Technology, Accuracy and Scientific Thought in Field Camp: An Ethnographic Study

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ABSTRACT

An ethnographic study was conducted on an undergraduate field course to observe and document lived experiences of students. This paper evaluates one of several emergent themes: that of technology dependence, and how it informs students' understanding of scientific reality. In the field, students tried to arm themselves with as high a degree of precision as possible. They assumed that technology was equated with precision, and in turn, precision with scientific reality; i.e., accuracy. Students rejected the notion that in some situations, low levels of precision may be "good enough" to be accurate.

This theme of technology dependence suggests five broad implications. First, students are rarely taught, and rarely understand, the difference between precision and accuracy. Second, students should be taught to appraise a situation to apply an appropriate level of precision, rather than to assume that more is better. Third, students should be taught to value the process of doing things "by hand," such as locating oneself on a topographic map. Fourth, students should have ample opportunity to explore the complexities of physical and scientific reality. Finally, field camp is a late opportunity for shaping the professional growth of future geoscientists, and thus deserves a prominent place in geoscience curricula.

INTRODUCTION

Geologists generally recognize field camp as the time when undergraduates make (or begin to make) the key transition from student to scientist. Field camp is a capstone, integrating separate courses such as petrology, stratigraphy and structural geology into a single experience. This integrative experience is part naturalistic description of the physical world, and part scientific interpretation of its long-term history. Field camp is a unique opportunity to study the real world, while reinforcing classroom experience and building student confidence and interest (Fuller, et al., 2006; Maskall and Stokes, 2008). Despite these benefits, the number of field camp courses being offered nationally has been steadily declining for some years (Costello, 2007). Field camps are expensive, and generally do not recover their costs through tuition (C. Andronicos and W. Cornell, 2003, personal communication). In times of shrinking budgets, many programs are forced to fight for their field camps, or to simply eliminate and outsource them. It is now, more than ever, crucial for us as geologists and as educators to justify the continued effort and expenses associated with field education. The purpose of this ethnographic study is to support field education by a narrating and interpreting the mental lives and constructed realities of a sample of undergraduate field camp students.

Many workers have described and analyzed field education. Whitmeyer, Mogk and Pyle (2009) provide an overview of the history of field education, and its subsequent evolution, as a prologue to a volume of field education contributions titled, "Field geology education: Historical perspectives and modern approaches." This Geological Special Papers volume (No. 461) contains accounts of established field programs, descriptions of technological adaptations and advances, original research in field education, contributions on field experiences for teachers, and treatments of field education pedagogy and assessment. I refer readers directly to this volume, rather than summarize it further here.

Ernst (2006) writes on the importance of field mapping from the perspective of a senior geoscientist. He considers field relationships to be the "ground truth for all earth science investigations" (p. 14). Nyman, et al. (2008) discuss the importance of field-based learning and teaching as part of the broader geoscience training of K-12 science teachers. They argue that geoscience departments directly contribute to and merge with their universities' missions by training preservice teachers in earth sciences. These workers then argue that for the general public, a strong background in the earth sciences (and by definition, this includes field-based learning) is crucial to coping with public welfare issues. Elkins and Elkins (2007) conducted an outcomes-assessment study comparing field and classroom learning experiences. Their study provides statistical and empirical data as evidence of the benefits of field education.

Riggs, Lieder and Balliet (2009) conducted a study of field camp learning as a function of navigation and movement. In this study, students carried global positioning system (GPS) transmitters that recorded their movements, which were overlain onto a geographic information system (GIS) grid. Riggs, Lieder and Balliet (2009) then produced GIS polygons that described each student's navigation choices over the landscape throughout their mapping efforts. These workers argue that learning by moving through a landscape has no classroom analog and is, therefore, an implicit justification for field education. Riggs, Lieder and Balliet end their discussion with a call for the use of qualitative methods in order to more deeply understand student navigation choices, their behavior in the field, and the nature of their field-situated learning. This ethnographic study is a response to their call is through formal, phenomenological exploration of the "essence" of student field experience.

This essence, and how it shapes field learning in the geosciences, has not been well studied. By "essence" I mean such things as day-to-day life in the field for students, their interpersonal interactions and, most

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importantly, how students construct reality, both on a private, individual basis, and as part of an interactive class group. The process of understanding these phenomena is distinctly different than measuring parameters such as what students know, identifying an improvement in skills or even assessing the impact of affective phenomena. Skills improvement, "knowing" and cognitive processes, in general, are in large part the end results of internal processes such as lived experiences and the personal (private) construction of reality. This is not to say that reality is only constructed through private processes. Given the highly social and interactive nature of field camp classes, the construction of reality is also dialectical and interactive in nature.

Petcovic, Libarkin and Baker (2008, 2007) explored skill acquisition and cognitive processes in their studies of novice-to-expert progress in geologic mapping. These workers tracked field mapping teams with GPS, followed up with interviews and systematically compared individual maps to evaluate them for completeness and accuracy. Students also recorded audio logs during their mapping activity. Petcovic, Libarkin and Baker (2009) concluded that the metacognitive skills of synthesis, hypothesis testing and ongoing revision distinguished novices from experts. These workers focus on the metacognitive differences between novices and students with greater potential to become experts. How are these differences developed? What are the internal processes—such as the private construction of reality—that lead to metacognitive sophistication?

Many workers (e.g., Boyle, et al., 2007) consider these internal processes to reside in the affective-domain of learning. No matter how we decide to locate or describe these processes, they remain critical in shaping the outcomes we measure. Yet internal processes resist quantification and measurement. They are best studied not through quantitative instruments, but rather by immersed, painstaking observation and documentation to produce a compelling narrative. This narrative is a detailed story of the processes and benefits of field camp learning, presented in the ethnographic tradition of inquiry.

ABOUT ETHNOGRAPHY

Ethnography is the traditional domain of anthropologists who immerse themselves in a "culture-sharing group" (Wolcott, 1990) in order to study that group. Much of the time, entirely different societies are the focus of ethnographic study. But the students enrolled in a field camp geologic mapping course are also a culture -sharing group, by virtue of their common experiences of traveling to the mapping site, negotiating the landscape, comparing and compiling joint maps, interacting with instructors, and living together under primitive conditions. Students in field camp classes also demonstrate shared patterns of observable behavior. The culture sharing in a field camp class is independent of the students' demographics, but is rather an expression of shared experience and behavior. As a culture-sharing group, a field camp class is appropriate for ethnographic study.

In the summer of 2009 I conducted just such an ethnographic study. My goals were to document and understand how the enrolled students constructed knowledge, perceived reality and coped with novel field experiences. I expected multiple themes ("results") to emerge that would describe the field learning process, which in fact did happen. In this paper I describe just one set of "results" and implications, which is the technology-dependence and construction of scientific reality that I observed among field camp students who were assigned to measure an interval of stratigraphic section. Before I present the methods and results of this study, it is important to note that ethnography is not a strictly empirical process, such as that typically practiced by traditional geoscientists. In order to provide a context in which to understand how I obtained my "results," what follows is a brief discussion contrasting the ethnographic method with our more familiar physical science methods.

Many geoscientists have legitimate concerns about the nature and appropriateness of non-numerical methodologies of inquiry, such as ethnography. However, some educational problems in the geosciences require qualitative approaches, because they revolve entirely around the personal realities, perceived truths and lived experiences of human beings. These variables resist quantification and their study is unfamiliar to many geoscientists. Furthermore, the ethnographic method is markedly different than the familiar empirical method. To be explicit: this study is not an experimental study. It is an ethnographic study of learning in the geosciences.

In typical physical science praxis, a geoscientist (who can also be an educational researcher) observes a phenomenon, formulates a hypothesis, and *then* goes out into the field to collect data. The research process is hypothesis-initiated, and the basic order here is:

Observe→ devise hypothesis→ collect data→ revise/reject hypothesis.

To use the ethnographic method, the geoscientist (an educational researcher) goes out into the field to generate data, figures out what she or he observed, and then narrates those observations and extracts meaning by describing a set of emergent themes. So the basic order here is:

Generate data→ synthesize observations→ extract meaning.

In the ethnographic approach to educational problems, the data are non-numerical, the approach is nonlinear and recursive, the researcher is not independent of the phenomenon, and the interpretations are not extrapolated to the general population. Ethnography is not hypothesis-initiated; rather, the hypothesis is explored after the observations are synthesized—this is the extracted meaning. In fact, this alternative methodological order occasionally shows up in the geosciences. A specific volcanic eruption, a meteorite impact, and a severe flood are all examples of ephemeral, non-reproducible phenomena that must be observed, measured or sampled right when they happen. The attending geoscientists form and evaluate hypotheses on the fly, or after the fact.

The purpose of a hypothesis is to explain an observed phenomenon in a generalizable way. A good hypothesis should be extrapolated from a sample size *N* to an entire population. In ethnographic study, the purpose is not to explain or represent an "entire universe" (Mason, 2002, p. 126) but rather to provide a vivid, illuminating "flavor" of a particular phenomenon. What I found in the current study may be pervasive and occur everywhere. On the other hand, that may not be true. The usefulness of this study is not in how it predicts exactly what will happen when students measure section (it does not), but rather in how it sheds light on, or varies from, the experiences, past or future, of other students who measure section, and faculty who teach them to do so. It is true that this is a generalization towards a larger population, but not to the extent that a scientific hypothesis generalizes. It is possible to extract meaning from a study even though it does not model an entire population. This meaning comes not from the verification of a hypothesis but rather the researcher's generation of data, his or her identification of patterned regularities and the development of themes (Wolcott, 1994) in those data, and how those themes are interpreted and shared.

The issues of "validity" and "reliability" do not apply to ethnographic data; these are parameters of numerical inquiries, which ethnography is not. However, ethnographic data are subject to analyses of trustworthiness (Lincoln and Guba, 1985) and reliability (Creswell, 2007). Ethnographers must establish that their data generation strategies are of the highest possible quality, and that their interpretations of the data are correct. In this study, I have worked to establish trustworthiness and reliability through two means. First, I have provided excerpted data to support my interpretations. One of the inherent risks of presenting interpretations of qualitative data is that the process may appear to be "black-box" in nature; that is, opaque, mysterious and difficult to agree or disagree with. In this paper, I provide the raw data of statements and actions, and my subsequent interpretations of them. Therefore it is possible to see how I constructed the latter from the former. This process establishes trustworthiness. The second method I used focuses on reliability. Ethnographers will often "triangulate" their interpretations in consultation with other experts. In such a process, a worker has one or more other experts to verify that the emergent themes are consistent with the data. In this study, I triangulated my interpretations with both a cultural anthropologist and a geoscientist to establish inter-coder agreement.

It is worth noting that qualitative inquiry in general, and extracted meanings (themes) in particular, can contribute to the development of a hypothesis in a more traditional (i.e., quantitative or experimental) study; qualitative inquiries often seed quantitative investigations. We can think of the process of extracting meanings as the "methods" of an ethnographic study.

"METHODS"

I present this study in a manner different from the familiar format of Methods; Results; Discussion. This format is characteristic of experimental, hypothesis-initated reports, which this study is not. Instead I blend a more traditionally "scientific" style with the format prescribed by Wolcott (1994) for presenting ethnographic data as follows: Methodology; Method; Narrative Description; Analysis; Interpretation and Implications. Table 1 presents these components, the purpose of each, as well as its analog in a traditional geologic investigation.

METHODOLOGY

The term "methodology" as I use it means the theoretical frameworks within which I approached and conducted this research, as well as my place in it as the researcher. The term "method" describes what I actually did. For example, interviews and focus groups are two methods, which will be used differently depending on the researcher's methodology. An ethnographer will extract themes; a phenomenographer will compare transcripts for variant experiences; a policy analyst will identify the impacts of a particular policy (or lack thereof). In this study, my methodology was hermeneutic (see below) ethnography and phenomenology; my methods included participant observations and interviews.

This study is informed by phenomenology because I endeavored to understand how students construct reality

TABLE 1. COMPONENTS OF THE PRESENT ETHNOGRAPHIC STUDY

COMPONENT	PURPOSE OF COMPONENT	EMPIRICAL ANALOG
Methodology	Identifies theoretical frameworks; locates the researcher and the study	None. The guiding framework for empirical studies is always logical empiricism (i.e., the "scientific method"). The researcher is always external to an empirical study.
Method	Identifies what techniques/tools are actually used	Method. Techniques, instruments and analytical tools are described.
Description	Presents data in narrative format; "Tells a story"	None. However, limited narrative description may occur in a section titled, "Geologic setting."
Analysis	Discusses emergent themes	Results
Interpretation	Contextualizes themes; Discusses what is to be "done" with themes	Discussion/Implications and future work.

and truth in what Orion (1993) calls novel spaces. What I considered relevant data are personal accounts and narratives, non-verbal behaviors, student-to-student interactions, individual choices, strategies and expressed attitudes. The ontological properties (Mason, 2002), i.e., basic realities, I investigated included people, people as social actors, emotion, memory, consciousness, understandings and interpretations, ideas and perceptions, attitudes, beliefs and belief systems. These data and ontological properties form and reside in communicated truths, which are not subject to empirical verification or numerical validity analyses.

The term "hermeneutic" is descriptive of my role as a researcher-practitioner. I sought to document field learning, but as an educator, I would use what I found to enhance and inform my own teaching. It was impossible for me to separate my identity as a teacher from the learning I was observing. As a result, I was constantly moving back and forth between my roles as an on-site researcher and a practicing teacher. This movement is labeled "hermeneutics" (Balfour and Mesaros, 1994). A hermeneutic approach seeks to understand a larger process through the understanding of smaller parts of that process, which in turn requires an understanding of that greater process itself (Schwandt, 2001). Further, a hermeneutic approach seeks understanding through a communicated truth, which itself is not verifiable (Gadamer, 1975). To understand something is to participate in it, not something to be relayed by an outside observer, nor to discovered empirically (Gadamer, 1975; Schwandt, 2001).

For this study, an ethnographic approach was preferable to either a case study or a grounded theory approach. A case study would be appropriate (but not limited to) a situation where a single person's experience was being studied, especially if that person was in a particularly novel situation (e.g., she or he was mobility-impaired, or in a virtual field environment). A grounded theory approach is suitable for workers who are seeking to define a consistent, generalizable model of a process.

METHOD

I attended a field camp course in 2009 from start to finish, accompanying and observing student groups as they set up and broke down campsites, participated in lectures and discussions, mapped field areas, compiled reports, and measured and documented a stratigraphic section. I obtained formal, informed consent from the student participants, and introduced myself to them at their orientation meeting. Once in the field, I occasionally placed myself in a more distanced position as an "observer." However, most of the time I was fully integrated into camp life, participating in chores and social activities. I conducted and transcribed formal structured interviews, and I engaged in unstructured, conversational interviews. These latter interviews were in some cases completely unstructured, and in other cases were guided by a "mental checklist" of items that I compiled on-site. I coded transcripts and my observational notes in a simple serial indexing process (Feig, 2004; Mason. 2002), grouping interview responses and observed behaviors into basic categories. This produced data "packets" that allowed me to perceive themes across different transcripts and different behavioral observations. For example, if in one recorded interaction I flag "technology dependence" in a serial indexing process, I then could lift all comments and behaviors under that theme from one transcript to compare it to the same flag in another transcript or observation. I then processed the extracted themes into mechanical arguments (Mason, 2002), presented in the section "Analysis" below.

DESCRIPTION

In the presentation of ethnographic data, the Description is a "straightforward [account] of settings and events" (Wolcott, 1990, p. 28), so that the reader has a vivid, detailed and interesting story that serves as a foundation for the inquiry. In the description, the reader sees what the researcher saw, through the researcher's eyes. The description should not be detached or impersonal. It can be chronological, it can go through a list of subjects in a particular order or it may be written in a day-in-the-life format. I have outlined my description chronologically, with occasional subordinated descriptions of characteristics, personalities and/or behaviors. I begin my description with a discussion of the class itself.

The field camp course I was immersed in is offered on a yearly basis by a public university ("University") located in the western United States. In order to maintain the confidentiality of the students, staff and faculty, I do not divulge the university or specific, identifying details about the course or the geology of its field areas. The course is team taught by senior faculty members (Professor X and Professor Y), and staffed with multiple graduate teaching assistants. Students are transported to three remote sites (labeled here as Sites A, B, C) for up to ten days at a time over the length of the course. They do not spend equal amounts of time at each site; the time spent at each site is progressively longer going from A to B to C. About ten of the students, or one-third, were from the local university; the rest were from other institutions that require field camp, but do not offer it. The student population represented a total of eight out-of-state institutions and one in-state institution, in addition to the host University. In this course, students and staff camp under primitive conditions without bathing or permanent latrine facilities. Kitchen facilities include portable propane stoves, but no running water. Students and staff provide and cook their own meals. All field areas contain rugged topography, with up to 150 meters of relief in some mapping areas. Structural deformation in the mapping areas ranges from moderate to extreme.

Students are given the primary task of compiling geologic maps of bedrock and surficial features. They also report on each area's regional geologic setting and tectonic history. They examine aerial photographs, collect structural data, assemble lithologic descriptions and, at the third mapping location, Site C, they measure and describe a stratigraphic section. Students measure this section before they begin mapping, as a means of becoming familiar with the local rocks. The section they measured is located several kilometers from their mapping area. The rocks are part of a sequence of late-Phanerozoic marine sediments that are very well exposed along several roadcuts. The package contains a total of nine discrete units, which have a moderate dip but are otherwise undeformed. However, these same units are intensely deformed in the mapping area. In this article, I describe the events that took place during the first full day of measuring section at this location, which was Day 12 of the course overall. Professor X led this activity; Professor Y was not yet present, but was scheduled to arrive within two days' time.

Before I go any further, it is worthwhile to go back in time to the second day of the field camp class, in order to set the stage for the events on Day 12. On Day 2 the class made its first visit to Site A, an area of moderately deformed sedimentary rocks and rugged topography. The students were each given a 1:6000 scale topographic map and instructed to locate themselves on their map. They were not given GPS units, but were told to use ridgelines and other topographic features to find their location. It was apparent to me that the instructors valued the skill of doing field tasks like this "by hand," versus relying on technology. I followed a small group of students, which included an individual named Joey-Ramon[1]. When his group split off to locate themselves, Joey-Ramon had this immediate comment:

> This is retarded; we have GPS and could figure this out in three seconds. What's the point of this?

On Day 9, while in the field at Site B, I had the opportunity to interview Joey-Ramon and his mapping partner. I asked Joey-Ramon about his sentiments above. In fact, I read his comment back to him verbatim. Below are excerpts from his response, edited for redundancy and clarity:

> Yeah, my sentiments are still mostly the same. I understand more or less now what [Professor X is] trying to do, because I think it's—it's kind of an art, reading a topographic map, there's not a lot of people that can do it…and then having taken structure, where we've gone out in the field and just located ourselves through GPS, it didn't seem like we needed to do that anymore. It's kind of a luxury that we have [GPS], living in our day and age…as opposed to somebody—way back in [Professor X's] time, they didn't have that opportunity, so they had to do it based on a topographic map. So I have like a new-found respect for it, I think it's kind of like an old-school thing to do, for lack of a better term, and something that our predecessors had to do…and I think we do things differently now…I think in this day and age, we've grown up with technology, and we've just learned to use it…but I've never questioned [it].

Returning to the events of Day 12 at Site C, the students were introduced to the lithologic units that they would find in their mapping area. Professor X began the day's discussion by asking students to describe the basal unit of the section, a thickly bedded marine sandstone unit. Most students looked at their handouts instead of the rocks. They called out formation names based on what they could visually correlate with the information on their handouts. One group moved off to take a strike and dip measurement. The teaching assistants then prompted the students to look at the rocks first, before attempting to name the unit. Within a few minutes, consensus was reached on the name and properties of this unit, which they had in fact seen at their first mapping site! Professor X led a discussion about paleogeography, asking the students to consider whether this location represents a shallower or deeper marine setting than what they mapped at Site A. A vocal minority of students decided this location was shallower, based on what they could remember of the grain sizes they saw nine days prior. The rest of the group remained passive.

Professor X responded by constructing a rough map in the dirt parking area. He led a Socratic discussion of the regional paleogeography, and eventually the students realized that by placing the mapping areas in context with paleoshorelines, the present setting was actually deeper. Professor X then walked the group over to a contact between the top of the marine sandstone and a shale unit. He instructed the students to follow the shale upsection. As they did, he led them through a Socratic discussion of transgression and regression. Professor X then gathered the group in the parking area in order to give specific instructions and outline expectations for the stratigraphic measurement activity.

Professor X is a veteran teacher who is highly skilled in active-listening techniques. He has been the principal instructor for this course for over two decades. He speaks deliberately and is not glib, and he converses with students in a respectful manner, with gentle humor. He is highly tuned to non-verbal behavior among students, gauging their understanding and comfort very quickly and without words. Throughout the course, students demonstrated a consistent, willing enthusiasm to internalize his advice and follow his instructions. At this point on this day, he distributed 1.5 m Jacob staves, and instructed the students in how to install a Brunton compass onto each staff.

Professor X then instructed students how to measure thickness by orienting the staff perpendicular to dip and walking along the road in an upsection direction. This technique was subsequently referred to as "jaking." Professor X repeated the explanation, and physically demonstrated the technique. Most students were not familiar with this technique, and they were enthusiastic about trying it out. However, Professor X was explicit in his directions; he wanted students to use the staff as a ruler ("ruling"), when appropriate. He made it clear that a majority of measurements were to be made by ruling. He wanted them to climb the rocks, and physically lay the staff on the rocks perpendicular to dip as they moved upsection. Professor X gave this instruction once before he taught them the jaking technique, he repeated it during the demonstration, and he repeated it once again as he

[1]Pseudonym. Assigned pseudonyms do not reflect the ethnicity of the participants.

broke them up to conduct the exercise: “Use your staff as a ruler!” Figure 1 shows the differences between ruling and jaking a stratigraphic section.

I initially followed two students, Chuck and Sid. These two, along with most students, expressed a great deal of initial confusion and a lack of confidence as they started the task. Chuck and Sid began by taking a strike and dip measurement. They then oriented their staff perpendicular to dip and began jaking the section. As they moved upsection, they did not hold the orientation of their staff consistently. As a result, most of their measurements of the basal unit were oblique to, not perpendicular, to its dip. When they reached the contact between this sandstone unit and the overlying shale, they compared their determined thickness with that of two other groups. Sid and Chuck were dismayed to find that their result varied substantially with other groups. I then heard Professor X in the background, earnestly redirecting students to rule instead of jaking the section.

Professor X was careful not to show his mild frustration, but I was in a position to observe it. Despite the detail of his instruction, there existed among the students great deal of uncertainty about this task. I moved over to Professor X and away from the students.

“Is this normal?” I quietly asked him, while gesturing towards milling groups of students.

“What?” He scowled, visibly annoyed.

“This,” I responded, gesturing to the students.

“You mean mass confusion?” Professor X shook his head.

“Yeah,” I responded, “And jaking, instead of using it as a ruler.”

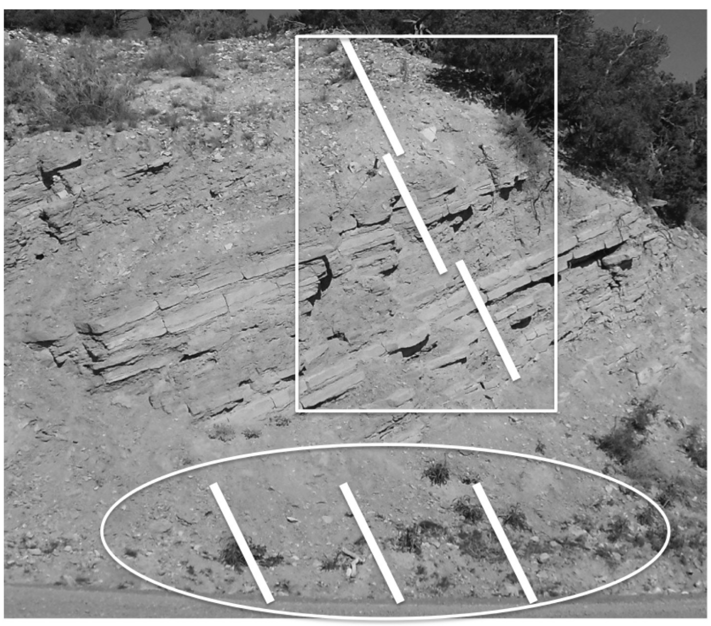

FIGURE 1. The contrast between “jaking” and “ruling.” In the image above, solid oblique white lines represent the Jacob staff. The use of the staff to rule section is shown inside the square. In ruling, the staff is placed perpendicular to rocks by physically climbing the outcrop. The use of the staff to jake is shown inside the ellipse. In jaking, the user stays along this roadcut, holding the staff perpendicular to dip while walking upsection without climbing the outcrop.

“Every year,” Professor X shook his head. “It’s like they don’t believe me. They…they don’t believe me. *Every year*, this happens.” [Emphasis his.]

I wandered away from Professor X to consider his statements. So far in the course, I had observed students carefully seeking and internalizing faculty advice and instruction. In fact, students were more inclined to seek external validation than to trust their own decisions. This was the first time that I had observed a mass disregard of either advice or instructions, and I found it frankly puzzling. I was not willing to concede that in this one instance, they arbitrarily chose, en masse, not to “believe” Professor X.

I decided to directly ask the students why they chose the technique they were using to measure the section. I moved through the area to converse with nineteen students distributed in nine different mapping groups. Each group I spoke with was jaking, and I asked them why they chose to jake instead of choosing to rule the section. I posed the same question in the same manner to each group. Their responses are summarized below, either by individual or grouped pseudonyms, in order. I did not audio- or video-record these conversations, and in most cases I was not able to write down full verbatim responses. Verbatim responses are italicized and enclosed within quotation marks (“”). Comments inserted by me for clarification are enclosed in brackets [ ].

Frank: “*This is easier*.”

Sid: “*Too tall*.” [Meaning the outcrop.]

Chuck (Sid’s partner): “*Everyone else was doing it* [jaking]. *Also, we did this* [ruling] *in our sed/strat class; it was difficult and confusing*.”

Bill and Charles: Too many students in the way to use it as a ruler. We did it once, though.

Joey-Ramon: Jaking is physically easier. Also, it is harder to be confident ruling when the roadcut is sinuous.

Hermione and Adams: It is easier to rule when the dip is variable. We prefer to rule because it is easier, but we feel that jaking is more accurate.

Paul and Lenny: We were doing both, jaking in shale because it is easer to go up. We both prefer to rule, but both feel that jaking is easier.

Kaye and Debbie: We prefer to jake, because the combination of outcrop shape, strike and dip make the overall geometry too confusing for us to be comfortable ruling.

Dave: Jaking is better and more accurate because you can level it each time. Also, we did it both ways, and the teaching assistant said our jaking result was better. [NOTE: I observed Dave’s measurements before, during and after this conversation. He consistently failed to hold his staff perpendicular to the bedding of the strata he was measuring.]

Clint: Jaking is easier.

Barbara: Does not matter. There is slop either way.

Dan: Jaking is more accurate because of the compass. When ruling, I feel I have to take too many of the same measurements, and I am never sure of the orientation of the beds.

Vince: You cannot rule the bigger, more thickly bedded outcrops, because it's inaccurate. You can only rule small sections of thinly bedded stuff.

Skye (Vince's partner): "*This is why we have compasses—accuracy makes science*."

I obtained these responses as the students were jaking, and I had to exercise sensitivity to not derail the students as they were working. A few of the responses are terse, but by this time the students appeared to have overcome their initial discomfort with me as an "observer," so that they were candid and did not idealize or otherwise bias their responses. Although the students expressed low confidence in the task of measuring this section *overall*, they expressed a high degree of confidence, both verbally and nonverbally, in their ability to Jake.

ANALYSIS

In an ethnographic study, the "Analysis" section describes the researcher's transformation of data into an argument (Wolcott, 1994). In this paper, the student responses to my questions are raw data. I describe what I flagged (observed as recurrent and significant) and how I interpreted these flags to be descriptive of meaningful ideas and processes related to student learning in the field, i.e., the argument. For further reference, Libarkin (2005) discusses qualitative analysis relevant to the geosciences, and the anthropologists Ryan and Bernard (2003; 2000) provide in-depth discussions on thematic analysis in ethnography.

Two emergent themes are readily flagged in these responses. First, the notion of finding a physically easier path, literally and figuratively, is prominent in these responses. I suggest that there is nothing at all new or interesting about students (or people in general) wanting to do things in the easiest way possible. Therefore, I have ignored these flags, and the emergent theme they raise of "the path of least resistance in fieldwork."

The second emergent theme is that of a desire to be correct, through being accurate. Unpacking their statements and behaviors further, it becomes apparent that the students feel they attain this accuracy through applying technology, in the form of the compass - which they discussed frequently. A Brunton compass is not computerized technology, but it *is* technology nonetheless, in the same way that wrenches, screwdrivers and a carpenter's level are technology. These tools are a higher level of technology than that of stone tools, and lower than that of GPS satellites and receivers (Table 2). All levels of the technology hierarchy may be used to obtain information about reality, and therefore can be perceived as having some role in "truth."

Educators and scientists tend to hold the general view that more technology is better. This argument is supported by 1) the growth of "online" education across STEM disciplines (Wofford, 2009); 2) the emphasis placed on cyberlearning initiatives by the National Science Foundation (NSF) (Borgman, et. al, 2008); 3) initiatives to increase computerized instruction in K-12 classrooms (e.g., U.S. Dept. of Ed., 1997); 4) the role of technology in scientific revolutions (Kuhn, 1995); and 5) the continuing funding of the development of instrumentation by federal

TABLE 2. SUBJECTIVE ARRANGEMENT OF DIFFERENT LEVELS OF TECHNOLOGY, AND THEIR IMPLICIT TRUTHFULNESS, THAT STUDENTS MAY ENCOUNTER[1]

	Reliance on Human Operator	Technological Level	Ostensible Degree of Precision	Perceived Implicit Truthfulness	Example Semiotic Confidence, on Scale of 0-1
Direct Satellite Measurement	None	Highest	Highest	Absolute	1.0
Topographic Map with GPS	Low	High	High	High	0.9
Jacob Staff with Brunton	Medium	Medium	Medium	Medium-high	0.5 to 0.8
Topographic map	Medium	Low	Low to medium	Fuzzy	0.3 to 0.5
Jacob Staff	High	Low	Low to medium	Fuzzy	0.4 to 0.5
Visual inspection Based on Skill, Experience	Total	None	Low	Low	0 to 0.3

[1]"Reliance on human operator" describes how much measurement is done by eye or hand. "Semiotic confidence" shown here is my own scalar measure of how a hypothetical worker might report his or her confidence in his or her own observations. For example, a geologist could have a certainty of 0.9/1.0 that a bed is 12 cm thick. For an extended discussion of semiotics see Parcell and Parcell, 2009.

granting agencies such as the NSF and the National Institutes for Health. Strong statements about the value of technology exist in the NSF's Mission and Core Values statement, as part of its Strategic Plan (NSF, 2009). Ostensibly, better technology improves our understanding of reality; otherwise, why would we invest so much in its development? So it seems that scientists, politicians and teachers agree that more technology is better. This ethos permeates our lived experiences, and it should be no surprise that it would manifest among our students, and that I would easily observe it in the field. Table 2 presents an arrangement of this argument, arraying the parallel technology and perceived truth hierarchies (measured subjectively).

I observed a desire on the students' parts to be accurate, and their attempts to actualize this through applying the technology of the Brunton compass. I also observed that they were, in large part, using the technology incorrectly. Their Jacob staves were often not oriented perpendicular to dip, and yet, it did not occur to them that they were using their tools incorrectly. They had a strike and dip, they matched their measured dip with the inclinometer on their staffs, and that was that. The numbers gave them certainty, in the way that visual ruling could not. Their apparent line of thought went something like this:

Technology = reliability = accuracy = truth = scientific & physical reality

The subtext to this line of thought (that is, what is informing it either consciously or unconsciously) appears to be:

Scientific method = instrumentation

These students had low levels of confidence in their "low-tech" field skills, and they did not trust their visual observations of spatial orientations. They relied on available technology to compensate for their lack of confidence, as well as their reticence to exercise their skill in "low-tech" measurement. The student Skye summed up this concept in her comment, "This is why we have compasses—*accuracy makes science*." That is, the ability to assign a numerical value to a behavior—in this case, how to hold the Jacob staff—made the process more reflective of scientific reality. The term she used was "accuracy," but what she appears to have meant was "precision." She interchanged the two concepts in her mind, as did all the students. However, I argue that the two concepts have important differences. "Precision" refers to measurement; that is, how many significant figures, how much resolution, how many pixels, and so forth. "Accuracy," on the other hand, refers to reality; that is, something is located here and not there, it is 12 cm and not 10 cm thick, it is fluvial and not deltaic. In this latter example, the differences between interpreting an environment as fluvial or deltaic rely on observation and measurement. As geologists, we want an appropriate level of precision in our instruments, and we also want to be accurate; not "as accurate as possible," but accurate in a way that reflects scientific and physical reality. Sometimes we get only the precision part right. For example, we can conduct very precise measurements and observations, but incorrectly interpret the environment. We had a high degree of precision, but we were wrong—that is, we were not accurate. The number of significant figures does not prescribe reality. Figure 2 provides an alternative example of the contrasts between accuracy and precision.

Joey-Ramon's discussion of reading topographic maps with and without GPS contributes to the theme of technology dependence among students. For him, reading the map without the GPS is clearly an *art*, versus a *science*! To him, this skill is simply a classroom abstraction, a training activity conducted by his "old school" professor. Modern science is conducted with technology, which Joey -Ramon grew up with and never questioned. Technology renders the old skill set obsolete. Why is it obsolete? Joey-Ramon does not value the technology for its own sake; he values it because he feels it is better descriptive of reality. GPS coordinates give him a more precise location on his map. Therefore, he can develop a more accurate picture of the geology of the area.

One question I cannot answer is why Professor X shared the jaking technique to begin with. This is troubling, because if he really did not want his students to do it, he would not have demonstrated it. Perhaps he assumed that they would try to jake, and he wished to exert an influence of uniformity on their technique. Perhaps he was running his own private "experiment" on jaking versus ruling. Possibly, he was merely being thorough in terms of technique. In any case, had he not made such a seemingly mundane choice—two minutes of instruction - the themes I describe in this paper would never have emerged. Such is the nature of ethnographic research!

The emergent theme that I have discussed includes technology dependence, the obsolescence of non-

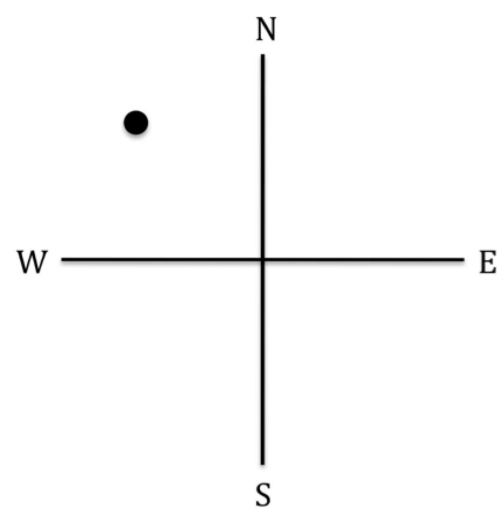

FIGURE 2. Accuracy vs. precision. To answer the question, "Where is the circle?" it would be accurate to say "Somewhere in the NW quadrant," but not very precise. On the other hand, to say "Assuming the intersection of axes is at 0,0, the circle is 4.56783564 units along the South axis and 3.45890987 units along the East axis," is an extremely precise statement, but not accurate, because the circle is not in the SE quadrant.

technological field skills, and a lack of understanding of the difference between precision and accuracy. It is worth noting that three other unrelated themes emerged from my ethnographic immersion in this field camp class. These other themes are beyond the scope of this paper, and form the basis for future work. I include them here to contextualize this paper within the broader ethnographic study I conducted.

The first unrelated theme has to do with risk behavior. I noted within the main culture-sharing group a division between those students who were risk-averse and those who were not when it came to movement over the landscape. Risk-averse students moved methodically over the terrain so as to minimize their contact with steep slopes, sheer drops and slippery surfaces. Other students appeared alternately to ignore or to seek out risks, moving across the landscape with minimal concern for exertion or even for their own safety. The interaction or "bumping" (Vélez-Ibáñez, 1997) between these two groups had implications for each group's learning. The second unrelated theme concerns student self-perceptions of athleticism and physical fitness with regard to their success in the class. Many students perceived physical fitness as a gatekeeper of their final grade, as well as their intrinsic understanding of geological processes. The third unrelated theme builds on the previous two listed. It concerns how teaching assistants acted as gatekeepers to learning by how they addressed (or chose not to address) students' questions and difficulties with physical exertion and the local geology. This gatekeeper behavior was often related to perceived physical fitness and risk behavior.

Returning to the technology-dependence theme and its components described in this paper, the next question to be addressed is, what is to be made of them?

IMPLICATIONS I: INTERPRETING THE STUDENT EXPERIENCE

The question, "What is to be made of them?" is the one that Wolcott (1994, p. 128) recommends for discussion in the "Interpretation" section of an ethnographic study. By "them" Wolcott means the members of the culture-sharing group, but I expand that to include not only the students I observed, but also the emergent themes and what those themes imply. What is to be made of the students who are technology dependent, who do not value doing things by sight or by hand, who do not know the difference between accuracy and precision?

What is to be made of the fact that they are technology dependent? If field camp is a key benchmark in the transition from student to scientist, and from novice to expert, then we must expect students to internalize, and then to master, a particular skill set. This at least includes locating oneself, judging spatial relationships, and the use of appropriate tools (technology) in the field. If students are dependent on technology to locate themselves and judge spatial relationships, then they have not internalized these skills. Externalized skills are not mastered skills. Students may, at best, become facile with tools such as GPS and Jacob staves. However, they remain near the novice end of the continuum if they do not master spatial skills such as locating themselves using the landscape and ruling section. They must also develop their own affective confidence in these abilities, which facilitates mastery.

What of student dismissal of "old-school" skills? As scientists, mentors and teachers, we should probably look inward to answer this question. How do we present these "by sight/by hand" skills? How do we appear to value them? Are we more like the stereotypical crusty old professor, grunting through clenched teeth, "You lousy kids! Back in my day we had to do this by hand! And we liked it!" Or do we teach these skills with the purpose of building affective and cognitive mastery of field geology? To say to the students, "Because you may not have a GPS," as justification for "oldschooling," is not sufficient. The students simply do not see themselves as ever being in a position where they do not have access to technology. More importantly, as Joey-Ramon stated, students tend not to question technology. It simply does not occur to them to compare an instrument's reading with their own internal skills, judgment or calibration. They do not ask, "What is this instrument telling me? Does this correspond with what I am actually seeing? What do these numbers mean?" This is what prevented them from realizing that they were holding their staves oblique to dip, and not perpendicular to dip.

Finally, what of the students not appreciating the difference between accuracy and precision? The primary issue here is that this informs their misunderstanding of how science works. They equate high levels of technology with high levels of truth, both of which have an ostensible inverse relationship with the human processes of observation and judgment. At worst, this suggests a cadre of future geoscientists who accept as reality whatever their instruments tell them. More likely, it suggests that this cadre will struggle to resolve discrepancies between their high-technology and low-technology data sources. It also suggests that they will lack confidence in their internal skills of appraising and understanding a field setting.

The accuracy/precision issue further suggests that as part of their training as scientists, students should be taught to appraise a situation to apply an appropriate level of precision (technology), rather than to assume that more is better. If students (and scientists) equate precision with accuracy, and accuracy with scientific reality, then they run the risks of misapplying their tools, and being precisely wrong. These risks are compounded by the fact that students will not be able to self-check to avoid those risks, because they do not perceive the problem to begin with.

The good news is that the accuracy/precision issue provides ample opportunities for students to explore the complexities of physical and scientific reality. By developing a clear understanding of these concepts, students can 1) develop greater insight into the workings of science; 2) understand that in some settings, low levels of technology are perfectly appropriate, 3) internalize non-technological skill sets; 4) develop confidence in their skills; and 5) move ever closer towards the "expert" endpoint on the continuum that marks their journey from student to scientist.

Joey-Ramon represents what is known as a "digital native," (Sheffield, 2007), while Professor X does not. These are conflicting conceptions of technology. Future research could explore how these different concepts of technology shape the expectations that students and faculty have of fieldwork. Do conflicts exist? Do students - and administrators - see field camp as less and less relevant in the face of rapidly developing technology? How does technology impinge upon field education pedagogy?

IMPLICATIONS II: AN ETHNOGRAPHER CONSIDERS FIELD CAMP

Field camp represents a late opportunity to intervene in the training of geoscientists in order to 1) fully internalize their field skill set; 2) increase their confidence in this skill set; 3) explore the complex nature of scientific reality; and 4) provide opportunities for reflection and synthesis. The reduction in the number of field camp classes nationally corresponds to a reduction in the quantity and quality of the training of future geoscientists.

It was clear to me that the students I observed had limited experience in certain spatial skills (locating themselves, ruling section), and little confidence in their cognitive abilities to do so. It was also clear that they had an unsophisticated approach to the application of technology, assuming that in every situation, more is better. They also felt that non-technological strategies are obsolete. These students were all advanced undergraduates, ready to graduate within a year.

Pavlis, et al., (2010) argue that paper-based mapping is obsolete, and must make way for GIS technology. They argue that students must be technologically current with industry and research institutions. I do agree that students should be facile with current technology, for the benefit of both the science and their own careers. However, my position is that for novice students, by-sight/by-hand skills are critical to their geological praxis, and that the technological applications described by Pavlis, et al., are appropriately applied only once these basic skills are mastered.

Field camp, then, is likely the last chance in the student journey in which we have influence to grow them into the scientists we want them to be. Where else is there a natural laboratory to explore the differences between precision and accuracy? What better setting to explore the efficacies of different levels of technology? What better place to develop, through application and practice, students' spatial abilities, independent of technology? What better outcome than for them to leave the field confident in their newly acquired skills? It is not enough to put students in front of rocks; they have to be put in front of a scientific situation, with the attendant challenges, pitfalls, unknowns and risks that exist in "real" scientific problems. Field camp is not just an expensive outdoors-oriented class; it is the opportunity to grapple and struggle with the real problems and issues in science. Unlike classroom settings, field camp has built-in opportunities for reflection: during mealtimes, around the campfire and in transit. Field camp forces students to think about a problem even when they are not directly facing the problem.

I wondered, and I still wonder, how the students would have felt about their jaking if they could have seen themselves doing it. Would they notice their misalignment with dip? Would it matter to them if they did? What would they do with the opportunity to reflect? It is my hope that this ethnographic study might prompt field camp instructors to integrate more direct reflection opportunities for students to consider the issues of technology dependence, "old-school" skills and the nature of field science. Reflection and synthesis are high orders of learning, and supposedly those that we value among our scientists. Perhaps successful field students are given— and take— ample opportunities to engage in reflection and synthesis.

Riggs, Lieder and Balliet (2009) indicated that they could not use their quantitative data and analyses to explain how students make the best field-navigation choices. Perhaps their students with good traverses took ample opportunities to reflect on their observations and behaviors. Perhaps those students did not get "bogged down" in misusing technology. Perhaps they did not have an issue with technology dependence. Perhaps it was their sophisticated understanding of scientific reality that allowed them to test multiple hypotheses as they traversed the field area. All these factors would have aided their mastery of and confidence in their non-technological field skills. In that case, they reaped the full benefits of the field-learning environment. That environment has no substitute.

CONCLUSIONS

Ethnographic study of field camp is an approach to understanding the essence of students' experiences as they learn in the novel spaces of the field. Meaningful themes emerge from the documentation and analysis of behaviors, choices, verbal and nonverbal interactions, and both formal and conversational interviews. In my study of a field camp class, I observed students struggle to measure a stratigraphic section. They rejected an appropriate, low level of technology in favor of a higher level that they misapplied and failed to master. They expressed a strong dependence on this technology. These students systematically devalued low-technology "by hand/by sight" skills such as locating themselves using the landscape and ruling section. They equated progressively higher levels of technology as being equivalent to progressively higher levels of "accuracy," which they consistently confused with "precision." Finally, they equated their misconception of "accuracy" with scientific reality.

Field camp is likely the last chance we have as educators to shape the training of future geoscientists. Field camp is also the best natural laboratory for students to explore affective, semiotic and meta-cognitive factors that shape not only their grade in the class, but also shape their essence as scientists. As field camp goes, so goes our discipline.

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