and Roth, 2000). They emphasize a linear approach to science rather than incorporating natural history, observation, and creativity (Dayton and Sala, 2001). Students interested in biology, and particularly ecology or environmental science, will spend their careers doing science, yet what they learn in most standard curricula is mostly about science (theory). In college most students do not get a chance to experience first-hand what being a scientist is like (designing a
study, conducting observations, looking at results, discussing with peers, and otherwise behaving as a scientist in the company of other scientists) until their junior or more likely senior year (if at all). Engaging in the entire scientific process in a contextualized setting such as an IDFB experience allows students not only to look at theoretical information in context, but also to relate personally with the process (both intellectually and physically), the people, and the ‘world’ of science. The ability to relate oneself to the larger context of activity and interactions is a powerful motivator; it enables students to better conceptualize their own future and the relevance of their course of study (Grady, 2001; Wells, 2000; Wells, 1999; Gallas, 1992; Moll et al., 1992).

Once students reach middle school, there tend to be very few opportunities to engage in these kinds of learning environments in school. By the time students get to college, many are thinking about what field to enter and choose classes accordingly. Although the number choosing a biology (or natural sciences) track is high, the number who drop out from that track is also high (National Center for Educational Statistics http://nces.ed.gov/surveys; National Science Foundation, 2003; Sanderson et al.,1999). As noted earlier, experiential opportunities in the sciences, such as IDFB classes, are usually not available to students until their last two years in college, if at all. If these experiences were available earlier, would it help engage more students in the sciences and help them stay in a science track? How valuable are these kinds of experiences? What impact do they have on
students? What do students think about the importance of experiential learning in the sciences? These are the questions that motivated the research presented here.

C. Introduction to methodology

Investigating students’ lives, their attitudes, what motivates them, and how successful they are from their own perspective, in addition to using objective tests based on a standard, is a fundamental part of understanding academic achievement and student engagement in academic subjects. Through qualitative inquiry researchers can investigate and understand the meaning or nature of an experience, rather than the intensity (effect size) of an event, or the relatedness of events, as in a more quantitative approach (Silverman, 2001; Strauss and Corbin, 1998).

1. Qualitative data collection

There are many ways a researcher can collect qualitative data with which to develop a theoretical framework. Each method requires a slightly different approach to designing the instrument (whether it be a questionnaire, interview questions, or observation notes), and the design can lead to vastly different results. Using interviews to collect data allows the researcher to learn about the context in which the response is placed, and what social and personal experiential factors come into play in shaping the respondent's views (Ryder et al., 1999; Goldman-Segall, 1998; Siedman, 1998; Kvale, 1996). This can be particularly important if the researcher is
Attempting to draw broad conclusions about an experience. A person's background as well as their current experience is shaped by the socio-cultural context of their own lives and by how they process experiences (Wells, 1999; Seidman, 1998). Diverse methods of data collection can provide complimentary and more complete information about the individual experiences of the 'subjects'. For this reason, I used a combination questionnaire and survey approach backed up with interview data on a smaller number of subjects for whom a more in-depth analysis was possible (Silverman 2001; Jones 1997).

Interview techniques themselves vary considerably. Interviewers can focus on collecting widely different in the types of data depending on the question they are interested in answering. Kvale (1996) describes two broadly different (but often used together) types of questions/approaches to interviewing. One is to 'mine' for information, or probe the subject for specific information that the interviewer is attempting to uncover (e.g. to get an answer). The other approach is for the interviewer to be a 'traveler', letting the subjects lead him/her through their experiences, providing insights into their experiences and a context for their responses. I used a combination of these approaches in my research.

The research questions are critical to determining what kind of data are collected, and the structure of the interview itself (independent of the actual questions) can influence the quality and type of responses (Fernandez-Manzanal et al. 1999; Ryder 1999; Seidman, 1998; Korpan, 1997; Kvale, 1996). A semi-structured interview, where subjects are interviewed before, sometimes during, and
after a particular experience, can provide information on the nature of the impact that experience had on subjects. Manzanal et al (1999), Ryder (1999), and Seidman (1998) all used at least a before and after interview approach (Seidman favoring a third interview during the experience) to investigate the impact of a certain experience (field work, research projects, or a teaching experience) on subjects.

2. A grounded theory approach to data analysis

Glasser and Strauss (1967) pioneered the grounded theory approach to qualitative data analysis which provides an important framework for many social studies. Grounded theory involves an inductive approach to research, using case studies or other methods (Strauss and Corbin, 1998; Charmaz, 1995; Glasser and Strauss 1967). Personal experiences are used as the basis for forming a larger theoretical framework which the researcher continues to fill in using a variety of approaches. Personal experiences provide a window into the complex web of issues surrounding student success. They document real stories told from an individual’s perspective—stories about what motivates them, and how they learn best. I used in-depth interviews to provide this level of insight in this study, and three of those ‘personal stories’ are documented here to illustrate and validate the major themes evident in the data. Qualitative methods, and in particular a grounded theory approach, lends itself well to this particular type of research.

A grounded theory approach leads to the discovery of information used to build hypotheses and theories, rather than testing an *a priori* framework.
The approach requires a willingness to ‘discover’ personal experiences through what others say, and to build theory and explanations inductively, letting the data ‘speak’ (Strauss and Corbin, 1998; Charmaz, 1995; Kvale, 1996; Miles and Huberman, 1994; Glasser and Strauss, 1967). This set of inductive strategies, starting with individual cases and developing progressively more abstract conceptual categories, allows the researcher to synthesize, explain and understand the data, and to see patterns within it (Charmaz, 1995).

A grounded theory approach also includes a set of systematic procedures for shaping and handling qualitative data. The researcher begins by looking for general themes, or ‘supercategories’ in the data. Data are looked at numerous times and are eventually organized into a framework with multiple categories, and relationships between categories. Hypotheses are generated from the data, and the data are used to validate the categories. The categories are interrelated into a larger theoretical scheme. An important aspect of the method is that the analyses and category development are on-going. It is an evolving process, and changes occur as the investigator learns more from the data and reviews it multiple times (Strauss and Corbin, 1998; Charmaz, 1995; Miles and Huberman, 1994; Glasser and Strauss, 1967).

Strauss and Corbin (1998) outline the following components to qualitative research, which is essentially how this study was conducted: 1) data collection through interviews and documents (including questionnaires); 2) procedures to interpret and organize those data and 3) conceptualizing and organizing the data (coding it). These components also allow for some quantification of data (Silverman
2001), though the quantified results, or how many said what, are secondary to what is said. It is important however for the researcher to specify whether what is said is presented to reflect general patterns and themes, minority themes, or unique cases. For this purpose, the numerical presentation of data can be useful, and was used in the presentation of data in this study.

D. This study

This study investigates the importance of student involvement in the process of science as an integral part of learning science and connecting personally with it. The study establishes that doing science both prepares students academically, and creates a personal connection to the process of science that enhances their confidence and motivation. It makes the tasks and subject more real and relevant for them, gets them excited and motivated, and gets them interacting with their peers. Engaging in the process of science helps them see how they relate with the material and tasks, and it helps them draw important connections between theory and application, putting other classes and information in a broader, more relevant context.

Cognitive learning is usually the primary driver in curriculum pedagogy and content. The results presented here indicate that science education without regard for the importance of the personal connections and motivators (affective learning) developed through strategies such as IDFB experiences is not fully effective. Based on this interpretation of the data, I propose a model in which both cognitive and affective measures of the success of an IDFB experience carry weight in preparing
students to be scientists (Figure 1). The model suggests that if students do not experience affective measures of growth in an academic context, their development as scientists could suffer. Students lacking this affective growth in science may drop out of the field, seek other ways to enhance a personal connection to science, or not pursue a science track; all of which could have negative consequences for science degree programs. IDFB experiences provide this affective development for students, and can also be very effective in promoting cognitive growth in students of ecological and environmental sciences.

Within the theoretical context presented thus far, and in recognition of the importance of inquiry-based learning, this study was designed to investigate the specific role of IDFB experiences in the development of science students—in particular students of ecological and environmental sciences. There were three main objectives: 1) to determine what students thought was most important or valuable about their IDFB experience; 2) to determine the major cognitive growth indicators for students (what specific skills and knowledge they thought they had acquired) and; 3) to determine the major affective growth indicators for students (how they felt personally about the experience, and the impact it had on them).
Inquiry Driven Field Based (IDFB) science classes/experiences can enhance the academic (cognitive) and personal (affective) development of students of science. Through their active engagement in the process of science, students gain important skills and knowledge as well as increased confidence, motivation, and ability to plan for their future. This growth is an important part of their development as scientists; the IDFB experience provides them a way to build a relationship with the world of science, and to better understand what science is, what scientists do, and their future role as scientists. There is a relationship between the cognitive and affective growth; students learn better when they are connected, motivated, and confident, and the process of engaging in ‘real’ science leads to motivation, confidence, and a personal connection. IDFB experiences have a particularly important role in affective measures of development: students develop an important personal connection to science.

Figure 1. Theoretical model

Inquiry-Driven Field-Based experiences in the ecological sciences:
Student involvement in the process of science in a contextualized setting

Cognitive measures of development through engagement in process:
• Skills
• Application of theory
• Enhanced knowledge of scientific concepts and theory

Affective measures of development through engagement in process:
• Personal growth
• Confidence
• Motivation
• Future career/educational aspirations

Development of students as scientists
SECTION 2: Methods

I developed a methodological approach based on grounded theory. I used a combination of personal experience, questionnaires with open-ended questions, semi-structured interviews, and surveys to gather information and develop and validate themes (Seidman, 1998; Strauss and Corbin, 1998; Kvale, 1996; Charmaz, 1995, Miles and Huberman 1994). Questionnaires with open-ended questions were used to develop the major ideas for the study. An initial pilot study was instrumental in providing the framework for additional data collection. Themes were fleshed out through in-depth, semi-structured interviews (Seidman, 1998) that provided individual student profiles and a closer look at the experiences of these students to add support for the developing theoretical framework. Finally, a more quantitative survey was conducted to gather information, including background information, on another set of students who had had IDFB experiences. The survey included both closed- and open-ended questions. Together the data from these different student samples and different collection techniques led to the development of a theoretical framework (Figure 1).

A. Data Collection

Seventy students at four institutions of higher learning in California—three universities and one community college participated in the study (see Table 1). Students were selected based on their current or recent enrollment in an IDFB
experience. Students participated in this study on a voluntary basis. I conducted all of the interviews, and I distributed the questionnaires at sites 1, 2, and 3. The survey was administered by class instructors or electronically.

Students participated in the study in one of three ways (see Table 2):

1) **Questionnaire participants**: Thirty-nine students from sites 1, 2 and 3 filled out a questionnaire with closed-ended and open-ended questions both prior to and following their IDFB experience. Questions were designed to encourage students to comment about the importance of the class to them in a broad sense, both academically and personally. I explained my study and the questionnaire to the students and then handed out and collected their questionnaires.

2) **Interview (and questionnaire) participants**: Twelve students from sites 1 and 2 also agreed to participate in an interview in addition to filling out the pre- and post- experience questionnaires. Interview questions were extensions of those asked in the questionnaire, and were designed to provide a broader context and more in-depth information for a smaller sample of students. I selected students for the interviews from those who had filled out ‘pre-class’ questionnaires. They were selected for the interview based on their gender and self-proclaimed academic achievement. I wanted to select both men and women, and an equal number of average, above average and excellent students.
3) **Survey Participants:** A separate sample of thirty-one students filled out a survey with both closed and open ended questions. Surveys were distributed to students both electronically, and by way of their instructors. Each survey was accompanied by a letter in which I introduced my study and the purpose of the survey. The survey contained a number of closed-ended questions designed to collect background data including students’ undergraduate classes, their income bracket and their parents’ level of education. It also included open-ended questions similar to those in the questionnaires used at sites 1, 2, and 3.

When student responses were coded and data were analyzed using the modified grounded theory approach, themes emerged consistently regardless of the instrument used to collect the data. Similarly, although students were from four different institutions, their IDFB experiences were alike in three key ways: 1) they all involved students designing and carrying out their own research project; 2) the research was conducted ‘in the field’, in an ecological setting and; 3) the research included a significant temporal component where students conducted repeat visits to their study site either over the course of a semester, or more frequently over several weeks. The similarity in their answers to questions and the consistent mention of common key components of their IDFB experiences made it possible to consider all 70 students in the same analysis, and to ensure a common core of information from which the conclusions of this study were drawn.
Table 1. IDFB site descriptions and student numbers by site

<table>
<thead>
<tr>
<th>Site</th>
<th>Description</th>
<th># students filling out questionnaire</th>
<th># students interviewed</th>
<th># students filling out surveys</th>
<th>Total students in study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site 1</td>
<td>Two week intensive field class. Students lived in the field while doing projects.</td>
<td>17</td>
<td>6</td>
<td>0</td>
<td>17</td>
</tr>
<tr>
<td>Site 2</td>
<td>10 week long class. Students spent 5 weeks in the field conducting ecological projects</td>
<td>17</td>
<td>6</td>
<td>0</td>
<td>17</td>
</tr>
<tr>
<td>Survey</td>
<td>Students in this category participated in a variety of IDFB experiences including several-week long intensive field classes and semester-long classes where they conducted field work and made repeated visits to a field site.</td>
<td>0</td>
<td>0</td>
<td>31</td>
<td>31</td>
</tr>
<tr>
<td>Site 3</td>
<td>16 week long class with lecture and field component. Students conducted field work and made repeated visits to a field site</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>5</td>
</tr>
</tbody>
</table>
Table 2. Study participant information by instrument

<table>
<thead>
<tr>
<th></th>
<th>Gender</th>
<th>Year in college</th>
<th>Self rated academic achievement*</th>
<th>Income bracket** (total respondents in parentheses)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Questionnaire participants</td>
<td>M</td>
<td>F</td>
<td>1st/2nd</td>
<td>3rd/4th +</td>
</tr>
<tr>
<td>13 (33%)</td>
<td>26 (66%)</td>
<td>8 (20%)</td>
<td>31 (80%)</td>
<td>10 (26%)</td>
</tr>
<tr>
<td>Interview and questionnaire participants</td>
<td>4 (33%)</td>
<td>8 (66%)</td>
<td>2 (17%)</td>
<td>10 (83%)</td>
</tr>
<tr>
<td>Survey Participants</td>
<td>12 (39%)</td>
<td>19 (61%)</td>
<td>3 (10%)</td>
<td>28 (90%)</td>
</tr>
<tr>
<td>Totals</td>
<td>25 (36%)</td>
<td>45 (64%)</td>
<td>11 (16%)</td>
<td>59 (84%)</td>
</tr>
</tbody>
</table>

* In ecological/environmental sciences

** 50 of 70 students provided information about family income

The majority of the students in this study were 3rd and 4th year students who rated themselves as having above-average academic achievement. There were more women than men, and for those who answered questions about ethnicity and income (35 students), the majority were European Americans whose families were in the middle to upper income bracket. 78% were European American, 11% were Chicano/a or Latino/a, 7% were Asian, and 4% were ‘other’, which included pacific islander and African American. The percentages of average and of above-average academic achievers were more balanced in the group of students interviewed than in other student samples because interviewees were selected to include a range of academic achievement. There were comparatively few underrepresented students, lower academic achievers, and lower-income students in the study. Student
demographics varied little by student sample or instrument used for data collection. What made the study results so powerful was the consistency of student responses regardless of their differences.

B. Data analysis and coding scheme

I used multiple instruments for gathering data as a part of the grounded-theory approach to discovering dominant themes in the data. I initially analyzed responses to the questionnaires, survey data, field notes, and interviews for major themes, which were then validated by having another analyst go through the same process. Data were further analyzed to develop subcategories. I organized all categories into a final coding scheme (Table 3). The coding and analysis process was an emergent and evolving one, and was not itself complete until the end (Strauss and Corbin 1998). The coded data were also counted to determine category ‘weight’ or ‘importance’ (see Table 4).

Individual responses and narratives (through the interviews) provided key descriptors to flesh out and support the major theoretical categories and framework of the study. I used what individual students said to describe the general themes for all of the students. Their statements also provided important context and insights from individual perspectives. This approach to analysis and presentation was highly instructive, and allowed the student responses, rather than my own preconceived ideas, to drive analysis and theory generation. In addition, student responses by code
were counted and divided into the major categories for a numerical representation of the responses (Table 4).

Student responses fit broadly into two main domains: those indicating cognitive development, and those referring to personal growth and other affective indicators. Statements in the cognitive category referred to a student’s enhanced ability to understand or do some aspect of science (in particular field work/ ecology/marine ecology). This included skills learned (including teamwork as well as specific sampling and scientific method skills), the application of theory, and knowledge of scientific concepts. The affective category included statements that referred to how students felt about the experience, and how the experience helped them develop personally, including statements about personal growth, confidence, motivation, future career/educational aspirations, and attitude in general (Table 3).
Table 3. Final coding and analysis scheme

<table>
<thead>
<tr>
<th>Cognitive domain</th>
<th>Affectiv e domain</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Process/application of science: (PRO/APP)</td>
<td>A. Personal Growth (PG)</td>
</tr>
<tr>
<td>1. Skills learned (SKL)</td>
<td>1. Relationships: (REL)</td>
</tr>
<tr>
<td>Asking a scientific question (SQ)</td>
<td>With others (REL O)</td>
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<tr>
<td>Problem solving (PROBSOL)</td>
<td>With professors (REL P)</td>
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<tr>
<td>Sampling (SAMP)</td>
<td>With self (LMY)</td>
</tr>
<tr>
<td>Teamwork (TEAM)</td>
<td></td>
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<tr>
<td>Write a report (REP)</td>
<td></td>
</tr>
<tr>
<td>2. Applying theory in a ‘real’ situation (AT)</td>
<td>2. Confidence in self (C)</td>
</tr>
<tr>
<td>B. Content Knowledge (KNO)</td>
<td>3. Motivation (MOT)</td>
</tr>
<tr>
<td>1. Content knowledge: Understanding/scientific relationships/content/knowledge (KNOWL)</td>
<td>Inspiration (INSP)</td>
</tr>
<tr>
<td></td>
<td>Rewarding (REW)</td>
</tr>
<tr>
<td></td>
<td>Enhanced creativity (CRE)</td>
</tr>
<tr>
<td>2. Adds to other knowledge I have (ADD)</td>
<td>4. Self role (ROLE)</td>
</tr>
<tr>
<td></td>
<td>Realize there is more to be done (discoveries to be made) (MORE)</td>
</tr>
<tr>
<td></td>
<td>Future career/education choice (CAR)</td>
</tr>
<tr>
<td>C. Importance of learning environment (LE)</td>
<td>B. Attitude (ATT)</td>
</tr>
<tr>
<td></td>
<td>Hard work (HW)</td>
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<tr>
<td></td>
<td>Fun (FUN)</td>
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<tr>
<td></td>
<td>Frustrating (FR)</td>
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<tr>
<td></td>
<td>Satisfying (SATIS)</td>
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SECTION 3: Findings

This section presents dominant themes in the data. The themes illustrate how powerful IDFB experiences can be in teaching the process of science, motivating students, helping students see and plan for a future in science, and shaping students into scientists (or teachers of science). The quotes used here, while unique to particular students, represent dominant themes. Quotes are presented in italics–
student’s words have not been changed unless aspects of the original quote might reveal a student’s identity. In that case, those portions were generalized, and appear in normal font type and in parentheses within the quote.

This section starts with a presentation of the major categories of responses, and quantitative results to support them. The analyses are presented quantitatively in two ways: 1) by individual student response, showing how many students made comments in each category; and 2) by an analysis of total coded responses (pooled) by category, emphasizing how often certain themes were discussed—how dominant they were. The remainder of the section will be devoted to illustrating specific dominant themes: increased knowledge and understanding, skill acquisition, increased confidence and motivation, and the ability to plan for future careers/education. Three student profiles will be presented for an in–depth look at their views about their field experience. These profiles represent many of the study’s dominant themes. They illustrate how students from different backgrounds and different academic achievement levels are affected by their exposure to science in an IDFB experience.

A. Major categories of responses

The four supercategories reflect dominant themes in the student responses. Two cognitive supercategories, ‘Process/application of science’, and ‘understanding content (theory)’ and the affective domain of ‘personal growth’ had the highest number of responses, both from individual students and combined (pooled) total responses (Table 4).
Table 4. Numbers and percentages of individual student and pooled responses in 4 super-categories

<table>
<thead>
<tr>
<th>SUPERCATEGORY</th>
<th>Individual student responses (70 total)</th>
<th>Pooled responses (432 total)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Count</td>
<td>Percentage</td>
</tr>
<tr>
<td>COGNITIVE Domain</td>
<td>Process/application of science</td>
<td>59</td>
</tr>
<tr>
<td>COGNITIVE Domain</td>
<td>Understanding content (theory)</td>
<td>41</td>
</tr>
<tr>
<td>AFFECTIVE Domain</td>
<td>Personal growth</td>
<td>65</td>
</tr>
<tr>
<td>AFFECTIVE Domain</td>
<td>Attitude</td>
<td>36</td>
</tr>
</tbody>
</table>

Responses coded in the cognitive domain were further broken down into four main categories for final analysis: 1) understanding process, 2) skill acquisition, 3) applying theory in a ‘real’ setting, and 4) understanding content (Figure 3). Skill acquisition was the most commonly occurring type of comment within this category. Students listed skills such as report writing, designing a study, scuba diving, using transects, data analysis and working in teams as being among the most important skills they learned during their IDFB experiences.
Responses in the affective domain were further broken down into five categories: 1) specific reference to personal growth, 2) confidence, 3) career and preparation for the future, 4) motivation, and 5) attitude. Of these, students most frequently said that they felt their IDFB experiences increased their confidence and helped them with their career decisions and preparation for the future.(Figure 4).
B. Dominant themes

The Cognitive Domain

1. The importance of participating in the process of science: making it real

It seems logical that a deeper understanding of scientific process and application would be an important outcome for students who participate in IDFB experiences, and this was clearly the case. In a standard science curriculum, even one that incorporates laboratory time, students rarely have the opportunity to discover the entire process of science from designing a study to interpreting the results.

“Being involved in the whole process of research, from conception to planning to execution, taught me more about the way science works”

“I learned so much more just because you can be told to do something but until you go out and do it for yourself, you have no idea...definitely challenges you as a scientist and a researcher”.

When students talked about how they learned scientific process and application in their IDFB classes, they were quite specific about the importance of being involved in all aspects of that process, and doing it for themselves. One student reflected,

“I think it is much better to have your own thing. Then you are motivated to answer your own questions...and to really care about the research and what you are doing and be careful about the data and stuff. In the (non IDFB) class, it was just sort of like taking the data...and so I wasn’t really so concerned... like having us try to do something that would be
valuable to them, but maybe because I wasn’t so passionate about it, I didn’t concentrate as much. This (project in their IDFB class) I really wanted to know and so I wanted to do a good job”.

Other students talked about how some non IDFB biology/ecology classes fail to teach them the nature of science as an integrated process. Many of these classes emphasize specific parts of the process, and it is sometimes not clear to the students why the specific aspect that is being emphasized is important, other than the fact that the teacher has decided so.

“Standard labs are hands-on experience of whatever your professor or TA wants you to experience. That could never compare with actually designing, taking data for, analyzing and writing up your own project. Standard labs leave no room for creativity or individual expression of scientific ideas. They merely help students understand how to write up experimental results in such a way that their TA is impressed. Field experiences...let you see the artistic side of science by allowing you to make up experimental designs etc.”

By engaging in the entire process of science, such as in an IDFB class, students are also gaining specific knowledge about methods: “This class has done more for me in terms of understanding and applying research methods than all my years in the formal education system” which, considering that 89% of the students were in their 3rd + year of college, is a substantial number of years.

2. Skill acquisition

Fifty-four percent of all comments in the Process/Application supercategory pertained to acquiring or enhancing skills. The ability for students to acquire skills,
and for teachers to assess them, depends on an educational setting where students can practice those skills. In many fields of science, particularly fields such as ecology, where skill demonstration requires the right environment as well as a sufficient amount of time, creating an educational setting appropriate for skill acquisition is challenging. IDFB experiences are ideal for this, providing a unique opportunity for students to gain expertise in skills many of them will use as foundations to build on in the future.

Students listed a variety of specific skills learned or improved. Specific skills mentioned were: conducting surveys, designing and applying a sampling protocol (various types were mentioned depending on the study), designing an entire study, using quadrats, using specific equipment (type depended on study conducted), conducting a census, using specific computer programs (including statistical programs), writing reports, preparing a presentation, scuba diving, working in teams, and data analysis. Students also elaborated on the more general skills they were able to practice, such as problem solving, critical thinking, and teamwork “...field work has its hurdles up and down it really helps your problem solving abilities and your abilities to work with others...”. It is interesting that students found these skills noteworthy. They are critical skills for general competence and success in many aspects of professional life. Though perhaps recognized as important, they are also skills that are difficult to develop in a standard curriculum, and often underemphasized.
“There are road blocks that you encounter in the field–like having a project idea that looks good on paper, but when you take it into the field it just doesn’t work the way you had thought.”

“Field experiences have less boundaries which allows a person to explore and seek more questions. This leads to thinking”

Teamwork

The specific skill of teamwork deserves some additional attention. This was a theme that was elaborated on in many ways, and crossed both the cognitive and affective domains. Although it is a skill, teamwork is also a very personal process, and can lead to personal growth and awareness.

Science is a process that relies on and emphasizes the role of peers. We often take for granted the skill of teamwork–not easy for all. There are cultural barriers, insecurities about knowledge levels, personality differences, and myriad other barriers to overcome for many to be successful at teamwork. Students of science need to be comfortable with the concept as well as the process of teamwork, and need to understand why it is important, and how to do it.

Working in teams did two main things for students. It provided an opportunity for them to learn how to do it, and why it was important, not just that it was important. One student realized that teamwork helped her work through problems and think about project ideas;

“We had meetings a lot and we are also talking, would always talk things through and it seemed like we are all in the same page…I would have an idea and then someone would expand on that…so it was really nice. …the whole proposing of a project and collecting the data
and stuff. We had a lot of different ideas because there are so many of us…If you eliminate that part, then it is just, I don’t know, not good.”

For many students the opportunity to work with others in depth on a complex problem helped them see why teamwork is so valuable, and what role it plays in project development. They talked about enhanced understanding “Because of the different ideas, an understanding of the subject could be enhanced”. They mentioned that more people allowed for more and new ideas, and different approaches to analysis “we could have more questions and more answers”, and “teams allow many ideas to come together and form a good analysis”.

In addition to these practical benefits, students also learned how to work in teams, and how that process requires them to grow and adapt personally— a key realization for them to be effective members of a successful team.

“Working in groups also always provides something new to learn regarding working with other people. Each new group experience has its own unique positives and negatives and it’s important to learn how to adapt to each situation. …Each person will be able to provide a unique perspective and additional thoughts/information on a particular project.”

3. Enhanced knowledge of concepts

The third important theme in the cognitive domain was students’ enhanced ability to tie concepts together, and learn new ones “It (My IDFB experience) has made me realize that all sciences fit together like pieces of a puzzle—they may be thought as separate areas of learning, but in the real world they are all related”.
This theme was often articulated by students describing how much easier and more relevant knowledge acquisition was when it happens ‘in context’.

“Lecture classes teach the facts and details of science. However it is rare that you remember all the details weeks later. While field classes engage you in the concepts you learn...anything I engage in remains at the top of my mind”.

“I learn facts and concepts much better when (I’m in an IDFB)...they are somehow more important and easier to remember when you actually use them”.

The Affective Domain

The 93% of students who talked about their personal growth as a result of participating in an IDFB experience were alluding to an outcome that is perhaps less obvious at first glance, and one that is not likely stated on many IDFB class syllabi as an outcome or objective. Yet the results in Table 4 show that it was the most important category for the highest number of students, as well as in terms of total responses analyzed. Students focused on three major themes within the personal growth super-category: confidence, motivation, and view of their future educational and professional objectives (their future ‘role’ in science) (Table 5).
**Table 5** Number of students indicating importance of IDFB experience in 3 sub-categories within personal growth: confidence, motivation, and future role (includes career and educational pathway)

<table>
<thead>
<tr>
<th></th>
<th># of the 70 students in the study indicating that their IDFB had this positive effect</th>
<th>% of the 70 students in the study indicating that their IDFB had this positive effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confidence</td>
<td>39</td>
<td>56%</td>
</tr>
<tr>
<td>Motivation</td>
<td>36</td>
<td>51%</td>
</tr>
<tr>
<td>Future role</td>
<td>45</td>
<td>64%</td>
</tr>
</tbody>
</table>

1. **Confidence**

By being responsible for their own projects, and tasked with conducting ‘real’ science, students gained confidence in themselves as developing scientists. Students learned about themselves and their abilities to do science “I learned how to press the envelope of my capabilities”. They gained confidence in their ability to do certain skills “Now I know I can collect data using tools I might not have thought I could use”. They feel more comfortable in doing science, being part of the entire process, making mistakes, and getting the answers right.

“Definitely have more confidence in my ability... before the class I did not know or understand the entire process (because I had never done it before) but now I somewhat have an understanding on how to go about it.”

“This class gave me more confidence. Usually the experiment is set and I perform and critique it. Here I... learn the confounds first hand by committing errors.”
“This class opened up pathways into new scientific processes. Going through the experience it wasn’t obvious any of the changes (in how I view science). Evaluating the overall experience I’ve noticed how much more I know. Now that is a change.... This experience helped me realize that most of my scientific tools are right in my head. After doing my individual project, I was stunned how far I got in the scientific process.”

2. Motivation

The discovery aspect of science, and being a central part of that discovery process, is exciting for students. Through the process they learn about themselves, and their abilities to accomplish new and often difficult feats “What the class expected of me was more than I thought I could do, but I prevailed”, and from a different student: “It re-inspired me to love science again”. This motivation was a tangible outcome for students in IDFB experiences. I distinguished motivation from ‘confidence’; motivation included statements that were not specific to confidence building, but it included words like ‘inspired’, ‘motivated’, ‘interesting’, and ‘excited’—words that described a deeper connection to science, which enhances motivation.

Students were motivated by a combination of factors that resulted from their engagement with the scientific/academic process and the social interactions needed to accomplish their work. These factors included increased confidence, an enhanced self image in the context of the scientific process they were engaging in, a better understanding of the field and its career potential, and a clearer vision of themselves as participants in, not just observers of, the world of science.
Some students were specific about what motivated them; “I was motivated by my interests and by the enthusiasm of the professors and TA’s.” or this student for whom being interested meant applying themselves: “This class has really been interesting for me...I apply myself better to a class that is interesting to me”. Others were less specific, referring to being rewarded or inspired; “It re-inspired me to love science again.” Another said “I think I have higher hopes for myself and my understanding.”

**Teamwork**

The skill of teamwork was discussed previously in the ‘skills’ section of the cognitive domain. However, it is worth bringing teamwork back into the discussion here. Students spoke of personal growth, confidence and motivation as occurring as a result of their participation in teams. Many students said they had not had many opportunities to work in teams. It was a new and sometimes uncomfortable effort for some, but one which they realized was important.

“The whole process of dealing with the everyday problems (of field work), working them out with a partner and discussing what happened is great, and I’m eased a little bit now”

For some, the team approach also brought enjoyment: “Partners often make observations and suggestions that would not occur to you otherwise. This makes projects more interesting and sharing discoveries makes projects more enjoyable”. The combination of enjoyment, increased confidence, and the excitement of discovery was a powerful motivator “Some people sell real estate until they are 60
and then say ‘I don’t want to do this anymore’. If I had this (field work), I can do this until I die’.

3. Future role and career/educational pathway

When students became more confident in their ability to do science after having practiced it, they also understood an important part of what scientists do, which gave them a way to connect themselves to that role. Sixty four percent of all students made direct statements about their enhanced understanding of their future role in science, whether it be what their future educational directions could be, their career choice, or both.

“It has made marine ecology seem more accessible as a future career. I feel like I’m more a part of this field now that I have done some of my own research in it.”

“I’ve realized science is extremely important. I will definitely follow-up on some sort of career”.

“My ideas of grad school have changed because now I see the involvement more than ever. I feel that it is more reasonable than I thought, and within my reach.”

“Now I know that I want to continue doing biology field work. Science is a way for me to understand the world around me, (it had) A HUGE impact. I feel much more ready to work in the science field now, whereas before I had some doubts.”

These declarations document the affective impact of an IDFB learning experience; they show evidence of students’ growth and development as scientists in ways that are more difficult to measure than the acquisition of theoretical and factual
knowledge, or even the demonstration of skills. If ecological science programs aspire to prepare undergraduates for graduate school and to be professionals in the field, it makes sense to engage them in IDFB classes that help them aspire to that. IDFB experiences allowed students to immerse themselves in all aspects of scientific process. As they learn new things, practice new skills, and do science, they also grow personally, becoming more confident and motivated. And as students grow personally, they become more motivated to learn and ‘do’ their projects, acquire new skills, and ‘be’ scientists. This connection between cognitive and affective growth becomes more evident in the next section which profiles three students.

C. Three student profiles

I decided to profile these three students because, despite their individual differences, their comments about their IDFB experiences illustrate the common themes outlined above. These students gained a better understanding of science, an opportunity to think like a scientist (by being one), motivation, confidence, and an ability to think about and prepare for their futures in science (academic and career). These are key outcomes for students, and could lead to better preparation and increased retention for students in the field of science; goals that many biology programs at institutions of higher education would hope to achieve in their graduates. Yet these students, and others in this study, are telling us that it was the IDFB opportunity—a chance to really do science—not the standard science curriculum—that achieved these outcomes. For these profiles, I chose three students who had vastly
different experiences and backgrounds to show how a field class can be important to all students—even those we suppose might not ‘need’ this type of experience to succeed.

Karen

Karen had never taken a field class nor participated in field work, despite the fact that she was a second year environmental science major, with an interest in field work. She rated herself as an average to poor student (one of the 26% to rate their own science achievement as average, and the only one to mention ‘poor student’). She expressed concern about the difficulties of a science curriculum given her academic achievement level. She said she wanted to take the field class to see if it was really what she wanted to do, given the mostly negative experiences she expressed regarding her science curriculum in a formal academic environment.

“I’ve learned from class that science can be really boring. I’ve learned from groups I’ve been in and from the news that science is important to change policy and help protect the environment. Since I want to help the environment, I’ll need science….Regular classes make me not want to learn science… Labs are boring, field experiences are fun. Maybe It’s because labs are planned, and we don’t get to see the relevance of them.”

Although Karen was motivated to pursue science to “help” and “protect” the environment, she was concerned that she might not succeed academically. Her science curriculum had failed to engage her, and she was losing interest. She hoped that this IDFB experience would help “Field experiences take me out into the field so I learn and understand by seeing things first hand”.
Luckily for Karen, she was able to participate in a field experience earlier in her academic career than many. Her cognitive growth during the IDFB class considerable. After her field class, her response to ‘how do scientists discover things’ had changed to include a greater knowledge of both process and the role of peers “…be patient, analyze data, and find correlations…discuss results with others, and discover new questions”, words that describe important parts of the process that scientists engage in. Her understanding of how to ask a scientific question had vastly increased, from “Why do (a specific animal) have long-term memories?” (a very broad and difficult to measure question) to “Does (a specific type of plant) influence the diversity of its surrounding habitat (plants)?” – a measurable question. By participating in the process of science through her IDFB class, Karen also gained important skills, and an understanding of how to apply the scientific process.

“I learned that there can be a lot of error in counting populations, and that some methods might not be very accurate. (I learned) point contact, quadrat counting, population census….now I feel like I can write a scientific report.”

This cognitive growth in skills and in understanding the process of science was also accompanied by increased confidence and the enjoyment of learning (affective growth) “…(N)ow I know I can do it (field work)…and that if I had a question I could probably come up with a method to test it. I learned things without having to memorize stuff. It’s easier to understand something when it’s done hands-on”. This from a student who also said, “In lecture I sleep, so I don’t learn much”.
As she gained confidence in her abilities, and became motivated by her connection and enjoyment of the process, Karen was able to put her career goals into context; “I have a much better idea of what this (field work) all takes now”. In a later conversation, Karen told me that having been involved in scientific projects through the IDFB class gave her a much better understanding of what field science entailed. When asked what she wanted to do as a career before the IDFB experience, she said “…work outdoors and be a field biologist…”, even though she had no real contextual knowledge of what that meant. Afterwards she said that her career aspirations had not changed (she still wanted to be involved in conservation), but she had renewed motivation to pursue them and a better understanding of which classes she needed and why graduate school was likely to be important.

For Karen, the IDFB experience offered an opportunity to better understand her field of choice, see that she was capable of doing things she had only heard about, and get a more realistic view of field science by actually doing it. This connected her to the world of science in a way her previous classes had not. She developed as a scientist through increased knowledge, skills, and understanding of the scientific process, as well as through renewed confidence and motivation. She gained a better understanding of what science is and what scientists do. Although I did not discuss this with her, she is the type of student (based on her descriptions of her classes and how much she disliked them), who may very well have dropped out of a scientific track. Karen is now prepared to make better informed decisions about her academic and professional future.
Maria

IDFB experiences can also have a significant impact on higher-achieving students who are juniors and seniors, and who have had significant opportunities already in their lives. Maria is an ethnically underrepresented senior biology major, interested in becoming a university professor and researcher. She was not sure just what she wanted to study, despite the fact that she was soon to apply for graduate school. Members of her family who were close to her were biologists, providing accessible role models. She rated herself as ‘excellent’ academically. She had participated in numerous field experiences, though none in which she had designed her own study and been responsible for data analysis and outcome. She was highly motivated “I put in a great effort… I was obsessed with my project, and I tried my very best”.

In spite of her prior experience with field-work, being responsible for her own project helped Maria learn new skills and gain a better understanding of scientific process. She discovered “how important observation was in science”. She also gained insights about data collection. For example, she discovered first hand that when collecting data, it is important to consider “…The conditions under which you collected them, so as to make sure no other variables than the ones you’re analyzing are affecting your data…..you can also try and analyze it pre-maturely, to see if the experiment is going where you think it should…”.
Although she was academically strong, Maria said that the IDFB class gave her “confidence to engage in scientific projects. It gave more of a sense of how it is to actually engage in this field, and the kind of mind-frame you need”. It also helped her realize that ecology is not just knowledge acquisition. “To me it was enormously helpful to get a glimpse of what I was actually getting into, and I must say it was really different in a very good way. I actually enjoyed the process of science, not just knowing the answer”. She was inspired. For her, science was suddenly “a whole new thing”.

Maria had always wanted to be a scientist, but her IDFB class helped her internalize what it meant to be a scientist. “All my life (or most of it) I’ve wanted to be a scientist, and I’ve been studying it exclusively now for four years…”. Designing her own study in the IDFB class provided her with a clarity that she had not experienced before. The IDFB class “has shown me basically what it is that I aspire to do”. She added….“And since I enjoyed the experience…..I think that I can look forward even more to doing my PhD and all, and not just wanting to get it over with, and finding something cool”.

Like Karen, Maria learned more about what science is and what scientists do through her IDFB experience. She developed as a scientist primarily by having the opportunity to be responsible for a scientific project--designing it, collecting and analyzing the data, and interpreting the results. “I(had) never seen this part and I realized that this what I was getting into”. She was better able to plan for her future
and put past experiences into context with herself as the ‘Principal Investigator’, or as she puts it, the ‘cook’:

“…The field experience is, however, the process of science. The process of making science… Like baking a cake, one must have the ingredients, and then go forth and do something with them. Hence, one will find if cooking is actually an experience he or she wants to continue to do.”

Aaron

Aaron was a junior in college, and he rated himself above average academically. Prior to his IDFB class, he had not participated in projects or experiences where he was involved with the entire process of science, and yet he was pursuing an ecology track in college—one that would involve fieldwork and project planning. He reflected on the importance of his IDFB class with respect to his college career; “If every quarter is like this (referring to the field class), I am sure I would have gotten so much more out of my classes in college”.

For Aaron, the IDFB class provided a baseline he could use to apply new and past information learned in science classes, allowing him to appreciate the application of science. “I have learned so much about algae and fish here, that when I take the next set of classes, I will be able to use those concepts and apply them to things that I have learned before this class and during this class, so that will be pretty neat to just back up everything with the systems that I have seen here and apply it to whatever else I have learned”. It gave him a broader cognitive picture of the field and of the process of science: “This class has definitely prepared us with a
lot more, a much more broad scope of what marine ecologists have done…”. He also gained valuable skills and knowledge: “I am much more comfortable with PC’s and SysStat and Excel and PowerPoint and making presentations and stuff like that”.

In addition to gaining new knowledge and skills, Aaron felt that doing science “like other scientists do” established his own capacity to do science. “…(I)t is just nice having that confidence level, where you know you have learned something; …now I know how to sample fish counts and test for this.” He also gained confidence in his ability to conduct research: “I feel very confident in myself being able to come up with another idea, run through the experiment … at least I know how to begin”.

The IDFB experience motivated Aaron to consider graduate school and a career in science. He had a clearer idea of the path he wanted take: “I would like to get a Masters first…then a PhD down the line…”. It had also opened his eyes to a new system to study: “I never really thought about the coral reef system, I have always been a kelp forest kind of guy”. He was excited about his future educational path. “Now I am considering applying to graduate school at the University (one known for its marine program), and I would never have thought of that in my entire life…. As far as grad school is concerned, I feel very confident”.

Aaron was able to make a very personal connection with science, and to see himself as a scientist: “I think it has been one of the most valuable, it is probably the most valuable, scientific experiences that I have ever had; it has made it real,
because we came up with a question like other scientists do and we came up, we set up our own project and we evaluated it ourselves and we wrote it up and so, you can’t get more real than that. It is not all on a professional level, but nonetheless still science.” Few experiences can better prepare students as scientists than one that makes students feel like a scientist, doing real science.

These three student profiles demonstrate the important connections that IDFB experiences create for students—connections to science as an academic subject, a process, and a world or community of scientists. The theme of learning by doing, as elaborated by Karen, “Field experiences take me out into the field so I learn and understand by seeing things first hand”, is central to the importance of an IDFB experience. It is through students’ involvement in doing science that the cognitive and affective measures of development occur.

Inquiry-Driven Field-Based experiences in the ecological sciences:
Student involvement in the process of science in a contextualized setting

<table>
<thead>
<tr>
<th>Cognitive measures of development:</th>
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<tbody>
<tr>
<td>Skills</td>
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<tr>
<td>Application of theory</td>
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<tr>
<td>Enhanced knowledge of scientific concepts</td>
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<th>Affective measures of development:</th>
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<tr>
<td>Personal growth</td>
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<tr>
<td>Confidence</td>
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<td>Motivation</td>
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<td>Future career/educational aspirations</td>
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All three students talked or wrote about how the IDFB experience affected their cognitive growth. They were able to practice and become more proficient at skills. Karen mastered point contact, quadrat counting, and population census techniques, Maria came to understand the importance of observation in science, and Aaron learned about algae, fish and the breadth of marine biology as a field. They were also better able to understand and apply the scientific process. Karen felt that if she had a question she could “come up with a method to test it”, while both Maria and Aaron articulated the importance of being scientists doing science—the entire process. Through this cognitive growth, they also grew personally, gained confidence, and became more motivated. As their confidence grew, they were able to engage more fully in the process. This was a positive feedback loop.

Karen spoke about the lack of engagement in her science classes and about how much more interesting it had been for her to “learn and understand by seeing things first hand”. She felt more confident and motivated by her experience. Maria described how inspiring it had been to be involved in the whole process of science, and the confidence she had acquired as a result. Aaron specifically stated “I feel very confident in myself,” which in turn helped him believe in his abilities and plan for graduate school in science.

Their enhanced cognitive understanding, along with greater confidence, motivation, and excitement about science, helped the three students think about their futures. Maria said, “It has shown me basically what it is that I aspire to do…I think that I can look forward even more to doing my Ph.D.” Aaron was able to think
through a Masters to a Ph.D. and expand his ideas to new systems (coral reefs).

While Karen did not specify her future plans as a direct result of participation in the IDFB, she was clearly better prepared to do so: “I have a much better idea of what this (field work) all takes now”.

Given their new contextualized understanding of the scientific process, their new skills and concepts, and their affective growth in confidence, motivation, and future career/educational pathways, these students have matured as developing scientists. They have gained a grounded understanding of what science is and what scientists do. Aaron said, “(IDFB) has made it real, because we came up with a question like other scientists do.” Maria noted that “(i)t gave more of a sense of how it is to actually engage in this field, and the kind of mind-frame you need.” Perhaps showing the greatest learning of the three students profiled, Karen said, “I learned that there can be a lot of error…and I realize that anyone can do field work.” Armed with new knowledge and an enhanced sense of how they relate to the field of science, these students were able to connect with the world of science.

Cognitive measures of development:
- Skills
- Application of theory
- Enhanced knowledge of scientific concepts

Affective measures of development:
- Personal growth
- Confidence
- Motivation
- Future career/educational aspirations

Development of students as scientists: understanding of what science is and what scientists do
SECTION 4: Discussion

There were five key outcomes to this study (see Figure 1):

1) There were more responses and comments from students related to affective development as a result of participation in an IDFB experience than to cognitive development. Clearly, their personal growth was as important to them, or more so, than their cognitive growth.

2) As a result of their IDFB experience, students grew personally, gained confidence in themselves and their ability to conduct science, became motivated, and gained an increased sense of their future potential and direction, whether that be future education (eg. graduate school) in science or a science career.

3) Participating in an IDFB experience allowed students to practice science, and learn the skills, knowledge, and process needed to conduct a scientific study successfully. This cognitive development was uniquely powerful in that it arose through their active participation and leadership in the process, rather than through passive learning.

4) Both the affective and cognitive growth occurred as a result of participation in the process of science in a contextualized setting: students were responsible for designing their studies and interpreting results. Based on the results of this study, I make the case that this led to a relationship between affective and cognitive growth whereby they
influenced each other. For example students gained confidence as a result of successfully applying a method, and as they became more inspired and/or motivated by their study, they were driven to learn more, and engage more.

5) By doing science, students learned to be scientists, and to understand science and science concepts in context. This development of students as scientists resulted from the particular type of cognitive growth (applied theory and practice), and personal growth they experienced in their IDFB opportunity.

In this section I place these results in the larger context of a science learning experience. I begin by making the connection between cognitive and affective learning, and how important IDFB experiences are in providing both to students. I focus on affective growth, since this was so important to students in this study, and it is often overlooked when analyses of the effectiveness of a learning experience are conducted. I make a case for the mutually influential relationship between cognitive and affective growth (Figure 1). I discuss these findings in the context of the educational system, and the importance of including an emphasis on affective development in programs of study. I then discuss the specific importance of discovery to the process of science, and the role IDFB experiences have in creating that experience—one that can motivate and excite students. Finally, I discuss the results of this study in terms of their potential application in two areas: 1) recruiting
and retaining students in the science pipeline and, 2) preparing students for future
careers/education in science.

A. Involving students in the scientific process: creating a relationship between
cognitive growth and a personal connection to science.

This study looked specifically at academically oriented field experiences in
which students have a key role in the entire scientific process, and are responsible for
many aspects of planning, conducting, and interpreting results from a research effort,
rather than being led passively through the process. Students of science are rarely
exposed directly to the process of scientific investigation until late in their
undergraduate career or in graduate school (Bowen et. al, 1999). It could be argued
that laboratory exercises involve students with hands-on science, and introduce them
to the process and techniques of science. However, the constraints of labs (including
time limits, the breadth of information covered, and a highly structured approach)
often limit students to just part of the process of science (Bowen and Roth, 2000,
Dayton and Sala, 2001; Jarrell 1999). In order to prepare students well for further
academic engagement in science, such as graduate school or careers in science, it is
essential that students also be taught how scientist think, and how science is done.
The most effective way to do that is to engage them in a ‘real-life’ science
experience, where they are responsible for the design and outcome of a scientific
project (Southerland, 2001; Ryder et al.1999).
We teach students to write by having them write, and to read by having them read. Yet we rarely offer students of science the opportunity to do real science, to actually practice it, come up with their own questions, methods, and analyses. While studies show the importance of self directed inquiry, ‘real-life’ context, and active learning in science for student success (Ash and Wells, in Press; Ash 2003; Minstrell, 1999), these methods are not common in college science classes, in particular for freshman and sophomores. Many students of science enter their science degree track through large and impersonal theory-based classes, which provide them few opportunities to practice the science they are learning about. Field experiences, with opportunities for students to plan studies and engage in analysis, is an effective pedagogical method for practicing science.

The results of this study show that through participation in IDFB experiences, students demonstrate both affective and cognitive measures of growth. Cognitive measures, such as skill development, can lead to affective measures such as increased confidence: “now that I’ve gone through the process and done my study, I know I can…” Likewise, affective indicators such as increased motivation, confidence, and a personal connection to the process can lead students to seek additional cognitive skills and theoretical knowledge, and to engage more fully in the scientific process: “[this IDFB experience] has made [science] more real for me…when I take the next set of classes, I will be able to use concepts and apply them”. This link between cognitive and affective measures of growth was a key outcome of this study; IDFB classes allow students to experience their overlapping
influences. Student growth in both the cognitive and affective domains was an important part of their development as scientists. The dominance of responses in the affective domain and the primary themes of personal connection, confidence, motivation, and future preparation and direction in science are indicative of how important these affective measures are to science students’ growth and development. Because of the dominance of these themes, I will focus on affect and its role in the learning environment.

B. The importance of affect to student learning

Most reports on the problems of the educational system in the United States have historically focused on the educational aspects of cognitive achievements (Sonnier 1986). This is reflected today in many of the policies and programs in place in the public school system, and the high stakes accountability mandated by current policies, which emphasize achievement in terms of cognitive knowledge and skills. This focus on facts and memory as indicators of achievement fails to recognize what is well known by employers (and employees once they enter the 'real world' of work): that the ability to apply knowledge, integrate concepts, solve problems, and stay motivated are essential to success, and in many instances are more important than 'just knowing' (Crane et al, 2000; Bishop and Carter 1991; Paquette, 1995; Johnson, and Packer, 1987). In addition, many employers emphasize the importance of motivation, enjoyment, and ‘upward mobility’ (Crane, unpublished data) to success in the workplace, and the lack of emphasis on such
'affective' skills in the educational system. Although there are researchers who recognize and study the importance of the affective domain— the attitudes, feelings and motivation of students,—there seems to be little movement to take these aspects of education seriously on a large, reform-scale level. At the college and university level, where many students are in the 'final stretch' of learning prior to seeking jobs or graduate studies, one would think that a recognition of the importance of motivation and application of knowledge and skills to their success would have been translated to programs of study that emphasize, or at least include, hands-on or experiential learning. Yet most do not, and those that do often offer these types of classes or internships at the end of a student's college tenure. Additionally, except for targeted programs, there is often poor advertisement of these opportunities, and consequently low diversity of students participating in them. This seems especially true in the biological (in particular field-based) sciences.

Most of us are motivated when we are successful at an endeavor, enjoy it, and/or feel that it is (or will be) rewarding in some way: “Some people sell real estate until they are 60 and then say I don’t want to do this anymore. If I had this (field work), I can do this until I die”. This study provided evidence through students’ words of how important the IDFB experience was in helping them connect to the field of science and feel and think like a scientist. They gained confidence in themselves through practicing science and being responsible for their research, and they learned about themselves through that engagement, often as a result of the social dimension of the process. For students in this study, this personal connection
and motivation led them to think about their future as scientists, and realize their potential as students of science, and as scientists. It is possible, then, that if students who were motivated to start a science track in college don’t have an opportunity to renew that motivation during what is usually an academically rigorous and often disconnected curriculum, some of them may not finish. Others may not be able to form a vision of their future role in science—critical to their planning for careers and/or graduate school.

C. The role of investigation and discovery in motivating students

Science is an evolving set of theories and hypotheses. It is a language, a set of descriptors, and a sometimes overwhelming volume of facts and ‘knowns’. But more accurately, science is a process. All of those theories and facts, and the language to describe them, are the result of investigation. Process and investigation are active words, and when we look at science that way, it suddenly becomes an experience that is done, as well as learned about (a much more passive way to describe it). The history of science is full of stories of investigators who sought to tell a story, or discover new species, or find cures. Stories such as solving the mystery of the double helix, the voyage of the Beagle, the Challenger expedition, and the discovery of penicillin. These are exciting stories, each one involving scientists and students who were motivated to help solve a puzzle, and discover new things.
“My ideas have changed…because before the class I didn’t realize how many things are undiscovered”. For many students, the way we teach traditionally (with facts, known outcome labs, etc.) leads them to believe most of science is ‘already known,’ making it more difficult for them to see a discovery role for themselves. “[Field experiences] help open your mind and realize that there is so much out there left undiscovered and so much more you can do with science”. This is truly an epiphany for many students who struggle to think about what they can contribute to the field, and if there is really anything left that could be novel or unique. The power of a program (such as an IDFB class) that shows students that there is, in fact, room for them to contribute, and that gives them the confidence that they can contribute, is evident in students’ responses in this study. The IDFB experience leads them to think about their futures and how they can plan for it. They have a clearer idea of what they want to do and what they can do.

Many contemporary ecological science classes offer few opportunities for students to truly engage and discover science for themselves (Dayton and Sala, 2001; Bowen and Roth, 2000; Fernandez-Manzanal et al., 1999). Young people who have the energy, enthusiasm, curiosity, and investigative nature so important to science are drawn to the field, in many cases only to be overwhelmed by a disconnected set of information. For many students, an early experience such as science camp, a field program, a camping trip or other experiences, is important to connecting them to science, and motivating them to pursue it (Jones, 1997; Crane unpublished data). Each time a student ‘drops out’ of science, the field loses an important potential
contributor. The result is that those who are able to make it through, and maintain motivation and interest, are often those who are able to afford special opportunities outside of school, find them in school, and somehow persevere through the curriculum. It does not seem to be a mystery why the field of science lacks diversity in the people who successfully enter it. There are often multiple steps and pathways to navigate in a science curriculum, and it can require significant skill to find and pursue a course of study that includes unique opportunities such as IDFB classes. It is clear that by the time a student graduates with a science degree, and especially by the time they go on to graduate school, many have been sifted out (National Science Foundation, 1998), and those that remain have had the means (and this does not mean just financial, but a variety of support mechanisms) to do so.

D. The science pipeline: a role for IDFB opportunities?

Learning opportunities in science that involve students directly in the process of science are an effective way to ensure learning, and, as this study demonstrates, to create a connection for them to the field of science, in particular through personal growth as a result of participating fully in the process of science in a contextual setting. Although this study is limited to the role experiential learning plays in the cognitive and personal development of college undergraduates and their development as scientists, the results point to a potential role for IDFB experiences in connecting more students to science—possibly serving as a mechanism to recruit
and retain students in the sciences, including underrepresented students, and help them plan for their future.

Retaining students in the science ‘pipeline’ is a challenge. The sciences in general suffer from high drop-out rates compared with many other fields, despite the fact that large numbers of students enter a science track as undergraduates (National Center for Educational Statistics http://nces.ed.gov/surveys; National Science Foundation, 2003 & 2000; Sanderson et al., 1999). Ethnic minorities and people from lower socioeconomic backgrounds are particularly poorly represented in science degree programs (National Science Foundation 2002 & 2000; National Center for Educational Statistics, 1998; Brown 1994; Thomas, 1984). There are numerous reasons for this, including socio-economic challenges, lack of access to programs, poor support, and ineffective recruitment (Dale, 2000; Ellis 2000; National Center for Educational Statistics, 1998; Sanderson et al. 1998; Jones 1997; Allen et al., 1992). Approximately 23% of science and engineering degrees are obtained by underrepresented students, and 26% of them switch majors away from science and engineering before graduation (compared to 14% of white and Asian/Pacific Islander students) (National Science Foundation, 2000).

This would indicate that many students’ initial interest in science fails and they become disconnected from the subject. For some of these students, IDFB experiences could help them remain in the science ‘pipeline’ (Bembry, 1998; Rosser, 1993; Collea, 1990). Experiential learning programs such as IDFB classes are uniquely suited to creating the kind of real-world community that engages students
helps them find meaning and motivation in their education, and prepares them for careers and future involvement in the field (Halpern, 2002; Gibson and Bejinez, 2002; Nagota et al, 2001; Crane, 2000; Stanton-Salazar et al 2000; Jarrell, 1999; Rogoff, 1998; Kahne, 1996; Posner and Vandell, 1994).

**E. The role of IDFB experiences in preparing students for the future:** “It has made (it) seem more accessible as a future career…”

College students who are prepared to think about and plan for their careers and educational pathways are able to arm themselves with information, experience and opportunities that will increase their ability to make good decisions based on personal interest as well as good information (Brown 1995; Rosser 1993). Being exposed to science process and career possibilities, such as through IDFB experiences, might even persuade some students to pursue such a career (Jarrell, 1999; Brown, 1995) “I wasn’t really thinking about a career in this field before this class, now I really am”. Another student thought about a career move because she or he enjoyed the experience: “I didn’t think that I would actually do research much after college, but because I’ve had a great time with it all, I can see myself doing it more than I had previously pictured myself”. Students such as these should be at the forefront of our efforts in science education at the undergraduate level: those who are bright and otherwise motivated (and in many cases lucky enough) to go to college and pursue biology, but who are disenfranchised with the field, and possibly at risk of dropping out of biology. They need a way to connect and see a role for
themselves, which could lead to higher motivation and retention (Rosser, 1993; Rodriguez, 1993, Thomas 1984).

Our curricula often place an undue emphasis on content, relegating the discovery of what students will actually do with all that knowledge after college—the practical applications—to extracurricular activities. Field experiences allowed the participants in this study to connect what they were doing in an academic program to what they might do in the future—either in graduate school or beyond. One student had participated in several field experiences that had taught him not only about what he wanted, but also what he rejected in terms of potential careers; “[IDFB experiences have] given me the opportunity to experience many occupations. Some I have liked, others that I thought I would have liked I have not, and that’s so valuable. The ability to ‘try’ something before committing to it is unprecedented, and the ability to do this at the undergraduate level is almost unheard of”.

SECTION 5: Conclusion and Future Directions

This study has demonstrated that IDFB experiences provide an understanding of what science is and what scientists do for students of ecological and environmental sciences. This understanding provides a solid foundation for students on which they can build their development as scientists—particularly in an area of science that emphasizes and relies on field research. For students in this study, that understanding came through a combination of cognitive growth, such as applied
knowledge and skills, and of affective growth, such as a personal connection, increased confidence and motivation, and an enhanced sense of future career and educational directions. The dominance of the affective themes articulated by the students in this study suggests that educators and administrators should pay attention to both cognitive and affective indicators when evaluating science curriculum. Students in this study provided important insights into the role these experiences play for them, and therefore the role they could play more widely in undergraduate science programs.

Using instruments to assess student views of their learning, rather than relying on instruments to measure cognitive growth exclusively, is an effective way to inform investigators about the overall value of an educational experience (Silverman, 2001; Strauss and Corbin, 1998). They allow us to explore student learning from the student’s subjective perspective. They also provide insights on what students find most important about the learning process. This approach allowed me to elicit information from students that shed light on the role and value of IDFB experiences to them. Students benefit from development of a better understanding of their relationship with science, and more confidence about cognitive growth, including skill acquisition.

The model developed as a result of this study will serve as an important framework for future research, including the development of additional instruments to investigate specific measures of student growth as a result of IDFB and other experiential learning venues. More data will inform and develop the model,
providing needed evidence for the role of experiential learning in preparing students of science for further education and careers.

Although results from this study agree with the larger body of evidence suggesting the importance of hands-on and experiential learning, the general findings suggest implications for students at different learning levels. For younger students, experiential learning might be key in attracting them to a field of study such as science, as well as help them grasp important concepts. For students in higher education, who have ‘decided’ to pursue a field of study, this kind of learning helps them think like scientists, relate to being a scientist, and understand the larger, more complex process of scientific investigation as a scientist. It may also serve as a mechanism for recruiting and retaining students who are unsure of their field/career direction and/or do not see a clear role for themselves in this particular field of science.

This study provides an initial framework and working model that can serve as a base for further research into the impacts of IDFB experiences in science education. In particular, the potential of IDFB experiences to enhance recruitment and retention of underrepresented students in the ecological and geo-sciences, at both the K-12 and undergraduate levels, is an area that warrants further investigation. We also need to know more about how IDFB experiences prepare scientists for graduate school and careers. More research is needed to tell us about the pedagogical and practical value of IDFB experiences at all levels, and about how IDFB experiences advance teaching and learning in the sciences.
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