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Envisioning Competence:
Learning, Problem Solving, and Children at Work
in the Exploratory Bicycle Shop

By

Charles Florian Hammond

A dissertation submitted in partial satisfaction of the

requirements for the degree of

Doctor of Philosophy

in

Education

in the

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of the

UNIVERSITY OF CALIFORNIA, BERKELEY

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Professor Bernard R. Gifford, Chair

Professor Jabari Mahiri

Professor George Johnson

Fall 2010

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Learning, Problem Solving, and Children at Work in the Exploratory Bicycle Shop

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By Charles Florian Hammond

Abstract

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Doctor of Philosophy in Education

University of California, Berkeley

Professor Bernard Gifford, Chair

This study examines the conceptual learning and cognitive development processes of schoolchildren engaged in problem solving activities in a non-school, workplace setting known as the exploratory bicycle shop. The exploratory bike shop is a commercial bicycle shop: a) that has been adapted for combined retail and educational purposes and b) where middle-school and high-school age students participate as bicycle mechanics apprentices. It shares certain educational strengths with other authentic work-learning strategies in which young people perform work with various degrees of economic use-value. For example, like youth media projects such as Oakland's Youth Radio, it provides apprenticeship opportunities with professional personnel such as mechanics and salespersons in a professionally-equipped shop space. Like school gardens, the exploratory bicycle shop engages students in work activity that produces economically viable products. Unlike any other authentic work-learning activity, however, the exploratory bike shop gives young participants, ages 10-19 a neighborhood-based, tool-intensive, commercially viable space where they strongly identify with the experience of having a real job, not just a simulated one.

To help reveal how apprentices access that intelligence through thinking and discursive practices, I employ visual anthropology (VA) methods. VA was designed to collect and analyze ethnographic data in ways that more effectively capture and reveal informants' true motives and practices by subordinating the verbal data stream and focusing instead on the visually available aspects of what informants do. Specifically, I videotape apprentices' actions during bike repair activity in order to track changes in their actions over the course of interaction with the bicycle and other bike shop participants. Through in situ dialogue and clinical interviews I then try to determine how changes in apprentices' actions relate to changes in both their conceptual development and technical competencies.

In a VA analysis, findings emerge in a manner different from that of more traditional studies since the very idea of studying a culture is subjected to a critical self-examination about the motives for the research and the degree to which the study faithfully represents that culture's voices rather than imposing its own voice, intentionally or not. With regard to student problem solving practices, one finding was that competence in bicycle repair tended to correlate positively with the ability to judge which type of knowing—abstract or concrete—is appropriate for any given problem solving situation. Theoretically speaking, but also related to the above

finding , the study also found that problem solving competence relies critically on a student's problem framing competence, an observation that corroborates findings by Hutchins and Lave. One methodological finding is that VA can open up new ways of conceiving competence that were previously unavailable using more traditional analytic methods. The VA ethic aims to understand the informants' attitudes and beliefs at an emic level, the level of the informant, rather than trying to understand verbal data collected from the informant through a series of direct or indirect interventions.

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Chapter 1: Introduction and Overview

1.1 Introduction

This dissertation presents my observations and interpretations of problem-solving practices among several racially, ethnically, and socio-economically diverse middle- and high-school aged students in the authentic work environment of the *exploratory bicycle shop*. Like many extracurricular opportunities, the exploratory bicycle shop engages students in thinking and problem solving activities comparable in cognitive demand to those encountered in conventionally organized, school-based classrooms. What distinguishes this particular educational environment is how it integrates tools and other community resources into the learning process, organizes interactions among students and staff, and shapes the specific manner in which students engage in activities and encounter problems.

Instead of doing prescribed activities designed to achieve preconfigured educational outcomes, students perform shop work—mainly repairing bicycles, sorting parts, and occasionally serving customers—as part of the normal daily operation of a busy neighborhood bike shop. Such “authentic” shop work is organized by the many contingencies of the localized, commercial work situation, not by a global standards-driven educational design. Instead of receiving problems from instructors, students find, frame, and analyze problems themselves in the course of routine work activity, then plan and implement their solutions. In this hybrid educational-work environment, students adopt ways of thinking and solving problems that appear to differ significantly from cognitive processes found in school classrooms.

Adding to the authenticity of the work situation is the economic context of the activity. Exploratory bike shops are economically viable commercial enterprises that have charitable, nonprofit legal status since their primary mission is educational and ultimate control over revenue is, theoretically, ceded by individuals to a governing board. Student employees experience both a direct sense of actively contributing to the economic development of their community and a sense of participating in a community of practice of bicycle professionals. Even beginning students tend to strongly identify with the “worker” status that participation in the exploratory bike shop confers, and that identity produces a strong motivation for continued work engagement.

I have been personally involved in the organization, operation, and continuous improvement of a variety of commercial-qua-nonprofit educational bicycle shops, known as exploratory bike shops, for 22 years. My experiences have led me to believe that this setting presents a potent learning opportunity, capable of engaging the competence of students deemed by the school system to be incapable of organizing thoughts, thinking critically, and solving complex problems. As one supportive school teacher observed among students in her classroom, “Anthony was no longer trying to get out of work. He was working to his personal best... Anthony has not always been this kind of student. In our conversations he began to tell me about the [bicycle shop]. I could see his enthusiasm and realized his new attitude was coming from his work at the [bicycle shop] (Rago, 1993).”

My experiences convinced me, moreover, that this setting represented an opportunity to view cognition and learning from research perspectives that had not been previously explored. In other words, observing a diverse group of students learning through the direct experience of solving authentic, spontaneous workplace problems—a circumstance Hutchins (1995) refers to

as “cognition in the wild”—sparked the idea of formally studying the problem solving practices of students in the bicycle shop. This dissertation represents my attempt to fashion a method for conducting such an inquiry in a manner that is rigorous, theoretically-based, and analytically sound.

1.2 Shaping the Inquiry

Personal factors

I undertook this study with the intention of subjecting my accumulated observations of students actively engaged in productive learning activities to an evaluation far more rigorous than personal observation. Extensive experience working in any particular situation, while a reliable source of deep understanding, also tends to obscure new insights and dampen efforts to examine alternative perspectives. It was therefore helpful and necessary to problematize my experience by contrasting it with alternative stakeholder perspectives and by using data collection methods drawn from the anthropological tradition, which emphasize the importance of representing a focal culture with the maximum degree of fidelity.

I subjected the results to systematic analysis using techniques drawn from both the cognitive science tradition and anthropology. The heavy reliance on anthropological methods highlights the underlying philosophical stance of this study: knowledge and knowing are culturally determined and learning is mainly a process of enculturation.

Educational equity

This study originated in the desire to explain why academic performance among students from nondominant cultures—determined by race, ethnicity, first language, and socioeconomic status—trends lower than that of students from dominant cultures, all other variables roughly equal. That inequity, a persistent feature of the U.S. educational landscape despite decades of educational reform efforts, symbolizes not just our nation’s continuing history of unjust racial relations but also the reluctance of our institutions to look deeply enough for root causes.

My curiosity about the academic underperformance of urban students from nondominant cultures emerged from over two decades of working with “street kids” in downtown Indianapolis and other urban centers around the country. At the time, my work involved motivating young boys and girls, ages 9-15, to explore the mechanical world of bicycle repair in a neighborhood bike shop with an educational component for young people. In this hybrid shop-school, I was stimulated collaborating with young minds to tackle the mechanical and social challenges of operating our urban enterprise and upset knowing that most of these young minds were not finding adequate opportunities to learn in school and therefore labeled “failures.”

The beginning of the twenty-first century started a new era in educational research that focused on improving diversity and equity and seemed determined to look beyond student “failure” to broader societal and cultural factors. Included in that movement was a major research and researcher training project, the Diversity in Mathematics Education (DiME) Center for Learning and Teaching of which I was a graduate student fellow. DiME (2006) published a book chapter in a prominent research handbook that urged exploring new methodologies sensitive to the interplay among culture, race, and power that has been reproducing educational inequities. Nevertheless, the prevailing reform model remains the No Child Left Behind Act

(NCLB), enacted by the US Congress in 2002, ostensibly aimed to improve equity in educational services by raising quality standards for “all students” through accountability measures.

Unfortunately, NCLB privileges the fixed-location, single-grade, conventionally organized school-based classroom. The emphasis placed on maximizing the effectiveness of this particular educational model, although consistent with a focus on accountability-based instructional metrics, overshadows the possible instructional benefits afforded to students in non-classroom settings. Undertaking formal research on learning in non-classroom settings, including the exploratory bicycle shop, will help raise the profile of these educational alternatives.

Problem-based research design

The remainder of this section provides an overview of the factors considered in deciding to use mainly anthropological methods to structure the inquiry. The first subsection outlines the key research questions that motivated the study and guided major analytic decisions. Subsequent parts of this section elaborate on the theoretical and methodological strategies used. A unifying structural device I have added to each chapter to help orient the reader is a section entitled “Problem Arcs”. It identifies and frames theoretical, methodological, and policy problems central to the study and introduces each one in a two-part format: first, the problem statement and then a planned solution strategy.

This feature is repeated in the same dual format in each subsequent chapter to provide narrative cohesiveness to what is a particularly wide ranging analysis and discussion. Problems thus identified appear in a logical sequence, throughout the dissertation, that indicates how the solution strategy for one problem generates a space for the next one. Taken together, these problem arcs provide a stepwise developmental chronology of theory and method over the course of the study. The first set of problem arcs is presented in the final section of this chapter.

Research questions

In this problem-driven study, research questions closely parallel and reflect the research problems. Table 1-1 displays the logical progression of the research questions that guide this study.

Table 1-1. Research questions aimed at improving understanding about the nature of learning and problem solving in the exploratory bicycle shop.

RQ 1.0 Theoretical	What relationship exists between an activity setting and a student’s problem solving practices?
RQ 1.1 Methodological	What insights into this question do conventional interview and participant observation methods provide?
RQ 1.2 Methodological	What does VA analysis reveal about learning and problem solving in the shop?
RQ 2.0 Methodological	How can competence in bicycle repair be assessed using a social practice epistemology?
RQ 3.0 Theoretical	How do peer-to-peer interactions in this setting affect the effectiveness of learning processes?

Transcending the psychological model

My effort to understand the cognitive processes of students, including problem solving behavior, revisits the same fundamental problem that cognitive scientists originally faced in the 1960s: How does one investigate a phenomenon that is not directly observable? Early cognitive scientists modeled cognition as a black box phenomenon that took place inside the human head so that cognitive processes had to be inferred from external, directly observable processes. Psychologists devised elaborate ways of poking at human cognition inside the black box with various interventions to find out how it reacted to experimental stimuli.

When anthropologists brought sociocultural perspectives into the study of cognition, they changed some of the underlying assumptions about the nature of reality. One of these paradigm changes was Hutchins's (1995) notion that cognition is distributed across social relations and physical artifacts. As a result of releasing human cognition from the confines of the individual brain, many cognitive processes became more directly observable as external actions. It was not just the observable physical manifestations or social interactions of distributed cognition that had become more accessible, however. The very notion of intention and executive control had also been decentered from the individual brain to a much wider sociocultural and historical context.

Workplace learning

This study occupies the category of workplace learning research, an active area of inquiry that has demonstrated how work environments organize thinking, doing, and learning in a manner very different from what occurs in the conventional school classroom. However, that research has focused almost exclusively on adult populations¹. A principal aim of the present study is to help expand workplace learning research into the realm of young people so that the special relationship between work setting and learners can be understood in a population whose conceptual development is less evolved, and whose development of cultural practices has much shorter and presumably simpler histories.

Hutchins (1995) explains how his detailed ethnographic analysis of the work of ship navigation vastly expands the complexity of our understanding of thinking strategies compared to the simplistic psychological study of students learning fixed sets of information since it considers adults in a complex social setting trying to execute successful work task performance. Hutchins, an anthropologist specializing in cognition research, recognized the potential of ethnographic methods to open up new approaches to cognitive research that the linear rationality of experimental psychology could not achieve. I reasoned that in my study, some of the methods of workplace analysis that Hutchins developed could be applied back to the more simplistic situation of children trying to execute simple work tasks successfully.

Situated cognition: A new paradigm for knowing

For decades now, cognitive research has focused increasingly on workplace learning because of the full-spectrum, naturalistic context that work settings provide for the dynamic study of knowledge in use. Studying how humans learn as they actively confront real problems

¹ The few investigators who studied workplace cognition among children (Carragher & Schliemann, 1985; Saxe, 1991) focused on informal situations such as street vendors in developing countries outside of the U.S., probably due in part to child labor law restrictions.

in a work environment seems likely to reveal aspects of cognition not accessible through research confined to a classroom or laboratory. Research findings so far strongly support that assumption.

If knowledge were strictly universal in character independent of the particulars of local situations then the choice of study setting would make little difference in learning research. This study assumes that, on the contrary, knowledge and the cognitive and sociocultural processes that organize it are fundamentally situated. In other words, knowing and thinking are processes that interact and co-develop with their social, cultural, and physical environment and therefore depend profoundly on local context over historical time².

Situated cognition has been a high profile topic in the research literature for over two decades—about the same amount of time as workplace learning research. Yet, with few exceptions workplace learning studies have examined adult work activity only, while learning in children has remained limited to a schoolwork or laboratory context. Unless school-based learning—e.g. solving preconfigured problems in artificial contexts, performing on standardized tests—is considered the ultimate educational experience, cognitive research in a school context is inherently limited to a narrow spectrum of factors in its ability to explain thinking and learning processes.

Some investigators have attempted to remediate this problem by researching curricular or pedagogical efforts to recreate conditions of real-world work environments within the school environment or in computer-based problem spaces. However, real-life simulations have produced surprisingly limited pedagogical success suggesting that certain qualities inherent in the total contextual ecology of physical, social, and cultural relations account for the “situated cognition” effect. If so, it points to the need for *in situ* research on workplace learning among children to help identify those relational qualities. But since school-age students spend much or most of their waking hours in school, alternative research settings for studying youth engaged in authentic work activities can be challenging to find.

Children learning and working in the shop

The exploratory bicycle shop is a commercial enterprise with an educational mission. Students repair bicycles and sell them. Beginning students perform basic bicycle repair activities in the same physical and social environment as the advanced students. Advanced students typically perform production-level bicycle repair, do sales work, and often become paid employees. This unusual combination of children as workers in a commercially viable retail and service environment makes it possible to apply the methods of adult-oriented research on workplace learning to an earlier developmental age group, thus benefitting child cognition research.

The bike shop setting also serves another purpose in the study: it provides an excellent testing ground for social practice theory, a type of situated learning theory and the primary component of the study’s theoretical framework. Described further in the next section and in detail in Chapter 3, social practice theory essentially argues that learning is best understood as a

² Far from arguing against the validity or existence of abstract, decontextualized, knowledge-as-information, this stance argues instead that all types of knowledge have a historical and cultural context and that privileging abstract knowledge as school tends to do exerts a cultural influence. The present study examines the effects of that cultural influence.

process of becoming a central participant in a community of practice rather than acquisition of a body of knowledge in isolation. More simply put, learning consists of enculturation into skilled practice. By contributing to the social practice model of learning and cognition, this study effectively strengthens the base for its research findings.

New Theory, New Methods

The fundamental move from a cognitive to a cultural conception of knowing described above, and from a psychological approach to an anthropological one for learning research, is a necessary development for advancing social practice theory. In many respects this anthropological-cultural “turn” in learning theory mirrors the poststructuralist rupture in the 1970s that held the “logical empiricist” academy accountable for its assumptions about value-free research and standards for evidence. That academic rupture questioned traditional conceptions of self and social interaction and embraced what Foucault (1976) called the “insurrection of subjugated knowledges.”

Social practice theory likewise promises to hold academia intellectually accountable by challenging fundamental assumptions about knowing and the nature of reality. It offers a new paradigm that cuts even deeper into traditional thinking and research practice than the poststructuralist phenomenon. One problem with such a disruptive and fundamentally alien theory of knowing and learning is that the entire infrastructure of inquiry—assumptions about evidence, validity, and the fundamental nature of knowledge and reality, for example—has to be recalibrated to the new paradigm. That includes analytic research methods, since most of the prevailing methodologies assume a traditional, i.e. positivist, epistemology.

Visual anthropology

One research method has been at the forefront of critiquing the research establishment on its fundamental assumptions about knowledge and reality: visual anthropology (VA). Since its emergence in the 1970s, VA has been at the leading edge of progressive scholarship within the anthropology discipline, arguing that the researcher-informant relationship strongly skews informants’ responses when not adequately attended to and challenging traditional scientific standards of validity. However, VA took a particularly radical turn in the 1990s (MacDougall, 1998; Pasqualino, 2007; Pink, 2006) in which it disparaged even the explanatory purpose of research. An explanatory approach to researching another culture serves primarily to distance and otherize that culture since the explaining is normally filtered through the knowledge structure of the researchers’ culture. Instead, the more radical VA practitioners attempt to cultivate the voice of the culture being studied, to represent that culture as it sees itself, not as the research establishment perceives it after it has been filtered through the knowledge structures of the prevailing epistemology (Nichols, 1991). This effort to understand a separate culture on its own terms has a close parallel in learning sciences studies that attempt to understand student behavior from the perspective of the student.

Several key researchers (e.g. Becker, 1998; Goodwin, 1994) have used earlier forms of VA to examine cognitive research problems, but the more recent, politically charged version of VA has not been used in conjunction with cognition and learning research for the very reason that the cognitive research tradition and its operative paradigm are antithetical to the new VA. The present study tests the possibility that since virtually all currently practiced methodologies

are text-based—that is, they ultimately rely on linguistic representations of mind for the analysis of data—one potential solution would be to try a non-linguistic form of analysis such as VA.

Naturalism and study validity

The overriding objective in VA is to represent a culture with maximum accuracy from the standpoint of the culture being represented. Inherent in that goal is an activist ethic that obligates practitioners to deeply evaluate their study design against the standard of informant-based point of view and to redress any aspects that violate that standard including any aspects that traditional positivist research practice perpetuates. The most common problem facing most of the current prevailing methods involves diminished study validity due to factors such as artificial tasks, detached researcher-informant relationship, and numerous other impediments to a sincere, truthful, and accurate exchange of information between researcher and informants. The very label of “subject” traditionally used to identify the person being examined reveals an inherent positioning of the researcher with a superior status and an objectifying perspective.

VA addresses these issues through a stance of *methodological naturalism* which is the general strategy I use for maximizing study validity. Naturalism in the researcher-informant relationship refers to any attitude or technique of the researcher that equalizes the power relationship with the informant or otherwise reduces factors which set the researcher apart from the culture of the informant. As a key element of VA, naturalism during the data collection process helps assure the most reliable quality of data. The less artificial the motives for action, the more reliable and valid will be the quality of the informants’ actions.

Figure 1-1. Marcus, a 15 year old apprentice in the Sierra shop.



Work plan

I employ a combination of VA and conventional research methods, which sets up a methodological tension. VA defines the principle methodology, however, consisting of 50 hours

of participant-observation resulting in an ethnography of the exploratory bike shop phenomenon as experienced by school-age participants. I videotaped students as they performed bicycle repair activities and solved practical problems in natural work activities, rather than in a contrived problem context. In my particular case as researcher, I functioned at a near-native level of participant-observer, further enhancing the naturalism of the research relationship.

I use the ethnographic findings to identify key research conjectures about social practice learning theory, which are then tested using a controlled conditions sub-study. I combine those quasi-experimental results with the ethnographic data base to further test the conjectures against the empirical data. Finally, I discuss the role of the conjectures and findings in advancing a few details about social practice learning theory. This mixture of traditional psychological methods with ethnography stretches the boundaries of both psychology and anthropology but is by no means a new combination. However, to use ethnographic and participant observation methods of “data” collection in conjunction with VA is a novel amalgam and a methodological experiment in itself.

Two central characters from the cast of study informants are introduced here to help put a human face on the densely theoretical discussions of the next few chapters. Marcus in Figure 1-1 has worked in the Sierra shop for a little over one year. In recognition of his verbal and mechanical skills, he was offered a paid position in the shop and spent two months in the summer of 2010 as an employee preparing recycled bikes for sale, instructing beginning students and occasionally helping customers. Figure 1-2 shows Emily who has worked in the Cascade shop for seven months. She mastered the skills of Cascade’s beginning level bike repair course and now occasionally helps other beginning students.

Figure 1-2. Emily, a 10 year old student in the Cascade shop.



The respective stories of Marcus and Emily, while linked by a common interest in working in a bike shop, followed distinctive paths to very different outcomes. Chapter 6 provides a detailed visual analysis of how both achieved a remarkable degree of bicycle repair competence. Marcus is shown truing a wheel that he built, the crowning achievement of bike mechanic apprenticeship, and Emily can be seen overhauling a hub, a skill she subsequently uses

to help an older student solve a vexing problem. Yet Chapter 7 mentions how their involvement with their respective shops eventually ended differently. Their stories will help ground the shop-level ethnographic case studies and the theoretical discussions to the level of direct human needs and goals.

Nomenclature and definitions

The term “educational bicycle shop” encompasses a wide variety of bicycle-related ventures that have a primarily educational purpose. All educational bike shops are nonprofit entities, either legally established as 501(c)(3) charitable organizations, or more informally, simply committed to a community service rather than the personal financial gain of their principals. The exploratory bike shop that provides youth with participatory learning experiences is the dominant subcategory within the larger educational bicycle shop category, and it is the most commonly referred to category in this study. Community bike shop cooperatives that provide professional tools and work space to adult fees-paying members are less common than educational bicycle shops. They have been around longer than youth exploratory bike shops, but are limited mostly to large metropolitan areas or progressive college towns with a collectivist-oriented adult cycling public. Few adult cooperatives exist outside of the West and East coasts, whereas youth-oriented exploratory bike shops thrive anywhere where there are plenty of children and bicycles.

In an educational context, the word “technology” has acquired the default denotation of computer technology. Only in the most politically progressive or environmentally oriented parts of the education community is the word taken in its larger sense of any technique or system or set of tools devised by humans to create a desired product or outcome. The latter definition encompasses bicycles as an example of “appropriate technology,” a term coined by environmental activist inventors to name human-made systems that conserve, are sensitive to, and are in tune with planetary resources. In the present study, “technology” refers to any tool system, whether physical or conceptual, that humans have created to help achieve a goal. The educational significance of tools as Hutchins (1995) explained, is in the coordination of relations between the tool user and his or her environment. In a broader sense, tools mediate thinking as Vygotsky (1978) explained. But that mediating effect specifically helps the tool user to align culturally with the appropriate community of practice, a notion that will be explained in later chapters.

There are two types of young participants in the exploratory bike shops described in this study. Beginning participants are referred to as “students” until they complete the entry-level skills training period. If they elect to pursue any additional involvement in the shop such as advanced level training, paid internship, or peer instructor work, they are referred to in this study as “apprentices”. Because the three shops participating in this study had significantly different approaches to instruction, youth development activities, and policies, strict definitions for “student” and “apprentice” cannot apply across all shops. Consequently, the terms are sometimes used interchangeably.

1.3 Structure of the Dissertation

Chapter 1 introduces the study, framing it as an investigation of workplace cognition in a population previously unexamined in a formal work setting: children. The research design is problem-driven, a quality emphasized by the use of “Problem Arcs” in each chapter that chart the

logical path of theoretical and methodological problem solving over the course of the study. Each research problem is presented in a logical progression that provides a chronology of study design decisions and strategies. Not every research problem is included in this chronological trajectory of study design decisions, but enough milestones exist to trace a coherent problem-based inquiry strategy.

The remainder of Chapter 1 then explains how, taken together, these key problems indicate a need for new research methods designed to circumvent these problems, some of which have persisted for decades. The solution chosen for this study is a combination of ethnography and quasi-experimental methods within a visual anthropology framework. This approach is designed to capture a more faithful representation of student thinking by examining students' problem solving strategies as they unfold in use in a naturalistic setting.

The literature review in Chapter 2 situates this study within a broad research context. It traces the history of learning research along three separate strands: a) work studies, b) practice-based learning theories, and c) visual analysis. These three research trajectories reveal a convergence of theoretical interests and methods around basic problems of cognition and learning. Of the three strands, visual analysis is the least explored, particularly in connection with problems of cognition, but it appears to offer considerable promise in the way it complements new knowledge paradigms including that of social practice theory. The latest work that ties these strands together encompasses numerous disciplines including organizational studies, public health, and philanthropic studies, in addition to the psychology, sociology, and anthropology of education. By demonstrating how the shop experience engages each of these disciplinary perspectives, this chapter completes setting the stage for a formal inquiry into the nature of thinking and learning in the exploratory bicycle shop.

The next four chapters apply the multidisciplinary perspective of the bike shop experience to an analytic framework. In Chapter 3, analysis of the principal research questions begins with an ethnography of the exploratory bicycle shop. The ethnography portrays the range of variations on this organizational model based on three years of participant observation of three shops in culturally distinct regions of the country. Parts of the chapter are autoethnographic in nature, drawing on my two decade career in the field. However, the chapter focuses mainly on case studies of the three focal shops. It presents the experience of participating in the exploratory bicycle shop from the perspective of students and staff members. Ethnographic data is drawn both from my field notes and from videotapes of work sessions in those focal shops including interviews with participants.

In Chapter 4 I describe how the new social practice paradigm for conceptualizing knowing and learning requires a visual analytic method to help describe what shop participants do spatially, temporally, and physically. Visual methods achieve this in ways that verbal analysis of understanding has not to date accomplished.

Chapter 5 lays out the sequence of study phases and the individual steps within those phases. Chapter 6 reports the study's findings in the form of individual case studies. Specific substudies include a quasi-experimental study of students performing a standard tire repair task and an extended analysis of two girls solving a challenging mechanical problem. Chapter 7 recaps the logical progression of the study's arguments and methods and discusses how the findings can potentially benefit educational reform efforts.

1.4 Problem Arcs

This chapter introduced the project—understanding students’ problem solving practices as they work in an exploratory bicycle shop—on a strongly personal note. As Macdougall (1998), a leading visual anthropologist, cautioned however, “Whose story is it?” In trying to tell students’ stories, am I inadvertently retelling mainly my own by overinterpreting students’ experiences principally through my own lens? The admonition to critically question one’s own research methods is a fundamental principle of the VA methodology, and it is particularly appropriate for an autoethnographic approach even though it was originally aimed toward the prevailing positivist model and its unreflexive, uncritical presumption of objectivity.

The answer to those questions, for now, is that I will later invoke other aspects of VA methodology to help ensure faithfulness to the informants’ perspective and to minimize the bias that my own perspective inescapably imposes. At this point I focus on other issues including methodological problems in studying student practices and the logical capacity of prevailing cognitivist theories to answer questions about student practices. The two problem arcs below address each of those two problem areas.

Effective methodology for studying practice

- **Problem Arc 1.** Prevailing research methodologies based mainly on experimental approaches are designed to detect students’ psychological and social reactions to interventions, not ordinary culture-based habitual practices. Even ethnographic methods of interviewing and participant observation seem limited in their ability to produce accurate, reproducible findings. What qualities does a research methodology need to transcend the limitations of prevailing study methodologies in the analysis of student practices?
- **Solution Strategy.** A culturally-based, situated cognition epistemological framework is necessary, but not sufficient to assure reliable gathering of data on student practices. A non-objectifying method of establishing cooperative relations with students would help ensure data accuracy and authenticity.

An example of a non-objectifying data collection method is VA. For example, VA rejects intervention-based experimentation in favor of observation techniques designed to record informants’ actions in the most naturalistic way possible. This focus on recording informants’ ordinary behavior rather than exclusively testing “subjects’” responses to verbal interview protocols yields greater data reliability and study validity. Such an approach is made possible to a large degree by the social practice framework which posits a participation-based conception of knowing and learning rather than the prevailing notion of learning as the acquisition of concepts. Since learning is seen largely as an ongoing process that unfolds in the practice of habitual activity, more than a specialized interaction between teacher and learner, the most authentic recording of informants’ actions will logically provide the most reliable perspective.

Combined with a social practice theoretical framework, VA methods of data collection would go far toward capturing visual data on students’ practices as they perform ordinary problem solving in the course of their habitual activities. In the educational research community there has been much self-examination about the effectiveness of research methods, however, research methodologies have not yet caught up with the radical changes in learning theories. For example, while advances in accessible video recording technology has made the video camera

one of the most widely used tools in learning research, analytic methodologies have not evolved much beyond using video technology as simply a convenient form of visual note-taking. The methodology of visual anthropology (VA), a novelty in the educational research community, addresses that limitation. VA strongly interrogates how the researcher's actions and intentions affect the research outcomes, and it devises new ways of minimizing researcher bias.

Logical capacity of theory to explain cognitive effects of setting

- **Problem Arc 2.** My instrumental role in the historical development of the exploratory bike shop movement puts me in a uniquely strong position to examine and report on the relationship between the exploratory bike shop setting and student cognition. However, it also potentially blinds me to new perspectives through over-familiarity with the topic. My interpretations need support from the research literature.
- **Solution Strategy.** Find justification within the research literature to support the research questions that emerge from this study.

A principal goal of this study is to understand the relationship between educational setting and the learning process in the case of the exploratory bicycle shop. The insights gained into that relationship are expected to be of value in solving the educational equity problem described above. For example, students from historically underserved racial, economic, or linguistic backgrounds who are inaccurately assessed as having low aptitude for learning constitute a common educational inequity. As this study attempts to show, a better understanding of how educational settings shape learning can help fix problems caused by inaccurate assessment of learning and competence.

Chapter 2: Literature Review

Existing studies relevant to this study fall into three general categories: workplace learning studies, practice-based learning theory, and visual analysis. Because these research categories overlap considerably, some of the cited work may belong in multiple categories even though they are assigned in this chapter only to one category.

The watershed development that established a foundation for all three of these research strands in the U.S. educational research community was the advent of situated theories of cognition in the 1980s. By decentering studies of learning and thinking from the mentalist, individual-knower conception of psychology and focusing instead on a wider social and cultural arena that Geertz called “fields” of knowing, situated cognition theory found a way to answer or circumvent some of the most fundamental theoretical problems that had vexed researchers for decades.

In contrast to other situated cognition research, this study applies the recent revival of interest in visual methods to the new situation of children solving problems in a work environment. The problem arc at the end of this chapter reiterates the flow of theoretical and methodological problem solutions that shaped the research design.

2.1 Work Studies

Bicycle shop research

The research literature on the educational aspects of exploratory bicycle shops is virtually nonexistent. The Youth Bicycle Education Network (1997) newsletter published an interview with Milbrey McLaughlin, a Stanford educational researcher, whose policy-oriented work focuses on community-based education and community-school relations. In the interview McLaughlin discussed how educational bicycle shops fit well into the type of community youth development institution she calls “urban sanctuaries” for focused learning and healthy social interactions.

In a similar policy-oriented vein, Wynn (1996), a research fellow at the Chapin Hall Center for Child Development at the University of Chicago, explained how the Indianapolis Bicycle Action Project exemplifies *primary supports*. The term *primary support* refers to a school, youth center, library, or similar community institution that provides youth with opportunities to explore and learn in healthy ways. The “youth development” model developed by researchers at Chapin Hall advocates policies that prioritize funding for strengthening *primary supports* rather than corrective measures. Those researchers describe their strategy as a “strengths-based” prevention model in contrast to the deficit-based intervention model used frequently in public health policy.

The only peer-reviewed research on exploratory bicycle shops was Kinnevy et al’s (1999) social work study of how group task-centered activities in a Midwestern shop improved the self-esteem and cooperative work skills of shop participants. The quantitative, quasi-experimental portion of the study found only limited evidence of increase in positive outcomes over the 12-week study period. However, qualitative data from a focus group conducted found a significant improvement in self-perception that correlated positively with length of time that the participants had been actively involved with shop activities (varying from 0 to over 12 weeks).

Learning mathematics, problem solving, and other skills in the workplace

Studies of workplace learning in other trades and industries are abundant. They began to proliferate in the 1980s, and studies of mathematics learning in the workplace by anthropologists were among the earliest examples. One particularly elegant study in this group was Scribner's (1984) investigation of dairy workers' invented mathematics. Scribner and her team observed the workplace mathematics used in the jobs of three different workers in three different order fulfillment jobs in a medium-sized, urban, milk processing plant: warehouse shelvers, order preloaders, and delivery drivers. Scribner's study is described in detail below because it presaged so many of the key research questions and conclusions reached in subsequent research on situated cognition, social practice learning theory, and distributed cognition, which are the focus of my study.

Order preloaders, who transferred varying quantities of product from inventory arranged in standard case quantities to an order load, learned to augment or diminish case quantities of products like skim milk and chocolate milk in various unit sizes to fill partial case orders. Because cases held a standard number of unit sizes—e.g., 4 gallons, 16 quarts, 32 pints—and the computer system expressed partial case orders as “ x cases plus or minus y units”, preloaders were predisposed by their work context to think in a kind of alternate-base arithmetic. For example, the computer represented an order for 10 quarts as “ $1 - 6$ ” quarts, i.e. 1 (case) minus 6 quarts. A 35-quart order would be represented in the computerized shorthand as “ $2 + 3$.” The first value in these two-term expressions always refers to the number of cases, similar to how the first digit in a two-digit number refers to multiples of 10.

On top of this computer-generated number representation system, preloaders would often overlay their own quantitative coding system. Since workers frequently did not find a full case from which to pull units to fill an order, they often diverged from the literal computer instructions. For example, to fill a computer-generated order for $1 - 6$ quarts, a preloader interpreting the order literally, would remove 6 quarts from a full case. However, if the preloader encountered a half-full case with 8 quarts, he might consider the option of filling the same order by adding 2 quarts from another case to the existing 8 quarts. An experienced preloader would opt for the “ $8 + 2$ ” solution because it involves less physical work than the “ $16 - 6$ ” option: just 2 quarts instead of 6. In a continuously repetitive manual job such as this, minimizing physical effort not only helps avoid stress-related injury but also improves worker efficiency and productivity.

Adding to the noteworthiness of this invented mathematics situation is Scribner's finding that experienced preloaders do not count or make arithmetic calculations when subtracting units from or adding them to a case. Instead the workers use a contextually-based form of *subitizing*, a visual way of judging quantity without counting individual units. In this case, however, the workers are not just evaluating quantities of product, they are visually and non-numerically solving maxima and minima problems. They seem to be comparing possible configurations of cases and units using a visual-geometric method to optimize, i.e. minimize, the number of moves required to match the quantity ordered. One preloader describes his solution process in the following exchange:

“Preloader: I was throwing myself off, counting the units. I don't never count when I'm making the order. I do it visual, a visual thing, you know.

Interviewer: OK, well, do it the way that you would do it, I mean, as far as that's concerned.

Preloader: If I did it that way, you wouldn't understand it. See, that's why...this is what's throwing me off, doing it so slow. (Scribner, 1984, p. 26)"

Scribner's interpretation of these findings was that preloaders first learned the "value of various configurations of containers (e.g. one layer of half-pints is 16; two rows of quarts is 8)" or what I surmised was workers becoming familiar with the number bases for specific sizes of unit containers and how they fit into a "case" container. Then, the preloaders were able to fill the orders "with little or no recoding into the number system" by relying on visual cues in the work environment.

As further support for the contextual basis of the preloaders' visual arithmetic system, Scribner compared performance on conventional arithmetic calculation tasks among population groups with varying levels of schooling, from warehouse workers with an average tenth grade level of schooling to office clerks with twelfth grade educations and to a group of ninth graders in a nearby school. Scribner found that flexibility in developing and applying creative solution strategies correlated inversely with level of schooling or with enculturation into school practices.

The fully school-enculturated students demonstrated the least flexibility, invariably applying the same standard arithmetic algorithms for each calculation. But office clerks, whose calculation practices relied on standard algorithms and calculators also showed much inflexibility. The manual laborers whose work environment supplied physical cues or physical "intelligence" which the workers resourcefully incorporated into their calculation system were the most amenable to trying a variety of solution approaches. Scribner considered flexibility in solution strategies to be a key characteristic of contextual thinking and an example of what Bartlett (1958) described as the adaptive component of expertise or "fitting the approach to the occasion."

Several other cognitive anthropologists extended Scribner's experiment on the contrasting correlation between work practices and school practices on thinking modes, drawing increasing attention to a dichotomy between practical and academic thinking. Carraher and Schliemann (1985) showed that Brazilian juvenile street vendors with little schooling developed distinctive arithmetic regrouping strategies in making complicated price calculations. Saxe (1990) working with a similar population also found invented calculation methods that were in many cases superior to conventional school-taught algorithms. Lave (1988) repeated the comparison using everyday practical thinking scenarios to contrast with school-based thinking modes, and her work is described in detail in section 1.2.2 below.

All of the mathematics learning studies mentioned so far found similar contrasts between in-school and out-of-school thinking and problem solving. This notion is central to my study, which seeks to understand how work setting can influence learners' thinking. How workers develop "indigenous" methods of solving quantitative or other problems is a question motivating many subsequent workplace learning studies including Hall (2001), my study, and Orr's (1996) ethnography described below.

Other manual trades learning environments

Orr (1996) published a seminal ethnography of workplace learning with his study of electronic copier machine repair technicians. His was one of the first studies to observe how the invisibility of work, particularly that involving technical support, indicates how work has "become an abstraction" absorbed into the production function of an organization. He described how much of the learning about repair techniques occurred not in formal technical training but in

the social milieu of technicians trading “war stories” about challenging repair problems. This discursive practice seems to be nearly universal among manual trades technicians, including apprentices in exploratory bicycle shops as described in Chapters 4 and 5 of this paper.

Service industry workplace learning

The most systematic study of organizational learning using a social practice epistemology was Wenger’s (1998) book that used the “community of practice” framework to describe how health insurance claims processors learned on the job. His analysis used the “legitimate peripheral participation” model of learning, co-developed with Lave (Lave & Wenger, 1991), to illustrate how workers’ professional identities interacted within the workplace community of practice. Varying levels of participation in negotiating meaning in work activities defined learning processes.

2.2 Practice-based Learning Theories

The most profound advances in educational research over the past few decades have occurred as a result of the fusion of previously incommensurate fields such as social cognition and cognitive anthropology. Much of the impetus for the development of such hybrid domains came not from within traditional educational research but from cutting edge explorations of thinking and knowing from fundamentally different epistemological paradigms. Ethnomethodology and symbolic interactionism helped lay the groundwork for social models of knowing and learning in the 1960s and 1970s. In later developments, activity theory and social practice theory posited that knowing consists of participation in communities of practice rather than the acquisition of domain content. Filtering through all of this was the influence of early twentieth century phenomenology. New interdisciplinary fields such as work studies and organizational studies harnessed these radically new perspectives to explore thinking in the everyday, situated cognition contexts of offices, workshops, teaching hospitals and other sites of active problem solving.

In this section I describe many of these intellectual traditions that this study embraces as historical trajectories of the development of pivotal ideas. In the case of social practice theory, for example, I start with Lave’s (1988) focus on the “everyday” arena of practice-based learning. I trace Lave’s roots back through Merleau-Ponty’s (1962) phenomenology via Bourdieu’s (1977) wide-ranging social theory and Vygotsky’s cultural-historical approach to Dewey’s pragmatism, to mention just some of the influences. Lave would not necessarily agree with this characterization of her intellectual heritage since she emphasizes her Marxist-Hegelian roots more than she does the roots of Vygotsky and Dewey. That is how I read the trajectory of ideas for my own purposes.

Contemporary with Lave and after that, scholars associated with social practice theory branched out in different directions but maintained a practice-based conception of knowing and learning. Those influencing this study included the cultural-historical activity theory (CHAT) proponents who trace their origins to Vygotsky and the other Soviet cultural psychologists. Roth (Roth & Lee, 2007), a key CHAT proponent, strongly advocated Lave’s version of social practice theory as did others such as Barab (Barab & Roth, 2006) and, to a lesser extent, Sfard (2002, 2008). Wenger (1998), mentioned earlier, developed the most systematic theoretical framework for the *community of practice* construct. Hall (1996; Stevens & Hall, 1998) was a key social practice advocate who modeled the combination of practice-based theory with work

studies and with visual methods that I selected for this study. I chose to examine learning using the conceptually simple technology of bicycle mechanics rather than the complex design-based architectural and engineering work that Hall tended to work with.

Everyday cognition

The cognitive “revolution” that started in the 1950s and lasted several decades was so intellectually fertile that it attracted scholars from many disciplines who had not previously been associated with studies of thinking, learning, and problem solving. One of the newly minted disciplines to emerge from that period was cognitive anthropology, the use of mainly observational methods to examine what a person needs to know to function in a culture. Unfortunately, the initial crop of cognitive anthropologists favored methods that examined cognition as a behavior that responded in global, predictable ways to various artificial interventions rather than as a practice to be documented in its naturalistic state (Hutchins, 1993). In other words, early investigators in this field abandoned the anthropological approach of observing how practices “unfold” in local, naturalistic activity and opted instead for more psychologically oriented controlled conditions for collecting data.

In the late 1970s and 1980s, a few progressive anthropologists, following the lead of Scribner and Cole’s (1973) seminal paper on the cross-cultural contrast between the effects of informal and formal education on learning and cognition, began to examine the relationship between learning and setting. Most influential among these was Lave (1977, 1988, 1993), who based her research on several novel precepts. Lave reasoned that a) learning was something that humans did in virtually all kinds of situations, not just formal educational settings and activities; b) to study learning and thinking at its most elemental level, she chose to examine mundane, basic practices in modern U.S. culture: adults engaged in grocery shopping and making dietary calculations as part of their Weight Watchers regimen; and c) the most reliable data would be obtained by observing “how mathematical practices unfold in everyday life” rather than testing her informants under controlled experimental conditions. Lave found that everyday problem solvers seemed to draw on non-formal (i.e. not learned in school) methods for basic arithmetic calculations and comparisons. Her findings corroborated the similar observational studies of dairy workers (Scribner, 1984, see detailed review below) and Brazilian juvenile street vendors (Carraher et al, 1985; Saxe, 1991).

Learning as legitimate peripheral participation

Lave and Wenger (1991) presented a social practice theory of learning and knowing based on a radically new ontological and epistemological paradigm, the notion that learning is essentially a social process involving a transformation of relations in the shifting of personal identities from peripheral to central participants in a community of practice. This model of learning offers a complete alternative to traditional acquisition-based models, but few other theorists accept social practice as an exclusive explanation for learning and instead have adopted a combination of social practice and conventional acquisition theories. This study attempts to test the social practice model in the case of child apprentices learning bicycle repair in exploratory bicycle shops.

Throughout this paper, social practice learning theory will be used almost synonymously with cultural-historical activity theory (CHAT) even though there are substantial distinctions between the two. Both can be called practice-based theories, and both use activity as the main

unit of analysis as opposed to the acquisitionist notion of learning content. The justification for using the two theories interchangeably in some cases relies on this common ground and strong commonalities in the sources for both theories which include Hegelian and Marxist materialism.

Hall and Greeno (2008) have specified a social practice framework that reveals how concepts travel across professional communities of practice. However, no one has yet used this framework to analyze student learning or learning among young apprentices. Hall and Greeno do discuss classroom learning in a social practice context, but that description defaults to a more acquisitionist conception of conceptual knowledge of mental structures that are acquired and transferred.

Several authors beginning with Bateson's (1972) example of the physical extension of a blind man's perception and cognition through his stick have described the socially and/or physically distributed nature of cognition. The seminal work on distributed cognition was Hutchins's (1993) study of how the complex task of maneuvering a large ship in tight spaces requires the coordinated participation of multiple crew members who continuously feed perceptual information to key decision makers. Hutchins found that the ship's captain did not in fact "know" all of the information being shared. Rather, the captain depended on the distributed network of intelligence under his command to collectively "know" the ship's position, bearing, speed, and general relationship to its surroundings.

Student practice and the influence of activity setting

Cobb and colleagues (Cobb & Hodge, 2002; Cobb et al, 2001) studied mathematical practices in the conventional school classroom. They developed one of the earlier models of practice-based analysis of learning. Not only did Cobb (1986), an educational psychologist, cross disciplinary boundaries to embrace the anthropological focus on student practice but also he articulated succinctly the problem of cultural mismatch between "the contexts of academic reasoning and everyday reasoning: ...the overall goal of everyday reasoning is not to construct compelling arguments in the face of potential scrutiny [as in academic reasoning]. Instead it is to act so that the individual can achieve his or her particular goals in a specific situation (p. 3)."

Cobb and Hodge (2002) fashion their analysis of mathematical practice on Wenger's notion of community of practice and Gee's notion of Discourse. Their analysis identifies mathematical classroom practices such as justifying arguments, and corraling evidence which are based on a cognitivist-constructivist knowledge paradigm. Such a model for practice-based analysis does not examine the non-cognitive aspects of the representational infrastructure realm of practices considered in VA analysis.

Despite Cobb's (1986; Cobb & Hodge, 2002) acute awareness of the theoretical importance of studying student practice, he does not adopt any of the principal methodologies of anthropology, instead remaining a hard core cognitive psychologist devoted to experimental and design experiment methods. This paradoxical incongruity between Cobb's culturally-oriented theory and his psychological methods could be resolved simply by calling him a cultural psychologist. It is more productive, however, to question the definition of "practice": What does practice mean in a learning sciences context?

The study of student practice as in "problem solving practices" in my study implies an anthropological theoretical framework and a corresponding use of anthropological methods that rely on naturalistic observation rather than psychological methods that record behavioral responses to artificial interventions. The former method describes cultural practice as what people do under ordinary circumstances while the latter method describes practice as behavior in

response to artificial stimulus. Notably, Cobb uses both methods, making him hard to classify methodologically. He studies student practices as they unfold naturalistically in the classroom. The classroom represents academic culture and the norms of cognitive and social behavior associated with it. In that sense he is using anthropological methods of data collection. Yet, Cobb is also one of the first researchers to recognize that academic culture differs fundamentally from the culture that students participate in outside of school. Cobb's distinction between academic-school culture and students' "home" culture goes a long way toward explaining culture-based differential academic achievement in the case of students from nondominant cultures. Since schools represent the values of the dominant culture and thereby perpetuate cultural and social reproduction (Bourdieu, 1977; Willis, 1981), students from nondominant cultures face an inherent cultural challenge and a cultural-political decision in determining to what degree they want to conform to the cultural practices and psychological norms of the academic culture.

2.3 Visual Analysis

VA emerged as a subfield within anthropology in the late 1970s and 1980s as a challenge to the prevailing focus on textual analysis of cultural artifacts—including interview transcripts and field notes—and the colonialist worldview associated with that analytic tradition. Early advocates of VA believed that the mid-twentieth century ascendancy of social and cultural anthropology had adopted a far too objectifying stance toward other cultures (Pink, 2006). They believed that shifting the principal medium of analysis from textual to the visual and other senses would open up new avenues for understanding other cultures and eventually would help disrupt the underlying epistemology that promoted cultural objectification.

The first principle of VA is to intensify the role of reflexivity in cultural research. Pink (2004) explained how this was not just a matter of increasing the degree of reflexivity about the relationship between researcher and informant but rather a qualitative change from "explanatory" to "deep" reflexivity. MacDougall (1998), a video pioneer among visual anthropologists, claimed that video enabled such a deep reflexivity through elicitation of informants' responses to the video production process and in some cases elicitation of the informants' own perspective through video self-representation.

Another key element of VA method is the use of montage as an alternative to the linear logic of textual scientific explication. Montage uses the sequenced juxtaposition of images to represent cultural realities in a more authentically informant-based rather than researcher-inflected manner. A drawback of the montage technique is that when used alone or in a predominantly visual and/or verbal montage piece, such an intentionally disruptive communication technique risks obscuring more than it conveys. Nevertheless, when disruption of the dominant culture's logical paradigm is the goal, montage can be effective. Becker (1998) wrote one of the most balanced, lucid, and simultaneously lyrical, descriptions of the process of VA analysis including the use of montage techniques. Becker likens the photographer's montage of images in a book or exhibition to a table of statistical data. The rows and columns of a tabular grid accomplish the work of comparing a list of items with each other along one dimension and also across a second dimension. When we try to induce the photographer's creative intentions by similarly comparing images along one dimension, then another, we are performing the same analytic work. Becker's (1998) analogy effectively describes how visual representation can achieve a multidimensional expression that transcends the unidimensional logic of most scientific explanations:

“The multitude of details in the documentary image gives viewers the material with which to construct not just one comparison of this kind. You can make more than one table, so to speak, out of a lengthy sequence of detailed photographs. There are many comparisons to make, many dimensions to explore, many stories to tell. (p. 9)”

VA in the study of cognition

Preceding Becker’s article by a few years was Goodwin’s (1994) seminal article on “professional vision.” That article also discusses how the human practice of organizing images into categories of meaning explains much about how humans develop conceptual understanding and increasingly expert identities. Goodwin was the first anthropologist to develop a visual method for analyzing learning interactions in a social practice framework:

“To analyze how practice is organized as a temporally unfolding process encompassing both human interaction and situated tool use, I require as data records that preserve not only sequences of talk but also body movements of the participants and the phenomena to which they are attending as they use relevant representations. (p. 607)”

Echoing Hutchins’s (1993, 1995) work on the phenomenon of distributed cognition, Goodwin observed how coding schemes embedded in data-entry forms enlarge the scope of the mundane practice of filling out a form to participating in the distributed intelligence of a large organizational system. In a related observation, Goodwin noted “The [physical setting] in front of [the apprentice archeologist] was a locus for embodied practice, not an object of contemplation (p. 627).” In the case of this apprentice, in other words, cognition was constituted in the visual practice of comparing dirt samples and filling out forms as opposed to more conventionally cerebral actions. Also relevant to my study was Goodwin’s examination of how tightly bound our ways of seeing are to our identities and our social status as members of a community of practice.

Closely related to Goodwin’s article is the work of visual anthropologist Grasseni (2005) who has advanced the concept of “skilled vision.” This concept addresses the way seeing is central to social practice theory’s conception of learning as the increasingly central participation in a community of practice. Skilled vision is also a powerful bridging concept between the anthropological perspective on practice as ritual and the psychological perspective on practice as behavior.

VA in the shop

Dant (2004) is a sociologist who used visual anthropology methods to study the work of automobile mechanics. Dant borrows Bourdieu’s construct of *habitus* to describe not just the “dispositions” of workers in the shop but also the set of habits and techniques they use in their work, which produces “a stage for analyzing how workers interact with the material objects in the shop.” Dant contrasts his analysis with Orr’s (1996) ethnography of copier repair technicians, explaining that his own study describes “work on machines rather than work determined by machines (Dant, 2004, p. 44). One interesting connection that Dant makes with social practice theory involves his description of auto mechanics’ methods for learning about the function of an

unfamiliar component. This study describes apprentices' learning about bicycle function by "reverse engineering" components to understand the original designer's intentions, Dant similarly explains his auto mechanics' processes of solving mechanical problems. Dant cites Merleau-Ponty's (1962) description of "intentional threads" as a label for this inductive process of reverse engineering to discover the original design intelligence.

2.4 Problem Arc

Practice, naturalism, and the influence of activity setting

Over the past four decades, some unlikely alliances have formed among previously incommensurable academic disciplines resulting in considerable self-examination and change within those disciplinary cultures. Anthropologists studying human cognition found irreconcilable flaws in the dualistic theories and positivistic empirical methods used by experimental psychologists. They devised radically new theories of knowing and thinking resulting in the situated cognition family of theories, which required a paradigmatic change in epistemologies.

This literature review has demonstrated how separate trends in cognition, learning, and anthropology research have converged around common issues such as situated learning and visual methods. However, because this cross-fertilization of disciplines has involved such fundamental, paradigmatic changes in academic cultures and epistemologies, the convergence is still in an early stage of development. Many changes have not yet been adopted at a mainstream level by the educational research community.

- **Problem Arc 3.** Ambiguity about the definition of "practice" as in problem solving practices exists in the research literature. The case of Cobb (1986, 2000) prompts my distinction between "practice" and "behavior". Even with my distinguishing definitions, however, Cobb's case remains ambiguous.
- **Solution Strategy.** My definitions for "practice" and "behavior" hinge on two questions: location, i.e. the setting for the thinking and learning practices, and the naturalism of the activity.

It was ironic that Cobb (1986) who so eloquently described the tension between academic and everyday reasoning practices would be the most influential researcher not to embrace the role of setting in shaping the students' everyday cultural practices. Instead, Cobb chose to use school as the default setting for learning, which relegated informal learning to a sharply subordinate role. Regardless of Cobb's motivations for that decision, the consequences were that the general trend of research on student cognitive practices during the 1990s and early twenty-first century adopted the school-based learning default, a circumstance that tended to marginalize critical parts of the situated cognition branch of study.

The most critical underdeveloped element in Cobb's work was the notion of the distributed nature of cognition. Cobb picked up on the socially distributed aspect of the concept, but he neglected the physical environment and its effects on thinking practices. This turn away from the concrete and deeper into the abstract realm of knowing is further reflected in Cobb's (2000) focus on symbolizing as the critical activity in students' practices. The tension between formal and informal learning, academic and practical reasoning is precisely analogous to the opposition between symbolizing and physical or concrete action. Cobb and Hodge (2002)

demonstrated that they understood the implications for educational equity, but still they chose not to explore the concrete activity.

My bike takes me places that school never could.

–“Bumper” sticker on bicycle parked outside of a Berkeley cooperative bakery.

Chapter 3: Reinventing the Wheel: An Ethnography of the Exploratory Bicycle Shop

The previous two chapters have suggested the importance of pursuing a research path that combines novel visual analytic methods with a focus on learning settings in order to tackle the problem of student underperformance in nondominant cultures. This chapter answers that challenge by providing an ethnography that depicts the world of the exploratory bicycle shop and its participants. It presents this world both from a historical case study perspective and from an autoethnographic perspective drawn from four years of the author’s formal field notes and an additional 18 years of informal journal entries. Other data sources included videotaped student work sessions in the shop and student interviews.

The resulting ethnography serves both as a backdrop to the subsequent formal intervention research phase reported in Chapters 5 and 6 and as an analysis in its own right of the cultural forces that shape the exploratory bike shop experience. In time, those cultural forces will themselves be shaped by the students who participate in the shop. Students’ sense of competence will eventually help redefine academic performance in terms that reflect a sense of ability and achievement that is not strongly biased toward the dominant culture.

Normally a discussion of analytic methodology would precede the actual analysis. That is the case with this dissertation insofar as the data analyses in Chapters 5 and 6 follow the discussion of method in Chapter 4. By placing this ethnography before the discussion of method, I am signaling: a) how an ethnography, as a standalone story of the bike shop setting and its participants, differs fundamentally from experimental data analysis, b) that an ethnography can often work well without an introductory discussion because it is narratively self-sufficient and it relies instead on a post-production interpretive discussion, and c) that an ethnography could have started the dissertation in Chapter 1 since it is so effective at setting the stage for subsequent analysis.

3.1 The Political History of Bicycle-based Education

Thanks largely to Susan B. Anthony (1896), who championed the bicycle as the greatest invention for the emancipation of women, the bicycle has long symbolized freedom in many forms, including economic freedom and the childhood freedom of personal transportation. The history of bicycle-based education ventures in the late twentieth century has likewise been aligned with progressive social movements and causes. Following the political ferment of social and environmental justice activism in the late 1960s and 1970s, isolated community-based or municipally-operated bicycle repair collectives and educational programs sprang up in the 1970s and 1980s in the U.S. and Canada. This initial crop of community-oriented bicycle education centers, although independently operated, held in common the social vision of facilitating access to economical, non-polluting transportation especially for lower-income persons.

One of these early bicycle education enterprises, called Bikes Not Bombs (BNB), had a particularly distinctive and politically radical mission. BNB started in Boston in 1984 to collect recycled bicycles and ship them to Nicaragua as nonlethal, constructive aid at a time when the U.S. government was backing *contra* forces to overthrow the Sandinista revolutionary government. Along with the recycled bicycles, tools, and spare parts, BNB provided

sophisticated technical training in bicycle repair and economic development to the Nicaraguan health worker and educator groups that received the bicycles.

From revolutionary Nicaraguan fields to urban U.S. streets

BNB's original mission was to use "the bicycle as a tool to create locally-controlled, sustainable development (Bikes Not Bombs, 1992)." Not content with merely providing material and technical aid to the Nicaraguan people, BNB's larger vision was to establish a bicycle-based economic and physical infrastructure in smaller towns and rural regions to work toward a populist-grounded peace. Figure 2-1 depicts this work in a pastoral setting. In this image, BNB co-founder Carl Kurz is at far left with farmers who have purchased bicycles with the help of BNB's revolving loan fund.



Figure 3-1. "Farmers from the Mario Gonzales Cooperative bought ten bikes with loans from [BNB's] "Bicicletas Al Campesino" Revolving Loan Fund," [circa 1987.] Reprinted with permission.

Against this backdrop of intensive international activism, two youth-oriented bicycle education organizations in the U.S. heartland were accomplishing education and community economic development work similar in many respects to BNB's but domestic in scope. In 1988 the Bicycle Action Project (BAP) opened a storefront "classroom disguised as a bike shop" in a gritty industrial-commercial-residential borderland neighborhood in downtown Indianapolis. The author was the founder. In distinct contrast with BNB's revolutionist roots, my occupation at the time was writing proposals for a division of a multinational conglomerate that contracted for U.S. Department of Labor funds to run technical job training programs. I conceived BAP as an educational experiment, an alternative learning center for urban youth that would use the allure of bikes and a professional shop environment to motivate participants to learn technical skills and then transfer that enthusiasm for learning to their schoolwork³.

A year later, in 1989, a similar storefront educational bike shop, St. Louis Bike Works (SLBW) opened in a predominantly low-income neighborhood of St. Louis. It was established

³ See "Community/school/parent Perspective," a subsequent section for a description of how school teachers and administrators reacted to the influence of the educational bike shop on student academic performance.

independently from BAP, but the two organizations collaborated closely for several years on developing policies, curriculum, and the general program model. SLBW's founding director was a credentialed secondary-level industrial arts teacher.

Both organizations were committed to community economic development in the sense that they trained advanced-level apprentices who lived in the surrounding economically depressed neighborhoods to be employees in the shop. As white middle-class community activists, the directors of both organizations shared the conviction that their success would be measured by the extent to which members of the immediate neighborhood, mostly persons of color and of low socioeconomic status, would eventually be running the organization. In such a scenario, the educational bike shop would simultaneously service the low-cost transportation needs of the adult community, train youth apprentices for employment (not just in the bike shop but in terms of general employability skills) improve apprentices' overall attitude toward formal learning, and ultimately improve apprentices' academic performance in school.



Figure 3-2. “Only the educated are free.” Left to right, BAP’s retail manager, executive director, and office manager pose in the shop’s reception area, in front of a quote from Epictetus.

Many circumstances changed in 1990 both for the politically-charged BNB and the fledgling youth bicycle education phenomenon, a politically isolated anomaly in a socially repressive section of the Midwest. In that year, a national election in Nicaragua removed the Sandinistas from power. That event spurred BNB to diversify its international aid efforts into developing countries elsewhere in Latin America and in Africa. It also prompted BNB to swing part of its education and economic development focus back to home territory, a move that resulted in the start of a neighborhood youth program in a low-income section of Boston’s Jamaica Plain neighborhood that taught bicycle safety and bicycle repair.

1990 was also the year in which BNB leaders fortuitously met the founding directors of the two Midwestern educational bike shops, BAP and SLBW, at a national bicycle advocacy conference. That meeting revealed the strong common ground that the three organizations had developed for education-based community development. For the ensuing three years, BNB and

the Indianapolis BAP organization sustained a close working relationship, and BNB started on a path to becoming the preeminent educational bike shop model⁴.

Disseminating the exploratory bike shop model

The alliance between BNB and BAP likely did more to disseminate the educational bike shop program concept than even the bit of national media attention that BAP had received. BNB was an exceptionally well-managed organization that had developed a nationwide network of local chapters mostly in progressive college towns across the U.S., such as Madison and Austin. BNB collected thousands of bicycles and funneled them to Boston or other container shipping ports. Archived newsletters and strategic plans from the period 1990-1994 show that word of BNB's own domestic youth program along with news about the Midwestern educational bike shops spread through BNB's political activist network. Such evidence strengthens the likelihood that the activist network was a primary vector for the spread of the educational bike shop concept and its development into an effective educational innovation.

The BNB-BAP alliance was timely because by 1994 both organizations were concerned much more about shoring up their own local operations than about developing a national movement. BNB in particular had opened its storefront exploratory bike shop for youth and had scaled back its own national network of BNB chapters. Nevertheless, in 1994, the Youth Bicycle Education Network (YBEN) national consortium of educational bike shops was established. By 1996, the number of educational bike shops nationwide had grown to about 40. In 1999, a study I conducted for the National Highway Transportation Safety Administration (NHTSA) and League of American Bicyclists (LAB) counted roughly 100 educational bike shops in operation in the U.S and Canada.

Next generation exploratory bicycle shops

There are clear signs around the country that a new generation of exploratory bike shops is emerging. This next generation of shops is based on a program design that better suits the cooperative spirit among genuinely grassroots activist organizations that is beginning to take hold. The collapse of the national coordinating organization, YBEN, in 2006 strongly indicates that the old model of independently operated shops struggling for survival was too dependent on the personal energy of charismatic social entrepreneurs. In many ways the nonprofit organizational model and IRS law together cultivate this figurehead leadership style and competition for independent survival or separate nonprofit empires.

The new model, exemplified by a coalition forming between the City of Richmond (California); major public health-oriented philanthropies; an emerging group of cooperative, employee-owned businesses; and a bicycle-based coordinating organization called Richmond Spokes that provides concrete youth in-shop learning opportunities but focuses mainly on building a cooperative network of social action ventures. Brian Drayton, one of the original crop of youth bicycle education activists, is building the Richmond Spokes network based on a new vision of market demand for youth development services rather than sustained dependence on philanthropic largesse. Drayton's management plan even includes a data-generating component

⁴ BNB was originally slated to be a data collection site for this study, but the costly and time-consuming logistics of coast-to-coast travel between Berkeley and Boston deterred that plan.

that will provide, or sell, up-to-the-minute survey data to public health providers like Kaiser Permanente and Robert Wood Johnson Foundation, since he can require his students to complete surveys as periodic course requirements. Youth participating in Richmond Spokes learn as much about achieving their own personal intellectual, political, and economic development as they do about fixing bicycles. On the East Coast, BNB is the best example of a similar, new, youth-managed cooperative organizational model.

3.2 Individual Study-Site Descriptions

Before describing in depth the exploratory bike shop experience, a description of each study site is given below. Each exploratory bicycle shop develops a distinctive institutional identity owing in part to the specific cultural and geographic character of its local community and participants and partly to the interaction between the founder's vision and the staff's expertise. BNB, for example, was intensely political because its founders, staff, and parent organization for several years—the Institute for Transportation and Development Policy—defined the organizational vision that way. Its identity was also a product of, a substantial supply of radicalized financial sponsors and progressive donors in the Boston area. In contrast, Cascade Community Bikes (Cascade), reflects a progressive, but much more muted political identity. Sierra Community Workshops (Sierra) teaches both youth and adults in its bicycle shop and also operates a boat building shop that educates young students in woodworking skills. Heartland Educational Bicycle Shop (Heartland) is in one respect a ward of the Protestant religious establishment in that it operates rent-free out of a church. The individual stories of each of the three study sites are provided below.

Eco-establishment: The Story of Cascade Community Bicycles

Comparable in many ways to the well-managed BNB organization, Cascade combined intense grassroots political organizing with a well-defined ideology. The ideology was environmental and the management style was professional, from an early stage. From its inception in 1993, Cascade had an experienced executive director in contrast to most educational bike shops that are run at least for the first few years on the energy and determination of activists with little to no management experience. Cascade's first executive director had been a manager with the regional Environmental Protection Agency (EPA) office, and she used that experience to establish a strong organization and even to procure substantial federal funding through one of EPA's pollution and congestion mitigation programs.

Cascade was originally conceived as a bicycle lending enterprise similar to the European model in which "community" bicycles painted an easily identifiable all-white or all-yellow are distributed in an urban area for free, available to anyone who finds one. Yellow bike programs have been started in nearly a hundred U.S. communities but have worked well only in two cities, Austin and Minneapolis. When Cascade discovered after a few years that its bicycle lending program was not going to work, it confined its focus to educational programs centered around bike mechanics and environmental education. In 1997 Cascade opened a storefront commercial bike shop in a two-story converted residential home. The commercial bicycle sales and repair operation were squeezed into the front, street-level room. A separate educational shop occupied the space of three other ground floor rooms and the administrative offices were upstairs.

Artisan Revival: Sierra Community Workshops

Sierra manages the complexity of the hybrid educational-commercial bike shop identity in a unique manner. In addition to providing youth apprentice training in bicycle repair and the typical sales and repair services of a retail bike shop, Sierra also opens to the public six professional-grade bicycle work stands four days a week. Anyone can use at no charge the work stands and the available tool set to repair a bike or build up a bike from used or new parts.

This kind of free, community-based open studio is available in many communities. What distinguishes Sierra from other educational bike shops is that it is part of a multi-craft group of studios and other facilities. Sierra also operates a boat-building workshop, which teaches woodworking skills. The bike shop is also equipped to teach metalworking skills.

Sierra's vision is to teach children and adults the traditional value of metal working and woodcraft while maintaining or building traditional and environmentally sustainable transportation vehicles. Until a year ago Sierra also offered industrial sewing instruction to adults. That program has been discontinued, but the remaining industrial sewing machines are used to repair or make sails as an adjunct to the boat-building activities.

Sierra inherited much of the bicycle repair, industrial sewing, woodworking equipment and material inventory from a similar multi-craft community workshop in the same city that had operated for many years but which did not succeed in establishing a sustainable funding base. The previous organization had a core of highly talented artisan-technicians, but that core staff, which included the visionary founding director, held onto an organizational vision and political principles that ultimately even the highly progressive community where it was located would not adequately support⁵. When Sierra's management team took over many of the assets including the city-owned buildings, it found financial supporters in the city government, local foundations, and private donors that were highly receptive to the change in management.

Located on city park property, on a lakefront, Sierra's bike shop occupies one building in a small cluster of former park buildings now occupied by Sierra and another nonprofit organization that equips physically disabled youth with high-quality, lightweight, hand-crank tricycles and takes those participants on road outings. Sierra's other main building houses the boat-building shop, administrative offices, and a café open to the public. The boat shop does not have open studio hours for adults like the bike shop. Instead it conducts classes for youth in basic woodworking skills and boat-building activities, takes youth on boating excursions on the adjacent lake, and occasionally takes on commissioned boat repairs or boat-building projects.

Reviving Enthusiasm for Learning: Heartland Exploratory Bike Shop

Heartland has a corner office in a house of God. Nearly all of Heartland's operations are crammed into a 350 square foot room in one corner of a grand, gothic, stone Presbyterian church in a low-income, mainly African-American neighborhood of a Midwestern city. Other than its churchly surroundings, however, Heartland runs a purely secular educational program. The

⁵ An interesting educational note to this history is that two members of the previous organization's core team were outcasts from the educational staff of San Francisco's venerated Exploratorium family science center. While the Exploratorium employs many creative and talented educators in its program design staff, it is easy to imagine how two of its educators became disaffected with the dominant-culture politics and institutional inertia of such a large, multi-million dollar nonprofit enterprise.

executive director is an ordained minister, but does not use her clerical title, and few participants other than the core staff members know about her professional history. Moreover, the lead instructor, a middle-aged, street-hardened yet “organic intellectual⁶,” African-American social activist and youth worker, is a devout atheist.

The church is a focal point of the African-American community for miles around. In fact, its youth sports program has launched several professional athletic careers. Its new AstroTurf football field was donated by the local NFL franchise. Indoors, its basketball court is occupied every day by youth basketball clinics and adult and youth pick-up games. The corner room that Heartland occupies lies at one end of the short foyer entrance to the basketball court, so a degree of competition for participant attendance exists between Heartland and the adjacent basketball court.

Like the bike shop’s educational program the sports program does not mix religion and sports with the sole exception of a pre-game prayer delivered by the program’s associate director. The coaching, both in the bike shop and the football field, does tend to be more strongly values-oriented than in less conservative regions of the country simply because of the dominant culture in this Bible Belt state. But unlike the practices of some of this city’s Baptist or Pentecostal youth sports teams, sports activity is not a vehicle for religious education or indoctrination.

A corollary to this conscious separation of church and community outreach is reflected in the church’s mainly high-brow congregation. A major portion of the church’s regular membership consists of key politicians and other local movers and shakers. Folks of modest means from the immediate neighborhood, although welcome, have not been drawn to the congregation. Their participation with the church is predominantly as recipients of the church’s largesse in the form of its sports program and other community service commitments. The Heartland shop strikes a notable middle ground between dominant culture charity and grassroots community activism.

3.3 The Exploratory Bike Shop Model in Educational Research

A remarkable tension exists between quasi-educational organizations and authentically alternative educational ventures. The former uses “educational” mainly as a marketable “tag” in their mission statements to designate a passive commitment to provide conventional educational services, while the latter are fully committed to exploring ways of improving youth learning opportunities.

The Earn-a-Bike Program Model

The bicycle education entrepreneurs who create community-based exploratory bicycle shops are an inherently independent lot. The typical entrepreneur gathers a few like-minded idealists and establishes a modest start-up venture that gradually attracts more volunteers, funding, and hundreds of bicycle donations per year. Normally, with no recruitment efforts

⁶ I use this term in the Marxist sense of a non-formal, non-institutionalized intellectual, who critically examines social relations and structures from the perspective that experience as a working-class member of the nondominant culture provides. Yet, this person cannot be categorized as Marxist in his political views. His beliefs encompass a complex mixture of revolutionary, atheist, and Republican individualist leanings.

beyond a brief write-up in a neighborhood newsletter or newspaper, a neighborhood bike shop will attract the attention of local youth, and another educational bike shop is born. That, from an educational activist's point of view, is yet another way to describe the educational bike shop phenomenon.

A critical part of the community economic dynamics that keep such a venture going is a program feature called "earn-a-bike" that provides a free bicycle to participants who complete a set of requirements, often a 25-hour curriculum of work-study in bicycle mechanics and related skills. Earn-a-bike is one of the few standard program features, if not the only one, in the individualistic, independent world of exploratory bike shops. The earn-a-bike program feature creates a work incentive for many apprentices as the following perspective of a 15-year old girl demonstrates:

- CH ...have you earned a bike?
Debra Um hmm. I've earned a bike.
CH And that took how long?
Debra I think around thirty hours.
CH Thirty hours. OK. Is that a bike that you use now?
Debra Um hmm. I use it now. So does my mom.

Debra and her mother use the bicycle for transportation in the bicycle-friendly urban neighborhood where they live. Her mother emigrated from Vietnam where bicycle use is deeply entrenched in the working class culture, so the daughter earning a bike and learning how to maintain it created cultural continuity in that family's daily life.

While the impact of an earned bicycle is dramatic in that family's case, a more frequent scenario is the child who uses an earned bicycle more for recreation. So necessary is the automobile to basic transportation, that even in urban areas with strong public transit, low-income families frequently spend an inordinately large share of income to maintain a car. A 1999 *New York Times* editorial chronicling children's bicycle use in Hannibal, Missouri, home to the mythical Tom Sawyer, noted the peak of U.S. suburban and exurban sprawl which spelled the demise of bicycles for transportation use. "A late-afternoon tour of a subdivision yielded two people on bikes and four on riding lawn mowers...As Hannibal goes, so goes the nation. In the shadow of a long, slow decline in cycling generally, the bicycle as a century-old symbol of childhood freedom and transportation is nearly extinct. (Kilborn, 1999)" Consequently, earn-a-bike, while an almost universal feature among the 200 documented exploratory bike shops worldwide, seemed to be a more symbolic than instrumental motivation for children to participate in exploratory bike shops.

Nevertheless the decline in bicycle use and sustainable transportation started to shift after 1999 due to public health concerns about sedentary life and obesity, gasoline price spikes, and a gradual trend in urban planning toward walkable, bikable, and otherwise livable cities. Momentum toward increased bicycle use has increased steadily in the twenty-first century, but the factor which has caused the most dramatic increase has been the deep recession of the past two years. The opportunity to earn a recycled bicycle may once again become a significant incentive for participating in educational bike shop activities. However, as described in the case studies below, other incentives for participation are apparently at work.

3.4 Experiencing the Educational Bicycle Shop

The reality of any philanthropic social intervention like the opening of an exploratory bike shop in a poor urban neighborhood by middle-class predominantly white social activists normally creates more distinctive purposes than the conventional opening of a commercial bike shop. The exploratory bike shop combines six types of stakeholders directly in its social network and several types indirectly. Not only is every type of stakeholder’s experience different but also the purposes of each stakeholder type are slightly out of phase in subtle but sometimes consequential ways. Table 3-1 lists key stakeholder types and their respective purposes.

Table 3-1. Stakeholder analysis.

Stakeholder category	Principal purpose or objective	Secondary purposes and explanatory notes
Apprentice	earn a bike, learn repair skills	belong to an ethical, professional community of practice
Paid staff – program	guide apprentice exploration and practice; develop learning opportunities	
Researcher/Guest Instructor	research, teaching	
Paid staff – admin & retail	<i>admin</i> : service funders <i>retail</i> : service customers	
Volunteer staff – all types	“give back” to community; assist program or admin staff	learn bike repair skills on-the-job
Retail customers	obtain professional repair services; buy a recycled bike	support a charitable cause
Parents, neighbors	<i>low-income parents</i> : obtain free educational experience for child <i>mid/upper-income parents</i> : obtain rare manual skills learning opportunities for child in a culturally foreign community	
Local school staff	obtain effective program option to service difficult-to-serve or underperforming students	
Funders – private	<i>foundations</i> : support an effective alternative education center <i>corporate</i> : piggyback on good publicity; build positive local image <i>individual donors</i> :	
Funders – public	enhance family support and youth development services with effective educational program	

Apprentice perspective

The numbers tell much about the attitudes of apprentices toward participation in shop activities. When a new shop opens in a neighborhood, enrollment numbers tend to grow rapidly as “word on the street” spreads the news about a place where kids can work in a bike shop and “earn” a recycled bicycle.” In the early years of the phenomenon, demand for enrollment sometimes exceeded the supply of opportunities, resulting in a waiting list. However, enrollment would eventually level off as it became clear to neighborhood youth that this was not a give-away opportunity but work incentive opportunity keyed to learning and becoming a competent beginning bicycle mechanic. That awareness seemed to dissuade the prospective apprentices who were frivolous and encourage ones who intended to complete the required work.

Deon, a 13-year old apprentice at Cascade described his understanding of the shop as follows.

- CH Tell me about the purpose of [Cascade]. What’s the idea behind this place?
- Deon I think the purpose is to help kids learn how to fix their own bikes. And to help them re-use things, because here we re-use a lot of things on other bikes.
- CH OK. So that describes what goes on in this room. How about the whole place. Cause there’s other things that go on here.
- Deon There’s like a lot of different people, so you meet new people every time a new class comes...and you like make new friends.

Another apprentice at Cascade, 15-year old Colin, shared his perspective on the nature of the shop.

- CH What’s your role here? What’s your job?
- Colin My role is usually for the drop-ins. I just help out. For the past few weeks I’ve been working on my own, cause I have enough hours to earn [a bicycle]. But usually I’ll help with whatever projects they have going on and help move that along.
- CH If you had to describe [the Cascade shop] to a friend as either a bike shop or a school, which category would you use?
- Colin I would use both. I would say, “Well there’s a bike shop in front where you can buy stuff, and there’s a school in the back where kids can learn how to fix bikes and work with bikes. So essentially, it’s both.

Becoming critical learners

Participating in the combined school and bike shop that Cascade represents constitutes a privilege because of the high demand for work space. Apprentices typically wait at the front entrance at opening time until they are called in to occupy one of the ten work stations. Apprentices who are working toward earning their first bicycle take precedence over the earn-a-bike graduates who are there mostly to accumulate hours on their time card to earn special parts for an existing bike. However, graduates who have also completed the advanced bicycle repair

program have *carte blanche* to enter since they contribute to the educational mission in a unique way.

The logic behind advanced students' privilege has less to do with a privilege hierarchy and more to do with allocation of knowledge resources. For example, Donte, who at age 13 is the youngest advanced bike mechanics graduate in Cascade's 15-year history, can enter the shop at will because the Cascade staff assign students to work together in beginner/expert pairs at each workstation. Advanced apprentices like Donte (see Table 3-2) are normally scarcer than beginning students, so he is always assured of a work station. Even if there were an abundance of advanced students, Donte would still be assigned to workstand because of his value as a peer instructor.

Table 3-2. Participation levels at Cascade.

Expertise Level	Entrance Requirements	Consequences
Beginning earn-a-bike apprentice	Open to all.	Qualifies to earn a bicycle and to enter advanced bike mechanics program.
Advanced apprentice, EAB graduate	Completion of 25-hour course of study	Becomes eligible for paid employment in bike repair and sales in the exploratory bike shop
Advanced mechanics program graduate (journeyman)	Completion of advanced mechanics course of study	Certified in basic mechanics skills. Qualifies for entry-level employment in any bike shop.

Community/school/parent perspective

The perception of the exploratory bike shop phenomenon by local educators was instrumental in establishing the shops as legitimate community-based learning centers. For example, the original Indianapolis educational bike shop, Bicycle Action Project (BAP) made a deep impression on many, but certainly not all, educators. Third-grade Indianapolis Public Schools teacher Barbara Rago shared the following observations about the influence of BAP on some of her students. This quote elaborates on the brief excerpt quoted from the same source earlier, in Chapter 1, expanding on the context of Mrs. Rago's sentiments.

“During the last two years, I have been aware of BAP [Bicycle Action Project] through some of our students. I saw some changes in students . . . Anthony was no longer trying to get out of work, he was working to his personal best. He listened, participated, concentrated, and worked willingly. He became well-liked by others at school, children and adults.

Anthony has not always been this kind of student...

I have seen the BAP in action. It is keeping kids off the street, teaching lifelong skills, giving a sense of accomplishment to children who have not experienced accomplishment. It is the brightest light in this community.”

In another Indianapolis elementary school, Assistant Principal Susan Childers used constructivist and situative learning theory and an economics framework to argue for the funding to support Street Scholars, a program of the Bicycle Action Project:

“Tomorrow’s adults will not have single job careers, but will need the skills that will enable them to retool for a new job five or six times during their lifetime. Our brains are always searching for ways to link information. In the tradition of the Bicycle Action Project, Street Scholars will enable educators to make meaningful connections between what young people are learning and their daily lives. This is especially important to the young people who live in the center city area of our larger cities. Far too early, these young people see little connection between school and their lives in the streets. Through Street Scholars, the children will learn skills that will keep them reading, not just decoding the alphabet; skills that will help them solve real-life problems not just complete a page of math computations. Street Scholars will guide young people to revisit the excitement of discovery, and so recapture the will and drive to learn.”

Researcher/Research-instructor perspective

The following excerpts from field notes in the Sierra exploratory bike shop illustrate interactions between myself and a group of students with severe emotional disabilities, one of the special populations that the Sierra shop specialized in serving.

I floated around to each student during the first 10 minutes, mainly just observing their activity, attitudes, and the general atmosphere of the work space. Alvin needed help immediately, and I started to work with him. During the rest of the session I occasionally stepped away from Adrian and his project just to give him some breathing room and sense of independence. I gave the others, except Adam, one or two suggestions during the course of the session. I didn’t even speak with Adam during the session except at the very end. He projected an air of independence and impatience, and one of the Lespoir staff commented that he seemed to be in a particularly bad mood.

Observations About Apprentice Learning and Problem Solving

Master-apprentice interaction

Watching Jorge work with Miguel this afternoon as they installed a longitudinal runner rib on the bottom of a small boat demonstrated how unproductive the educational workshop can be. One problem that the pair encountered was that Jorge was working at a pace that was too close to normal for him. I think he is still learning how to adjust to the perspective of the initiate as in the interaction between senior and junior archeologist that Goodwin (1994) describes. This interaction illustrates the process of managing the balance between competence and incompetence, knowing and ignorance, in the master-apprentice interaction.

Visual grammar

Jerome competently diagnosed and tightened the bottom bracket in a manner that illustrated thinking with a visual grammar rather than a verbal one, (to adapt Sfard's commognitive framework.) He then struggled with, but mastered, tightening of the rear hub cones. Having successfully adjusted the bottom bracket, he was conceptually prepared to adjust the hub cone, especially since the nutted rear wheel allowed easy hub adjustment without removing the wheel due to the axle vise effect of the one tight axle nut. However, the different appearance of adjusting cone and locknut (or maybe it was the more complex combination of axle nut, dropout, locknut, and cone) confused Jerome. After loosening one of the axle nuts, he repeatedly tried to tighten the cone by turning it counterclockwise. Even after I advised him to tighten it in the other direction, he persisted in trying to tighten counterclockwise after sensing that turning the cone clockwise seemed to loosen it. It took a couple attempts to explain to him that he was loosening the cone from the locknut when he turned it clockwise. When he grasped that problem image, he correctly tightened the cone against the bearings, but he did not demonstrate any sensitivity to the precision needed for the adjustment because he cranked the cone down hard against the bearings until, once again, I had explained that he needed to tighten the cone lightly, then back it off slightly. After a few more trial-and-error attempts, he reached a perfect point of adjustment as determined by the looseness-tightness test. I think his understanding of cone adjustment is strong. The only concept he may have missed was the notion that the best way to feel hub cone looseness is to wiggle the rim between the seat stays because that position provides the maximum frame rigidity in contrast to a moving rim, hence the most noticeable sensation in the case of a loose hub cone. Admittedly, it's not an easy concept to explain verbally, so maybe that was the cause of Jerome's incomplete understanding.

The Emergence of Peer Tutoring Practice

One of the most striking images and the most satisfying to shop staff members is to see one apprentice teaching another. The teaching often takes the form of traditional didactic instruction in which the more advanced apprentice explains to the novice apprentice how to do a procedure, or what concepts underlie a particular repair technique. Peer instruction often takes such a form because that is what education has come to mean after many years in the school system. Imagine, then, the satisfaction of seeing apprentices mimic the constructivist techniques of allowing their less experienced peers learn by exploration, working to create learning opportunities for them. It does not take long for apprentices exposed to constructivist teaching methods to understand the value of exploratory learning within these unusual learning communities and to reject the didactic teaching model that they had learned for years by example.

All three study sites practice peer tutoring to some degree, either in the traditional didactic style or the progressive constructivist style. The following dialogue illustrates such an interaction at the Heartland shop.

Adult Instructors

The style of instructing/mentoring in all three study sites was remarkably consistent considering that there is no standardization of curriculum among the exploratory bike shops across the U.S. much less any common source of teacher training. Yet, the current generation of

instructors in the three study sites uniformly used an intuitive version of constructivist instruction in which the instructor usually guides the students toward learning opportunities rather than explaining procedures and concepts beforehand. There are often circumstances that require immediate instructor intervention and explanation, but for the most part the student is encouraged to guide the inquiry.

3.5 Problem Arc

The challenge this chapter inherited from the previous chapters was to find out how the bike shop setting shaped students' problem solving and other thinking practices. Ethnography appeared to be the appropriate analytic tool since it addresses a broader swath of context than psychological experimental methods attempt. This chapter presented a detailed history of the exploratory bicycle shop movement and brief case descriptions of the three exploratory bike shop study sites. It also provided samples of text-based data from student interviews, educator statements, and my own field notes about learning interactions in the shop. Altogether, these illustrations painted a general picture of the exploratory bike shop experience. Drawing conclusions from this general ethnography would be premature. However, the ethnography does provide a critical perspective from which to launch the quasi-experimental analysis in Chapter 5 and the more detailed VA-based ethnographic analysis in Chapter 6.

- **Problem Arc 4.** Setting is a key factor in situated theories of cognition that ties problem solving practices to that theoretical framework. To examine the relationship between setting and student problem solving practices this chapter developed an ethnography of the exploratory bike shop experience that provided a broad spectrum of perspectives and potential analytic frames. By itself this analysis does not produce significant new findings about setting and student practices.
- **Solution Strategy.** Subsequent study phases will attempt to explore new perspectives on student practice by using VA methods to open up the visual and haptic dimensions of student activity. Expanding the data stream to include new sensory dimensions is one way VA elucidates thinking practices in a videotaped work session more clearly than a traditional cognitive analysis. Other VA strategies include penetrating beyond the persona that informants often project during data collection by strengthening the researcher-informant relationship.

This chapter was the first step toward documenting the thinking practices of students in the exploratory bike shop. While the data described here were collected following VA principles, the analysis consists almost entirely of a text-based ethnography independent of VA methods. Chapters 5 and 6 will incorporate mainly VA analytic methods.

In an interview I conducted with Heartland executive director, Nora Simpson, the highlight was a discussion about how to determine competence in shop apprentices. The problem of assessing apprentice competence emerges from the situational need for the shop staff to know how well the apprentice is learning so the appropriate measures to change the apprentice's level of participation in shop activities can be taken. This intrinsically determined need for assessment stands in sharp contrast to the extrinsic purpose that educational assessment is normally used for, namely to rank student performance for subsequent placement into further educational or career pathways.

This difference in purpose of assessment can also be seen in the methods used by the shop compared with typical educational methods. Shop assessment invariably tries to evaluate the apprentice's knowledge *in use*, while conventional methods test for abstracted forms of knowledge. The consequences of this distinction in assessment methods are further explored in the next chapter. Chapter 5 uses standard task comparison and participant interviews to investigate apprentices' processes of learning and problem solving.

Chapter 4: Visual Methods: Theoretical and Historical Context

“Swooping god-like into other people’s lives and gathering ‘data’ (including visual ‘data’) according to a predetermined theoretical agenda strikes me not simply as morally dubious but intellectually flawed.” (Banks, 2001, p. 179)

In this chapter, I explain why research on learning and cognition needs to embrace the perspective offered by visual methods and why visual anthropology in particular is appropriate for the study of learning in the educational bike shop. I begin with an overview by examining how conventional research methodologies are inadequate to demonstrate the analytic power of newer practice-based learning theories, such as social practice theory and cultural-historical activity theory (CHAT), which form the theoretical framework for this study. I then introduce visual anthropology (VA) methodology as an appropriate choice for coupling with practice-based versions of sociocultural theory. The remainder of the chapter presents a detailed case for using visual methods. It introduces three “positions” that further argue for the complementarity of theory and methods and explain other key advantages of using VA methodology. In the next chapter, I focus on VA methods, describing in detail the specific procedures used and the social and historical context of the study.

4.1 Social Practice and CHAT: Two Theories in Search of a Method

Cognitive research methodology has not kept pace with the revolutionary advances in learning theory over the past 30 years. A case in point is the social practice model of knowing and learning that constitutes part of the theoretical framework of this study. The model measures learning in terms of centrality of participation in a community of practice, not in terms of knowledge content acquired. This radically alternative way of conceiving knowing has made significant inroads into accepted theoretical usage (e.g., Barab & Roth, 2006; Roth & Lee, 2007; Sfard, 2002, 2008). However, neither social practice theory advocates nor users of the closely related CHAT seem to have found an analytic methodology that unlocks the full potential of these innovative theories for the purpose of empirical inquiry into learning and cognition.

One of the best attempts to rectify this problem and craft a new methodology appropriate to practice-based theory was the *disciplined perception* strategy developed by Stevens and Hall (1998), based largely on the pioneering visual analytic method of Goodwin (1994). Taken up subsequently by others, including Jurow, et al. (2008) and Lindwall and Lymer (2008), disciplined perception analysis relies on examining the perceptual asymmetries between novices and experts while they interact during an activity central to a particular discipline. For example, Lindwall and Lymer (2008) analyzed the ways in which two postsecondary students and their physics instructor discussed ways of seeing a linear relationship between force and acceleration in a graph of messy data. The experienced perspective of the instructor enabled him to see an overall linear relationship among scattered data points, which the students could not see until they negotiated a common understanding of “linear relationship” with the instructor that relied on what Hall and Greeno (2008) call *representational infrastructures*. Representational infrastructure encompasses a broad class of environmental factors—social and physical structures including classification systems, discursive practices such as styles of reasoning and argumentation, tools, and artifacts—that indirectly contribute to knowing and learning.

Stevens and Hall (1998) originally devised *disciplined perception* to accommodate various modes of perception, but the visual mode has emerged as the most commonly studied.

The strength of the method lies both in its intensified focus on the ordinarily neglected visual data stream and in using activity as the unit of analyzing learning rather than the more customary based on acquisition of new cognitive structures. In these ways disciplined perception provides an analytic method that directly taps the distinctive features of practice-based learning theory. Another example should help clarify the elusive nature of social practice theory and begin to describe the particular learning content of the present study, which includes bicycle mechanics, mathematics, and classical mechanics concepts.

Social Practice Theory and the Assessment of Bike Shop Knowledge

An educational bike shop apprentice who does not use the specialized language of the bike shop and has difficulty executing a basic repair procedure effectively will likely be judged to be a peripheral participant, a beginner. However, even though that assessment may be accurate, it leads to inaccurate perceptions of the learner. It is not sensitive to the degree of the learner's intent to participate. It is highly subjective, since standards for evaluating participation vary from observer to observer. It relies on local knowledge of the cultural and historical situation surrounding the community of practice. Due to the difficulty of standardizing the unit of measure—centrality of participation—ranking of students either locally or on a more general scale becomes inefficient, if not impractical. While some of these problems are not so difficult, they do present substantial obstacles to the complex realities of making systemic improvements to public instruction.

It is these challenges of assessing learning and knowledge that came to the fore in the initial phase of this study, the ethnographic analysis of learning in the educational bike shop. Without a clear and practical method for examining learning that is commensurate with participation-based theory, any effort to understand learning processes in the educational bike shop environment would have to rely on traditional assessment methods and the acquisitionist epistemology they embody. That kind of forced cross-paradigm combination of acquisitionist method with participationist theory possibly accounts for much of the slow progress in adopting social practice theoretical frameworks for empirical studies.

Visual Anthropology Methods in Learning Research

The VA methodology used in this study addresses this fundamental mismatch of theory and method on several levels. First and foremost, VA engages cognitive inquiry at a deeply cultural level, not simply in the superficial sense that learning is now widely recognized to have social, cultural, and historical dimensions. My working definition of *culture* itself operates at two levels. At a more concrete level *culture* refers to what members of a coherently identified group do in their everyday practice. At a more abstract level, *culture* encompasses the system of practices that results from a group's particular combination of social structures, beliefs, artifacts, and network of ecological relations.

In order to understand how an apprentice knows and learns, particularly in the case of apprentices belonging to cultures that are racially, ethnically, linguistically, or economically distinct from the dominant white middle-class culture, a study must both understand and reflect the apprentice's cultural perspective. The *disciplined perception* methodology described earlier succeeds in addressing novices' and experts' different "ways of seeing." VA, however, takes additional steps toward understanding a learner's cultural perspective. *Methodological*

naturalism and ecological validity are two key features of VA that enhance its cultural sensitivity.

Methodological naturalism refers to any aspect of research methodology that is designed to reduce the historical differences in status and authority between the researcher and the informant or to reduce the artificiality of the study design and settings so that informant behavior will be as close as possible to its natural state. Historically, anthropological research methods have often exalted the cultural stance of the researcher; however, VA uses ethnographic data collection methods designed to minimize the personal distance between the researcher and the informants. For example, VA researchers sometimes diminish the “otherness” of the cultural “other” they are studying by inviting informants to collaborate in shooting photos or videos to capture the informants’ practices and environment from their local point of view. I use a variation on that collaborative technique that involves apprentices in viewing and discussing some of the video footage of them that I collected. Equalizing the status of researcher and informant in the research process also contributes to the educational equity purpose of this study. It helps ensure sensitivity to the informants’ voices and ways of seeing.

Guiding Questions

The foregoing overview of practice-based learning theory and bike shop knowledge sets the stage for a more thorough discussion of using visual methods to investigate adolescent work-based learning processes. The next section presents detailed arguments explaining how VA methods help illuminate apprentices’ discursive practices and help clarify the relations among those practices, the apprentices’ conceptual growth, and their work competence. It is organized into three broad positions in support of VA methods. These positions, or arguments, help establish the basis for using VA methods most effectively to address both the higher-level questions, including why many students perform better on cognitive tasks integral to work activities than on school-based “academic” tasks and more focused questions.

This study is guided by the following questions. What kinds of knowledge best represent student competency in work activities? How do changes in apprentices’ actions over the course of work in the educational bike shop relate to their conceptual development and technical competence in bicycle repair? Finally, how can assessment better identify competencies that are valuable within economically viable communities of practice? The findings from such an inquiry could potentially help explain and remediate the differences in academic performance between dominant and nondominant cultural groups that continue to afflict the U.S. public school system.

4.2 The Case for Visual Methods

There are three principal arguments for using VA to examine learning in the educational bike shop that are grounded in three broad positions that form general themes that resurface throughout the study. First, the study design creates *critical synergisms between learning theory and practice*. Visual anthropology methods, including closer relations between researcher and informants, enable theoretical learning models to be examined closely and accurately in a naturalistic and developmentally appropriate context. Promotion of naturalistic researcher-informant relations is a key theme that binds many components of the study.

Second, the design capitalizes on the way that the work setting enhances both the learning context and *methodological naturalism*. However, this is not a test to demonstrate how

well the setting improves learning. Rather, the study aims to demonstrate how the setting serves to illuminate the learning process and improve the ecological validity of the data.

Third, early iterations in the study's design experiment process uncovered a need to develop a new method for assessing student learning based on the social practice framework. My assessment method emerged during visual data analysis from the practical question, "What kind of assessment instrument best serves the employer's need to know how competently an employee can perform a task?" I then used visual data to help create an assessment method that was used in later iterations of the design experiment. The alternative epistemology underlying the study's theoretical framework also prompted a serious review and, to a degree, redefinition of key conceptual elements of learning models. These include *assessment*, including *knowledge*, *learning*, *culture*, and *data reliability*. It also shed light on the equity problem of how to counteract learning demotivation among students from nondominant cultures. An additional, equally important benefit of the study as a whole stems from improvements to the quality of educational opportunities and services provided by educational bike shops, reflecting the action research aspect of this project.

Position 1: Theory-Practice Complementarity

One of the great paradoxes of the last 30 years of educational reform is that paradigmatic advances in learning theory have resulted in so little progress in reducing culture-based underachievement. Constructivist learning theory (Cobb, 1986, 2002; Gagnon, 2006; von Glasersfeld, 1995) provided the insight that humans assemble new knowledge mentally or socially from elemental schema instead of receiving it via transmission or behavioral conditioning. In a more radical shift, situative theories, such as *social practice* theory (Lave, 1988; Scribner, 1984; Sfard & Lavie, 2005) and the closely related *activity* theory (Cole, 1996; Engestrom, 1999; Vygotsky, 1978), argue against the nearly universal notion that learning is the mental acquisition of knowledge content. Instead, learning results from increasingly central participation in enculturated practice, a model that at least partially resolves the theoretical dilemmas of cross-cultural variation in cognition (Scribner, 1984), contextual learning, and mind-body dualism (Lave, 1988).

Yet, for all the theoretical problems that these theories overcome, they have not yielded strong results in solving the practical problem of academic underachievement among nondominant racial, ethnic, linguistic, and economic groups. For example, landmark reform initiatives launched by the National Council of Teachers of Mathematics (NCTM, 1989, 2000) incorporated both constructivist and situative theory-based pedagogical standards, yet these reforms produced little effect in improving the performance of students from nondominant cultures. Numerous sociological and anthropological theories have added understanding to this persistent problem, including cultural opposition theory (Ogbu, 1992) and racial identity theory (e.g., Martin, 2000), but those theories also have not yet widely affected educational practice.

In short, cognitive research over the last three decades has given fuel to critics of research-based reforms, who claim that the cure is worse than the disease. Generally, such critics fall into one of two camps. One group opposes research-based reform because of principles or politics. Those critics reject the culturally relativistic, postmodernist tone of the sociocultural researchers who embrace the most radical alternatives to epistemology. The other camp rejects recent research-based reforms for a much more rationally supportable reason: it supposedly does not work in the classroom, particularly for children from nondominant cultures who often achieve more with didactic pedagogy (Delpit, 1996).

One possibility for such theory-practice disconnect might not lie in the theories themselves but rather in the ways that practitioners interpret them and even in the way influential scholars frame them. That possibility seems particularly acute in the case of social practice theory, which challenges the fundamental paradigm of how we conceptualize knowledge. The job of opening up, reexamining fundamental conceptions, and dislodging prevailing ideas requires a correspondingly fundamental disruption of analytic approaches. This provides a strong reason for harnessing the pioneering methods of visual anthropology.

Framing of Situated Theory and the Role of Context

The limited, or in some cases negative, impact of reforms based on the situated notion of *learning in context* is largely the result of two factors: a) focusing on the *context* aspect of the theories independently of other essential theory components and b) poor translation of the theories into classroom practice. Greeno’s (1998) commonly used taxonomy of learning theories (see Figure 4-1a) categorizes social practice theory and activity theory under the *situated* rubric.

Figure 4-1a. Greeno’s (1998) taxonomy of learning theories views the cultural and historical origins of situated theory as an outgrowth of psychological foundations.

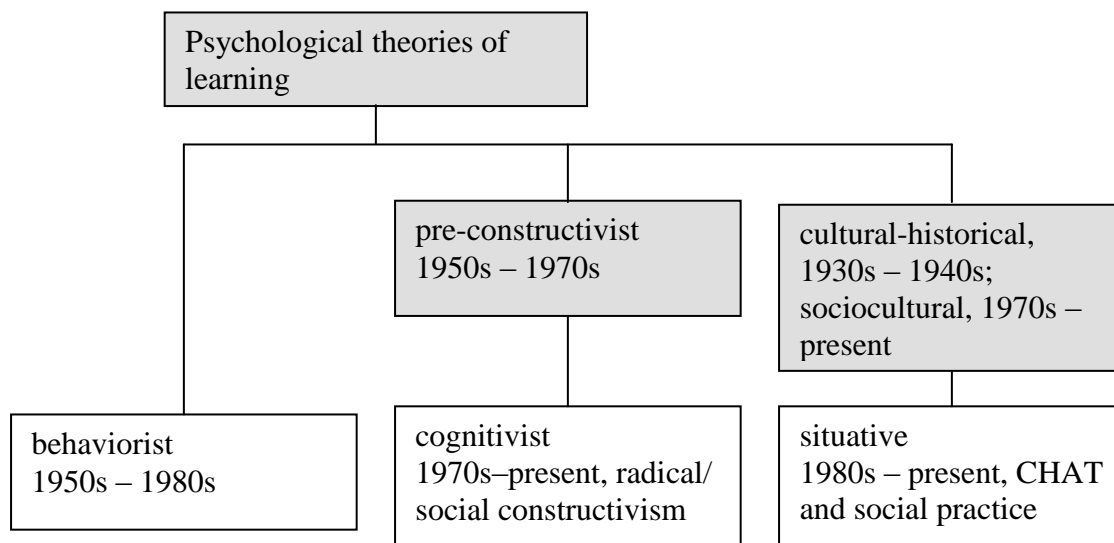
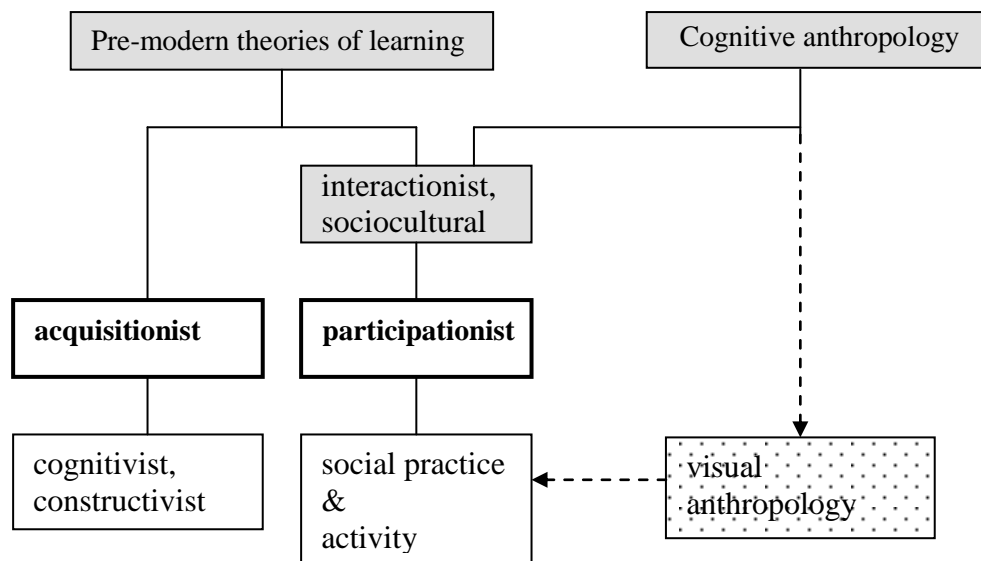


Figure 4-1b. Sfard’s (2002, 2008) alternate taxonomy actively crosses disciplines to anthropology, paving way to innovative approaches including visual anthropology.



Situative theories assume that knowledge is situated in local, historical, and social contexts in opposition to the notion of universal, generalized knowledge, as mathematics is commonly conceived. But framing learning models as *situative* tends to promote an over-reliance on the role of “context” at the expense of “practice” and “activity,” which are fundamental to *situated cognition* as defined by Lave and Wenger (1991) but are conceptually less accessible. Categorizing social practice theory as *situative* predisposes educational practitioners and other scholars to focus on the much more accessible, but easily misguided, notion of advocating contextualized learning and to neglect the powerful but hidden cultural-historical aspects of the theory. I discuss the context problem at length in a subsequent section.

In contrast, Sfard’s (2008) taxonomy (Figure 4-1b) labels social practice and activity theories as “participationist,” emphasizing their opposition to the prevailing “acquisitionist” knowledge paradigm. Sfard’s work is especially valuable in that she originated in the cognitivist tradition, yet has embraced the sociocultural tradition to the extent that her learning model is among those pushing the leading edge of the participationist frameworks. Over two decades of cognitive researchers preceded Sfard in elevating the discipline from psychological and social studies of learning to a cultural plane, but Sfard deserves credit for pioneering reconciliation among the different perspectives. In that respect her work serves a bridging function in the evolution and cooperative development of working models in the learning sciences.

Integrating psychology and anthropology

Figure 4-1b illustrates how Sfard reached across disciplinary lines to embrace the cultural perspective of anthropology and how that openness creates a supportive environment for visual anthropology theory and methods. However, the dotted lines in the chart indicate how that connection to visual anthropology represents my extrapolation of Sfard’s principles, not Sfard’s own connection to the field.

Unfortunately, Sfard’s more helpful classification of learning theories has not displaced the deeply entrenched misconception that situated cognition translates practically into contextualized mathematics pedagogy, or realistic math, or “connected” mathematics. Because these context-sensitive pedagogies isolate the importance of context at the expense of the critical participation-based and cultural aspects of these innovative theories, they fail to faithfully

represent the theories they are supposedly based on. To compound this failure, Carraher and Schliemann (2002), among others, have argued that contextualized mathematics is inherently difficult to translate from theory to practice. A few carefully designed contextualized mathematics initiatives (e.g., Greeno, 1998; Moses & Cobb, 2001) have produced good results, but they have not been widely replicated.

Theory-Method Synergism

Such antagonism between a theory's purpose and its actual use is ironic and unnecessary. Framing research and its theoretical assumptions in terms of VA resolves the dilemma and, in fact, enables theory and practice to work synergistically. In contrast to the acquisitionist-based perspectives of constructivism-cognitivism, visual anthropology builds from the anthropological method of ethnographic observation of cultural practices.

Because VA theory accommodates a broad, practice-based definition of learning, it enhances rather than detracts from analytic methods. Using VA, I can examine learning as an enculturating process that is not confined to the cognitive process of accumulating knowledge. Rather it can be understood as the ecological set of relations surrounding the informants' activity in a community of practice. The drawback of defining learning in such a broad, intricately networked way, however, is that such a definition resists standardization, thereby complicating analysis. My use of VA not only overcomes that drawback by specifying well-defined procedures for analysis of visual data but also grounds the analysis in the cultural perspective of the informant rather than relying solely on the interpretive skill of the researcher. Visually examining what apprentices do in the shop environment and how their discursive practices relate to their ways of seeing reveals regularities in their knowing and learning processes, leading to a reliable assessment of their competencies.

Indigenous Ways of Thinking and Educational Equity

A related line of research that addresses the question of differential performance across cultures conjectures that academic knowledge is a direct product of the dominant culture. Therefore, to learn the ways of knowing and thinking and solving problems requires enculturation into the expert practices of the prevailing culture in the society (Cobb & Hodge, 2002; Hall, 2001). Within this general theory of differential performance is a hypothesis that modifying the nature of the curriculum to reflect the kind of thinking indigenous to a broader range of cultures and closer to the developmental register of schoolchildren would improve academic performance across cultures more equitably. One way to achieve such an improvement in curriculum would be through project-based instruction, which engages students in thinking and problem-solving activities much closer to the recognizable tasks involved in the adult working world. Educational bike shops take project-based instruction to a higher level of realism by providing a working world setting that accommodates schoolchildren.

Field-Testing Theory

Because the study design elements resonate strongly with social practice theory and CHAT, they appear to offer a promising avenue for testing these theories in a practical application. In fact, the educational bicycle shop phenomenon—there are over 100 similar enterprises across the U.S.—originated in 1988 as an informal action research project. This study

represents a step toward formalizing the action research role of educational bike shops⁷ and an opportunity to ethically field test my proposed refinements in learning models. Still, to summarize this subsection, the most important net effects of theory-practice synergism are: a) the way in which visual methods operationalize the radical epistemological paradigm of practice-based theories which heretofore has remained largely unrealized and b) the focusing of analytic attention on the enculturating aspects of learning processes.

Position 2: Work Setting as Vehicle for Naturalistic Inquiry

The educational bike shop setting provides an authentic workplace that engages learners in productive, economically meaningful, activities rather than the learning exercises that comprise school activities. It generates two products: reconditioned bicycles for public consumption and skilled apprentices whose problem-solving competencies have use value, and in many cases also exchange value, well beyond the discipline of bicycle mechanics. A commercial production situation in turn creates two research advantages. First, learners have practical motivations for improving their skills and enlarging their conceptual toolkits. This clear purpose produces apprentice behavior that is not complicated by the academic identity issues that are normally present in the school classroom context or the byzantine and imprecise logic of academic assessment. Work behavior is governed by comparatively simple production-based rules.

Second, the productive work context makes students' thinking and learning processes visible in ways that the school classroom context does not. Consider some of the historical origins of research on workplace learning over the past 30 years. Some of the earliest investigators in the "cognitive revolution," who recognized the important role of culture in models of learning, chose to conduct their studies in professional work settings (Stevens & Hall, 1998; Lave, 1988; Saxe, 1991; Scribner, 1984). Reasons for this early trend in cognition studies ranged from the strong intrinsic motivations shown in workplace learning interactions to the desire to move beyond the "captive audience" quality of the school classroom and other aspects of traditional psychological learning research.

Work environments are the setting of choice for researchers using a situative learning framework because intrinsically motivated thinking, reasoning, and learning occur naturally in these settings. Early situative learning studies—for example, Scribner (1984), Carraher et al (1985), and Lave (1988) examined how work activity and the physical work environment constitute the learning process. They showed that workers solve arithmetic problems more accurately in the work environment than in decontextualized settings like classrooms. This raised a paradoxical comparison between learning in school and outside of school, which engendered a number of theoretical questions about the role of context in learning (Resnick, 1987).

⁷ In this regard, the educational bicycle shop movement can be compared to the nationwide system of after-school programs that have adopted or emulate Michael Cole's (1996) Fifth Dimension program design, which is well-known and documented in the learning sciences research community. In both cases children voluntarily participate in cognitively challenging activities in high-motivation, research-inspired learning environments designed to enhance their cognitive skills. Fifth Dimension participants play educational video games designed by Cole and colleagues. Educational bike shop participants learn a basic bike repair curriculum through an apprenticeship in which they apply their skills toward earning a recycled bike and reconditioning donated bikes for resale.

The logic in this line of inquiry was built on a strong empirical basis that included a series of studies (e.g., Carraher et al, 1985; Scribner, 1984) showing that users of indigenous forms of mathematical practice (Stevens & Hall, 1998) solved problems more accurately than those relying on school-based practices. One of the most promising strands of this research has tried to specify models of learning processes by studying how old-timers in a disciplinary domain try to get newcomers to “see” conceptual distinctions in the way they do.

Ways of thinking and ways of seeing

Learning in work environments is by definition contextualized in ways that contrast sharply with school environments, where it is usually decontextualized, i.e., separated in time, place, and affect from students’ everyday lives. This critique goes to the heart of differences in ways that students from different cultures think, solve problems, and organize information. When interpreted accurately, work context can be seen to constitute knowing-knowledge that is distributed beyond the individual mind across multiple dimensions. For example, a master bicycle mechanic’s expertise—relative to the novice’s—resides outside the mind partly in historical and physical dimensions. The experience of accumulating experience over time habituates the master mechanic to the verbal and kinesiological intelligence of doing expert repair work. This shift to a situated approach to learning, in turn, accommodates a situated, participation-based conception of knowing as opposed to the prevailing, nearly universal, conception of knowledge as mental structures that are constructed or otherwise acquired.

A key reason for choosing the educational bike shop setting is that it offered a unique opportunity to observe and record apprentices’ learning and thinking processes mainly from the vantage point of a guest instructor rather than from the more distant role of a researcher. The apprentices’ acceptance of me as a bike shop insider at all three shop sites, due to my strong bike repair credentials and social standing with shop staff, heightened the level of naturalism in my relationship with the apprentices. In other words, the apprentices’ behavior while I was in the shop interacting with them as a guest instructor presumably resembled their ordinary behavior in the shop with their regular instructors. Adding the presence of a video camera to that mix was then expected to have less of an altering effect on their behavior than if I had been identified as more of an outsider researcher. If true, then that circumstance would bolster the ecological validity of the data collection process. Both of these concerns—naturalism in data collection and ecological validity of the study—are central to the VA methodology that guided this study.

Another principal reason for using this setting is that virtually no studies exist on children’s learning in a true, economically viable, work environment. The main reason that opportunities to study children in a commercial workplace are so rare is that children are not allowed to work in the U.S. Educational researchers who embrace the principles of authentic learning and situated cognition have addressed that problem in the past by using clever ways of bringing the world of work into the project-based classroom (see Greeno, 1998; Hall, 1996; Jurow et al, 2008; Stevens & Hall, 1998). Educational bike shops have navigated that dilemma so far by framing the setting as a commercial bike shop to apprentices and as an educational institution, a classroom disguised as a bike shop, to legal authorities.

Visual anthropology and naturalism

The study design addresses head-on the central problem of data reliability in several ways. A participationist epistemology sets the stage for an understanding of cognition that views

cognitive development from the perspective of the student, rather than the already developed cognition of the adult researcher. As a practice-oriented (in contrast to information-oriented) environment, work-based learning accommodates a cultural approach to defining and investigating processes of knowing and learning.

Even though videotaping data became an affordable and commonplace research practice many years ago, video records are still used almost entirely for verbal rather than visual analysis in cognitive research. In other words, both verbal and visual data are recorded, but except for isolated studies on gestures or occasional observations about body motions, it is the verbal data stream that carries the analytical weight in cognitive studies. Visual anthropology methodology, by contrast, relies about equally on visual and verbal data in interpreting the meaning of informants' actions. This study is among the first to apply visual anthropology methods to the study of cognition and learning. Only in isolated cases have learning researchers looked deeply into the visual data stream (e.g., Erickson, 2006; Goodwin, 1994; Hall, 1996). In those exceptional cases, there is still a strong bias toward a focus on verbal data. Visual anthropology methods, in contrast, focus on the visual data; on the physical interactions among informants, other interlocutors, artifacts, and setting; and on the visual forms of knowledge used by informants and co-produced with the researcher.

An example that clarifies the distinct nature of visual anthropology is an ethnographic study of cattle breeding in Northern Italy. Grasseni (2004, 2007) used visual anthropology methods to elucidate the nature of professional breeders' expert knowledge. Grasseni's ethnographic strategy was to apprentice herself to the breeder community of practice in order to see and judge cattle in the way a professional breeder does. She accomplished this by using the video camera to trace her visual perspective during the act of cattle judging. The electronic video record allowed her to share the video trace with breeder-experts who could then critique her "way of seeing" and explain how different viewing angles would enable more accurate judgment of a cow's physical features. This apprenticeship method worked well because cattle breeding depends so strongly on the visually nuanced knowledge obtained from the detailed visual inspection of cows.

"The camera functioned as the catalyst of my attention, tuning my eyes to the visual angles and the ways of framing the cow through the inspector's gaze" she said (Grasseni, 2004, p. 21). Grasseni calls this process of learning to see as others do in a directed way "skilled vision." She argues that "the idea of participant observation should be reformulated as not simply imitating what other people do, but (drawing from ideas of ecology) as a way of learning about how people's shared visions (or understandings) 'co-evolve'" (2004, pp. 28-29).

Implementing Visual Anthropology Methods

The educational bicycle shop is a setting in which students perform work activities as true members of a community of practice—in essence, members of a working subculture—rather than as trial or temporary members. I videotaped students, ages 10-17 years, performing their normal work activities in educational bicycle shops located in three different regions of the U.S. The video data stream is used first to identify episodes of knowledge development and learning in students and then to help determine the nature of students' understanding of critical bicycle repair concepts and procedures.

Position 3: Redefining Assessment in a Social Practice Framework

The methodological outcome of these research improvements (analytic perspective) and benefits is a new approach to learning assessment necessitated by the alternate epistemological framework. Ultimately, though, it is the new assessment approach that grounds and validates the epistemological framework, since the new knowledge paradigm has little practical value until educators have a way to assess its existence and extent.

The new assessment was implemented in this study in the following manner: I gave students a choice between two basic bike repair tasks, tire repair and brake adjustment. These two repairs serve as primary benchmarks in determining a student's readiness to progress to more advanced work and to start instructing their peers in the basics, a key element in their own conceptual development. I first selected bicycles from the "unrepaired" inventory of recycled bikes that needed either or both repairs. Before asking students to perform the repairs, I engaged them in a 10-minute individual interview protocol. I then teamed students with the bikes needing the particular repair job for which they had selected to be assessed.

Multiple students worked simultaneously on the repair assessment module, and in some cases, two students worked on different repairs on the same bike. However, the repair tasks were designed so that all students could complete their assessment module individually. Students who selected brake repair had a general timeframe of 5-15 minutes in which to finish the work, which liberally reflected a standard time allotment for commercial shop labor.

Once students finished the repair module, they participated in a 15-minute consultation with the researcher in which both student and researcher watched the video replay of the repair work that the student has just completed. That consultation was itself videotaped. In the consultation, the researcher asked the student to evaluate his or her own work, starting with a list of task performance criteria, then progressing to a less structured discussion of the strengths and weaknesses evident in the student's work performance.

After the video replay interviews were over, the researcher then watched the video record of those interviews and rated the student on performance criteria. The three criteria that received the most attention at this stage of the assessment were: a) how extensively the student has adopted the discourse of the expert mechanic, b) how well the student uses tools and handles components, and c) how well the student understands the interrelations of systems in bicycle operation.

Individual test response and task completion, the prevailing standard units of measure for assessing learning, do not apply in a social practice and activity theoretic universe. The new participationist theories offered conceptions of knowledge that were not defined in terms of the amount of knowledge acquired and therefore were not measurable as "right" or "wrong" answers or performance on skills. Yet these measures remain the "industry" standard because assessment methods have not yet changed to accommodate the participationist epistemology.

Preliminary analysis of my video and field note data suggests that an effective way to assess student competency at bicycle repair requires two preparatory steps. First, the instructor must distinguish the particular kind of knowledge to be assessed among several different types as shown in Table 4-1. Only after the type of knowledge is identified can the instructor then plan an assessment strategy—which is step two—based on resources available and stage of instruction.

The study of technical repair work provides an excellent opportunity for analyzing knowledge and parsing it into different forms. The nature of technical work specifies well-defined knowledge types, and this holds particularly true for the discipline of bicycle mechanics. For example, two types of knowledge commonly used in commercial bike shops are types 5 and

6. Both categories involve knowledge used in repair work, which differs from production work in distinctive ways.

Post-design production work requires cutting standardized stock material into predetermined lengths and assembling it to within dimensional tolerances. By contrast, technical repair work requires little measuring, cutting, and shaping. Instead it consists mainly of making pre-existing technological products work efficiently by coordinating multiple variable adjustments for optimized system function.

Table 4-1. Types of Knowledge in Use

Type of knowledge	Principal characteristics and types of problems solved
1. Knowledge banked for future use	Abstract, generalizable, decontextualized.
2. Purposive knowledge for a productive end	Concrete, can be localized or global
3. Knowledge for production from raw materials	Design, procedural, creating structures, quantitative problems
4. Knowledge for production from recycled materials	Design, improvisational
5. Knowledge for repair of uniform systems	Procedural, adjustments, fine tuning of functional systems, spatial relations problems
6. Knowledge for repair of non-uniform, highly variable systems	Contingent, synthetic

The majority of tasks in educational bike shops involve the last three types. A typical brake repair task would fall into the last type, “knowledge for repair of non-uniform, highly variable systems” since there are five major classes of brakes and considerable variation among different manufacturers within each class of brake.

Once the instructor has completed the two preparatory assessment steps, an implementation plan will be needed since standardized instruments do not apply in this case. Any single bicycle repair task is embedded in a set of relations to other tasks. Any student or apprentice brings a personal history of learning to the assessment process. The instructor then considers these two parameters in devising an assessment plan.

4.3 Persistent Issues Facing the Study of Thinking and Learning

Long after Ericsson and Simon’s (1993) landmark monograph on verbal protocol analysis, the prevailing epistemological paradigm continued to be an information processing (IP) model. That model contradicts the theoretical frameworks used in my study in fundamental ways. It equates knowledge with information, defines learning as acquisition of information as mental structures, downplays the importance of distributed cognition, and assumes that psychology provides the principal method for investigating mind. While the IP model still serves the majority of cognitive studies that use verbal protocol methods, it conflicts sharply with the activity-based epistemology and anthropology-based methodology of the present study.

Specifically, my study assumes that knowledge is activity, learning is enculturation in practice through participation in activity, cognition is extensively distributed, and anthropological methods of observation and description predominate in the study of mind.

Nevertheless, to help fill the assessment vacuum in social practice theory and CHAT, Ericsson and Simon's (1993) IP model and verbal protocol methods do provide a meticulously reasoned—if partially incomplete in the matter of social practice models of knowing and learning—foundation for devising an alternative assessment method to fit within a social practice paradigm. The following subsection describes how verbal protocol is used to complement visual analytic methods in interpreting video records of students at work.

Origins of Cognition-Based Educational Equity Research

The “cognitive revolution” that began around the 1970s brought methodological rigor to the black box stimulus-response learning model of mid-20th century behaviorism. Unfortunately, the desire for scientific credibility was so intense among the social sciences that scientific rigor was, and continues to be, interpreted in terms of a physical sciences positivism rather than the descriptive methods that are more appropriate for social science disciplines. One manifestation of this positivistic zeal appeared in Gardner's (1985) review of the field, which barely mentioned the sociocultural work of Scribner, Cole, Lave, and Hutchins and instead devoted its attention almost entirely to neuroscience, psychology, and artificial intelligence.

In contrast, a more recent assessment of the cognitive science discipline (Cole, 1997) argues strongly for the central role of culture in formulating models of thinking and learning. Cole describes his own “model of mind” as an artifact-mediated activity model influenced by the traditions of Vygotsky, Luria, Leontiev, Dewey, Bakhtin, and Bateson, among others. His model depends heavily on the distributed cognition theory developed by Hutchins (1995), a theory that has been widely acknowledged but is still eclipsed by the prevailing acquisitionist model. Cole cites Hutchins's position on the role of culture in theorizing cognition: a cognitive science that neglects the role of culture confuses the properties of the sociocultural system with the properties of the person.

The working model adopted for the present study defines learning in terms of increasingly central participation in an (external) community of practice rather than the (internal) acquisition of mental structures. Besides diverging sharply from the currently prevailing cognitivist conceptions of knowing and learning, this model elevates the locus of learning above the individual psychological level to a sociocultural level of everyday practice. In this respect, learning can be modeled more effectively based on studies of learning situated in work practice other than the contrived work of classroom exercises.

The Problem of Context

- Context provides a large share of knowing in terms of information, relations, and influences. In other words, knowing by a human consists largely of intelligence located external to that human and in the social and physical environment. The social component of this distributed cognition is quite distinct from the kind of social cognition commonly understood to occur among a collaborating or closely communicating group of people. Instead, the social component of distributed cognition constitutes part of the knowing experience of the interlocutor.

- My focus has been on the object (physical) share of knowing, i.e., object-distributed intelligence as opposed to Hanks's (1993) focus on the interactional source of knowing.
- This, not the common "contextualized lessons" model, constitutes the social practice arguments for learning and the greatest importance of context. It also contradicts much of the information accumulation model of knowledge and learning.

Suburban middle-class students may focus their learning efforts in the classroom, but most urban students come from a tradition of learning outside of the classroom. For that reason, the present study is set on the repair shop floor of three different educational bicycle shops in different regions of the U.S. In that setting, students aged 10-17 years voluntarily participate in the physical and cognitive work of diagnosing mechanical problems, devising solutions, and carrying out mechanical repairs. In some locations, students may also perform computer-based inventory, bookkeeping, or other clerical tasks.

The economically meaningful and productive work made possible in this setting creates a social-psychological system of motives, thinking processes, and cultural practices that are a world apart from those of the classroom. Students' participation in the shop activities is meaningful to their everyday lives, unlike the artificial practices of classroom exercises, even including many "project-based learning" activities. The community-based bike shop is a good place for studying the intrinsic learning behavior of urban youth and, by design, the one place where I can investigate students' naturalistic behavior. Because I am intimately familiar with the instructional design used in educational bicycle shops, I can enact the role of staff instructor or "coach," thereby interacting with students as an ordinary member of the setting rather than an external researcher.

4.4 History of Visual Anthropology

VA has only begun to be used in cognition and learning research. VA emerged from the cultural film work of Margaret Mead in the 1950s and initially served merely as an adjunct to text-based cultural analysis. In the 1970s, however, VA realized its complicity in the domination of exotic "other" cultures. In a gesture of deep atonement, the VA community defined a new identity in terms of opposition to the linguistic, text-based analysis of culture that had predominated in the entire anthropological discipline until then. Not limited to the visual sense, VA opened up a new perceptual dimension in the representation of culture that complements the social practice theory paradigm. In fact, considering how methodologically alien—even antithetical—the social practice paradigm is to the prevailing view of knowledge, and how effectively, by contrast, VA methodology complements it, VA may well represent a key future avenue for learning research.

Aside from questions about the ultimate reliability of any data collected under the subjective influence of researchers with a strong interest in preconceived analytic outcomes, VA questioned the authenticity of informants' responses to researcher queries. This concern about informant authenticity led VA-based researchers to develop methods for naturalizing the conditions of the data collection process, in other words to minimize the artificiality of the data gathering process in ways that produce informant responses more likely to be genuine and less likely to experience interference.

Traditional Research Methodology	VA methodology
professional gaze (p. 39, ¶6)	interaction, participatory dynamics
logical empiricism	phenomenology
extracting concepts and categories, falsifiable rules and generalizations	evocation, provoking of esthetic integration that will have a therapeutic effect (p. 39, ¶8)
referential and explicit meanings, pertaining to another culture	implicit and symptomatic meanings pertaining to our own

Like most methodological innovations, visual anthropology originated as an antidote to the shortcomings of a prevailing tradition. The faulty tradition in this case consisted of the positivist research methods that prevailed in anthropology, psychology and other social science disciplines for the better part of the middle and late 20th century. In the quest to understand better how humans think, learn, and act, many social science researchers started around the 1970s to seriously question the validity of data obtained by experimental methods favored by traditional social scientists. Rather than pursue invariant laws of causation and universal truths explaining and predicting human behavior, adherents to the new post-structuralist paradigm—the theoretical source for the visual anthropology methods used in the present study—advocated descriptive methods that used narrative rather than causative logic to explain social phenomena.

The post-structuralist perspective challenged experimental controls as inadequate to provide the same objectivity as they do in the biological and physical sciences contexts. Moreover, the overarching research goal was not to find data to support objectified truth claims. Instead, these researchers sought subjective evidence to enrich ecological perspectives on human nature based as much on integrative as analytic interpretation. Not surprisingly, this group consisted primarily of anthropologists (Lave, 1988; Scribner & Cole, 1973; Suchman, 1987) who initiated ethnographic and other naturalistic approaches to studying how cognition and learning unfold in everyday practice.

Visual Methods Precursors

The earliest anthropological expeditions, including Haddon’s 1898 venture and Spencer and Gillen’s study of Australian aboriginals shortly afterward, took advantage of the early photographic methods available at the time. Investigators found visual methods more reliable than the reports of missionaries or travelers. They also realized that photography captures the atmosphere and total experience of local rituals exceptionally well.

Yet, toward the middle of the 20th century, ethnographic photography was used mainly for illustrative purposes, not as part of an analytic method. The exception to this trend was work by Bateson and Margaret Mead, who used still photography and film to capture the sensory experiences of their informants. Still, visual methods generally were not received well during this period in the general anthropology community due to a strong bias toward written observation records. Boas mistrusted the visual because it showed only the surface qualities of a culture or its practices. He believed that a more thorough understanding of a culture could only be attained through the language medium, not photography or other visual media. The ascendancy of positivistic standards of evidence among the social sciences during this period

also hastened the rejection of visual and sensory data in favor of more objectified forms of knowledge, such as diagrams and maps.

Nevertheless, Mead's championing of observational methods eventually won adherents within the discipline to the use of visual forms data collection and analysis. Film gradually became accepted as a scientific method. In the 1980s a phenomenological turn in the field questioned the status of text and elevated the position of context, the visual, and applied anthropology.

Contemporary visual anthropology, starting in the 1980s, shifted from the realist visual recording methods of the mid-20th century to an emphasis on: a) subjectivity, b) reflexivity, c) the notion of the visual as knowledge and a critical voice, d) theories of representation, reflexive and collaborative ethnographic methodologies, and e) awareness of the materiality and agency of the visual and recognition of the ambiguity of visual meanings (Pink, 2006).

Main principles of visual anthropology

Pink (2006) describes modern, post-structuralist visual anthropology as a method that relies more on collaboration with informants than on observation of objectified data sources. The logic of this approach to studying human activity is that the enormity of the network of interrelating factors affecting human actions defies the idea of identifying universal truths. Instead, visual anthropologists describe human actions and view them in a framework that can be judged as logically valid according to well-specified methods. Since objectivity in interpreting experimental results has been discounted as unreliable (in many circumstances), this approach offers at least a logically cohesive system of analysis. The strategy of visual methods dovetails with the theoretical framework that views thinking and doing as parts of the same process.

However, as Pink noted, mere awareness of the existence of social structures means little compared to the meaning of the synergetic interaction between sociological products and their social environment. For Pink, the interaction itself is more important than any of the concrete or non-concrete products, in the same way that she describes how objectified knowledge itself is less significant and consequential than the practices that constitute it over time. That is why she claims that visual anthropology for the sake of recording data is not so valuable as when the method itself is examined as an interaction. Pink's assertion above reasons that knowing is composed of situated activities and social relations rather than mental structures. Interactive method can potentially avoid the truth claim traps that plague objectified data methods.

Visual analysis introduces a new information stream in the reading of cultural activities. As Pasqualino (2007) describes, the visual channel adds a dimension to observed performance that can confirm or disconfirm the validity of textual interpretations or other more conventional information channels. This is a valuable capability considering that so much verbal data have been ineffectively or spuriously interpreted because of overzealous researchers or inadequate methods. Visual analysis is so new that it is also subject to misreading. For that reason, this study combines visual analysis with verbal analysis.

Qualitative data are particularly vulnerable at the interpretation phase because they have multiple possible interpretations, unlike quantitative data, which have unambiguous meanings. That is the conventional wisdom, at least. Under stiffer scrutiny, it becomes evident that the more mediating levels used by numerical analysis, the more possible meanings it encompasses. Visual meaning seems by comparison to be open to almost an infinity of interpretations. Yet, careful

study of visual data does not add layers of interpretation indiscriminately but rather provides an additional dimension of information that can help triangulate with verbal data.

Adapting Visual Anthropology to the Present Research Questions

At this point in the evolution of learning theories, highly original ways of conceptualizing knowing and learning promise to resolve some of the perennial theoretical problems facing conventional knowledge transfer conceptions. Yet academic inertia has kept conventional knowledge building and knowledge transfer in the foreground of scholarship while the more revolutionary aspects of activity theory and social practice theory are kept in the background.

Visual anthropology accommodates these two theoretical perspectives well and adds the dimension of visual analysis to the customary, virtually universal, practice of verbal-textual analysis. Even the most promising learning models based on innovative approaches—including social practice theory and cultural-historical activity theory—were not providing enough conceptual tools for building adequate policies, partly because of their use to analyze strictly verbal data, such as dialogue and written text.

Several factors converged to produce the specific mix of research traditions and methodologies selected for the present study. Originally my purpose was to explore ways to engage academically underachieving students in cognitively demanding activities that would mirror in some ways the thinking requirements of academic tasks. Such a project was intended to directly contradict standardized testing results that contributed to labeling these children as intellectually compromised and to challenge doubts that school-based educators might have had about these students' cognitive abilities.

Ultimately, the present study intends to identify ways of defining learning and knowing that would help eliminate the labeling of students from nondominant cultures as failures mainly because cultural differences produce disparities in performance measures. Those measures are currently defined according to standards biased in favor of the dominant culture. VA methods of analysis will help avoid the cultural bias in interpretation of linguistic data gathered in this study by providing an alternate stream of visual data that will be used in triangulation of research findings. This study will combine VA with traditional verbal analysis methods using a design experiment strategy to further ensure a balanced examination of the data.

Combining visual and verbal methods

This study accommodates different methods by using two different phases of data collection, with a third phase for self-evaluation. Phase I consists of an ethnographic analysis of several general observational data sources, including field notes and “real-time” video of whole-shop activity with some detailed video of individual apprentices or small apprentice groups doing normal activities without any researcher intervention. Phase II applies results of the ethnographic analysis to designing specific comparison conditions to videorecord. For example, comparison conditions included standardized tasks compared among apprentices and an interview protocol combined with various less formal discussions with individual apprentices, probing questions during apprentice work sessions, and focus group sessions.

The shape of Phase II data collection emerged from a design experiment strategy. Several versions of design experiment methodology have been independently developed over the past few decades. Like most of the variations on this approach, Collins's (2004) design experiment version tested the effect of different instructional designs on dependent variables for learning and

cognition. This study incorporates the ongoing, formative design feature of this method to refine successive iterations of data analysis and collection.

Visual anthropology methods hold promise for opening up new perspectives on questions of learning and cognition that can enhance the study's naturalism, triangulate analytic perspectives, and otherwise improve the reliability of informants' protocol responses. These methods and the perspective they support challenge prevailing conventions concerning the researcher-informant relationship. The cultural unit of analysis, either explicit or implied in anthropological methods, complements this study's sociocultural theoretical framework based on social practice learning theory and activity theory.

Focusing on students' activity-oriented relations rather than "acquired knowledge" provides a more dynamic, accurate picture of student competence in a work situation than conventional measurement and testing methods. In effect, the study's use of a work-based setting combined with visual anthropology methods and a social practice theoretical framework has problematized a number of fundamental assumptions about cognition. The cultural nature of learning, the situative aspects of knowing, and radically new approaches to assessment produce a novel way to model the learning process that may achieve greater verisimilitude than more conventional methods.

4.5 Problem Arc

This chapter presented a critical analysis of recent learning theory. Additionally it proposed adopting a practice-based epistemological stance toward learning and finding a methodology or combination of methodologies that would best demonstrate how social practice theory can help shape learning opportunities. In the following chapter I detail how this combination of methodologies is applied to the specific case of examining learning in the exploratory bicycle shop. I explain the steps taken in this study to document apprentices' learning according to the principles of VA and then process the resulting ethnography results into a form that can be further studied using both visual and verbal forms of analysis.

Problem Arc 5. One conclusion from the ethnography in the previous chapter was that the problem of assessing student competence is central to understanding the relationship between the shop setting and student thinking practices. This finding emerged from an interview with one of the study site directors. How does student competence relate to setting and thinking practices?

Solution Strategy. The theoretical analysis in this chapter revealed many good reasons for using visual methods of analysis to interpret student thinking practices data. Nevertheless this conclusion is itself theoretical and the problem remains to effectively implement VA analysis.

Chapter 5: Implementing Visual and Linguistic Methodologies

It is not possible to work in some abstract world where the constitution of knowledge through a politics of representation has been magically overcome. –Goodwin (1994)

The previous chapter explained how the study methodology derived from visual anthropology theory complements practice-based learning theories, a pairing that both broadens opportunities for the empirical study of practice-based learning models and positions such studies for greater analytic validity. This chapter provides practical details about how I use VA and related methodologies to investigate the learning processes of apprentices in the educational bike shop setting. The first section describes the overall design strategy of using two different research approaches—ethnography and traditional intervention studies—organized into two phases of data collection and analysis to sequentially frame, reframe, and refine the analysis. The next two sections describe the nuts and bolts of selecting the setting and study participants. The last two sections describe in detail the processes of data collection and analysis.

5.1 What Kinds of Questions Does Social Practice Theory Generate?

The top-level research question guiding the study is “What relationship exists between the educational bike shop setting and apprentices’ knowing and learning processes?” In other words, how do features in the shops’ physical design, participation structures, pedagogical approaches, and representational infrastructure (Hall & Greeno, 2008) correlate with the way apprentices learn or think or solve problems? Implied by this question, is the issue of how to describe the relationships within a social practice theoretical framework. Or in more theoretical terms: How do theories of situated cognition help explain the apparent effects of setting on apprentice learning, and conversely, how can apparent effects of setting on learning help refine and validate situated cognition or related theories?

Table 5-1. Sequence of research questions generated, organized by study phase.

Phase I – Ethnographic Methods	Phase II – Interventionist Methods, Case Studies	Other Emergent Questions
What role does setting play in the knowing and learning processes of apprentices in the educational bike shop?	How do changes in apprentices’ actions over the course of work in the educational bike shop relate to their conceptual development?	In what ways does the naturalistic and visual-based methodology of VA help clarify learning processes?
How do perspectives vary among apprentices, shop staff, and school/community?	What kinds of knowledge best represent student competency in work activities? How do those kinds of knowledge differ from the knowing and learning that occurs in school classrooms?	How do differences between bike shop knowing and school knowing illustrate the differences in academic achievement across cultural groups?

VA analysis. The VA perspective views the visual record without making assumptions about the informants’ goals or intentions. I interpret physical actions based on a much larger universe of possible motives, relations, and influences. Like other analytic approaches, VA

records and catalogs procedures, but the procedures examined are not confined to those within the sphere of bicycle repair. In fact, the majority of procedures have more to do with social and cultural relations than with technical information and concepts bringing to mind Hutchins's (1995) reference to Andrade's notion about the importance of not assuming that a car factory worker

5.1.1 Methodological tension

To help frame an initial research question of this breadth, the study uses two different research approaches: naturalistic observation (ethnography) and intervention (controlled conditions). The study design organizes these two approaches into two consecutive phases to break down the top-level research question into a sequence of progressively more refined questions (see Table 5-1). Phase I, the ethnography, generates an ethnographic video record of students' dialogue and actions during both naturalistic and experimental activities in an educational bicycle shop. Phase II, the controlled interventions, analyze and interpret student interactions and physical actions according to a theoretical framework that combines visual anthropology (Pink, 2006), communicational learning theory (Sfard, 2008) and activity theory (Roth & Lee, 2007) into a novel variation on the "knowing as doing" model. This approach iteratively applies initial conclusions from analysis toward formative changes in study conditions. Table 5-2 illustrates the sequence of specific research activities within each phase. It also references the sections in this text that address each aspect of the study.

Table 5-2. Study phase details and associated chapter sections.

Study Phase	Dissertation Chapter and Section and Related Notes
<i>Phase I – Ethnography</i>	
General observations of shop activity	Section 4.2.2: Sierra, Cascade, Heartland
Detailed observations of students engaged in bicycle repair activities	Section 4.3.1: Deon, Colin (Cascade) work group and interviews Section 5.3.1: Josh-Emily (Cascade) work group
General interviews	Fragments of interviews in both Chapters 4 and 5.
<i>Phase II – Controlled conditions</i>	
Standard task comparison	Section 5.3.2: Across-student comparison of performance on standard tasks including tire repair, headset adjustment, and brake repair.
Standard task video-based self-evaluative interviews	Section 5.3.3: Students watch videos of themselves performing standard tasks and discuss their performance with researcher
Follow-up work group case study	Section 5.4.1: Emily-Debra work group at Cascade repairs hub and brakes.
Follow-up interviews	Section 5.4.2: Follow-up interview with Emily and Debra at Cascade.

5.2 Phase I, Ethnographic Methods

Phase I uses a broad ethnographic observation approach to take stock of the various actor-stakeholder perspectives on learning, doing, and being in the educational bicycle shop. It is an exploratory stage of the inquiry conducted with a minimum of preconceived questions in accordance with principles of both VA theory and Glaser and Strauss's (1967) version of grounded theory. Its main purpose was to collect enough data to determine which data deserve further scrutiny and what specific questions emerge from the data.

As shown in Table 5-2, Phase I-A gathered general observational video from all three study sites to produce a picture of the typical physical and social shop environment. Phase I-B focused on recording specific work group activity at all three sites. Work groups consisted of one to four people performing a wide range of specific basic and advanced repair tasks such as tire repair, brake adjustment, hub adjustment, wheel truing, and frame alignment. This phase of data collection accounts for the bulk of the video recordings, approximately 30 hours (see Appendix B for a complete inventory of videotapes made.) Its purpose was to sample enough different tasks and work environments that a representative database of activities and interactions could be assembled for a preliminary analysis.

Data from all three parts of Phase I contributed to a database that was analyzed for thematic trends. The principal themes that emerged from this process shared one aspect. They all related to the question "What kind of assessment accurately evaluates the competence of workers in the shop environment?" This question became the basis for the final analysis in Phase II, which is reported in Chapter 5. Based on this preliminary analysis I chose one of the work-group video episodes (Josh and Emily from the Cascade shop) working on hub adjustment, as the focal data set for the final analytic process.

5.2.1 Democratizing the Research Perspective

Individual interviews with students and instructors are used both initially in Phase I and as part of the follow-up interventions in Phase II. Interviews rely almost entirely on verbal data to represent the informants' thoughts and feelings and place three mediating factors between the informants' actual thoughts and the researcher: a) answering the researcher-initiated questions, b) presenting of self to the researcher as outsider, and c) using language to represent thoughts. To minimize interference from these mediating factors, the VA approach to interviewing used in this study includes a variety of innovative techniques. One set of VA techniques shifts the source of questions to the informant. For example, following completion of conventional clinical interviews with apprentices, the study protocol includes a follow-up conversation between researcher and apprentice in which both watch and discuss a video recording of the apprentice doing bike repair work. In this interaction, the authoritative roles become more equalized. The situation allows the researcher and apprentice to discuss the apprentice's work as fellow participants in the same community of practice, rather than in the conventional clinical relationship. Another VA technique is video elicitation, which places the authority for determining which questions to ask and which topics to discuss entirely in the hands of the informant. This study used video elicitation on a limited experimental basis but time limitations and other circumstances prevented that ordinarily promising technique from being productive.

5.3 Phase II, Interventionist Methods

Data collection in Phase II picked up where Phase I ended. At Cascade and Heartland, students performed standardized bicycle repair tasks, Phase II-A, within days after the naturalistic observation video phase ended. Phase II-B immediately followed at those sites. Students were videotaped as they watched videos of themselves performing the standardized tasks and discussed their work with the researcher. At the Sierra site, in contrast, several weeks intervened between the Phase I observational video and the standard task activities (see the timeline in Figure 5-2).

Shortly afterward, a preliminary analysis of the Josh-Emily hub episode generated new research questions centered on issues of competency assessment (see Table 5-1) that required a repeat task performance. However, because Josh was not available for a follow-up activity, he was replaced by Debra. The Emily-Debra duo became the sole focus of follow-up investigations mainly because of logistical and time constraints. In Phases II-A and II-B students were asked to do a standard task, which could include tire repair or brake repair. Data from these tasks contributed some additional data to the new focus on competency assessment. Other possible inquiry paths generated by Phase II-A and II-B data had to be shelved for a later study. The repeat hub adjustment task in Phase II-C further developed the competency assessment focus. A final interview of Emily and Debra in Phase II-D completed the study.

5.3.1 Types of Data

The *interventionist* class of data consists of information collected after students received instructions to complete standardized tasks. Videotaped formal interviews of students also fall into this category of data. Design experiment methodology, like all experimental methods, necessarily falls into this class also. In contrast, the *naturalistic* data are obtained through participation with students in the course of their normal activities and observation of students' interactions with their physical and social environments via video records and field notes. There is no experimental intervention into the ordinary unfolding of activity in the educational setting. The resulting naturalistic data can claim greater validity due to its truer, more emic, reflection of student actions as compared with generated data which results from etic interventions.

For example, in the educational bike shop setting, asking a student to perform a standardized repair task in order to examine patterns of repair performance across students would result in generated data. Let's say the researcher asked the student to repair a brake that had been prepared beforehand to have certain faults. That same brake repair task could then be given to multiple students simply by preparing the brake to match the desired fault conditions. Below is a sampling of the different kinds of experimental interventions used in this study beginning with the naturalistic option of pure observation.

The distinction between interventionist and naturalistic might be considered trivial, however, if that example of interventionist data were compared with a video record of a student performing the same repair task in the course of spontaneous repair work in the shop. Many of the environmental circumstances for these two data sets would be identical such as physical setting, nature of the activity, and artifacts in use. However, the social and affective aspects of each data set—e.g. motivation, performative audience, and even goals—might be different in critical ways. The following section provides an illustrative case of these different kinds of data and how this distinction is important to the overall methodology of the study not to mention the research objective of better understanding student thinking and learning.

5.3.2 Visual Analysis

The Phase II visual analysis entails a set of questions and processes that are radically different from those of conventional text-based analysis. Because learning in a social practice context is defined as increasingly central participation in a community of practice, my overarching research question has little to do with the standard cognitivist query “What (or how much) has the apprentice learned?” Instead, the focus shifts from the learning *content* acquired by an individual to the *context* of social and physical relations in which the individual practices an activity. That focal shift results in a research question such as “How do interactions between the learner and the social or physical situation facilitate an increase in bicycle mechanics competence?”

Such a shift toward a conception of knowing as widely distributed across context presents considerable challenges for observing, analyzing, and measuring learning. In the case of a manual trade like bicycle mechanics, it also means that an apprentice’s activity has a strong physical component in addition to a substantial conceptual component. A visually-oriented analysis opens up a new dimension—the visual—beyond the standard verbal-conceptual dimension in which to uncover relationships between the apprentices’ physical actions and their tools, other artifacts, and the general environment. In fact, VA opens up the entire perceptual dimension including auditory and haptic sensory perceptions. In the case of bicycle repair, as will be seen in subsequent chapters, the sense of touch is key to a master mechanic’s way of seeing what is happening inside a closed, otherwise opaque mechanism.

Because the focus of VA methodology is on the sensory rather than the verbal, there is a stronger emphasis on examining interactions between the learner and the physical environment. Interactions with the social environment still constitute a prime component of VA analysis, but the emphasis is on the learner’s interactions with the physical environment.

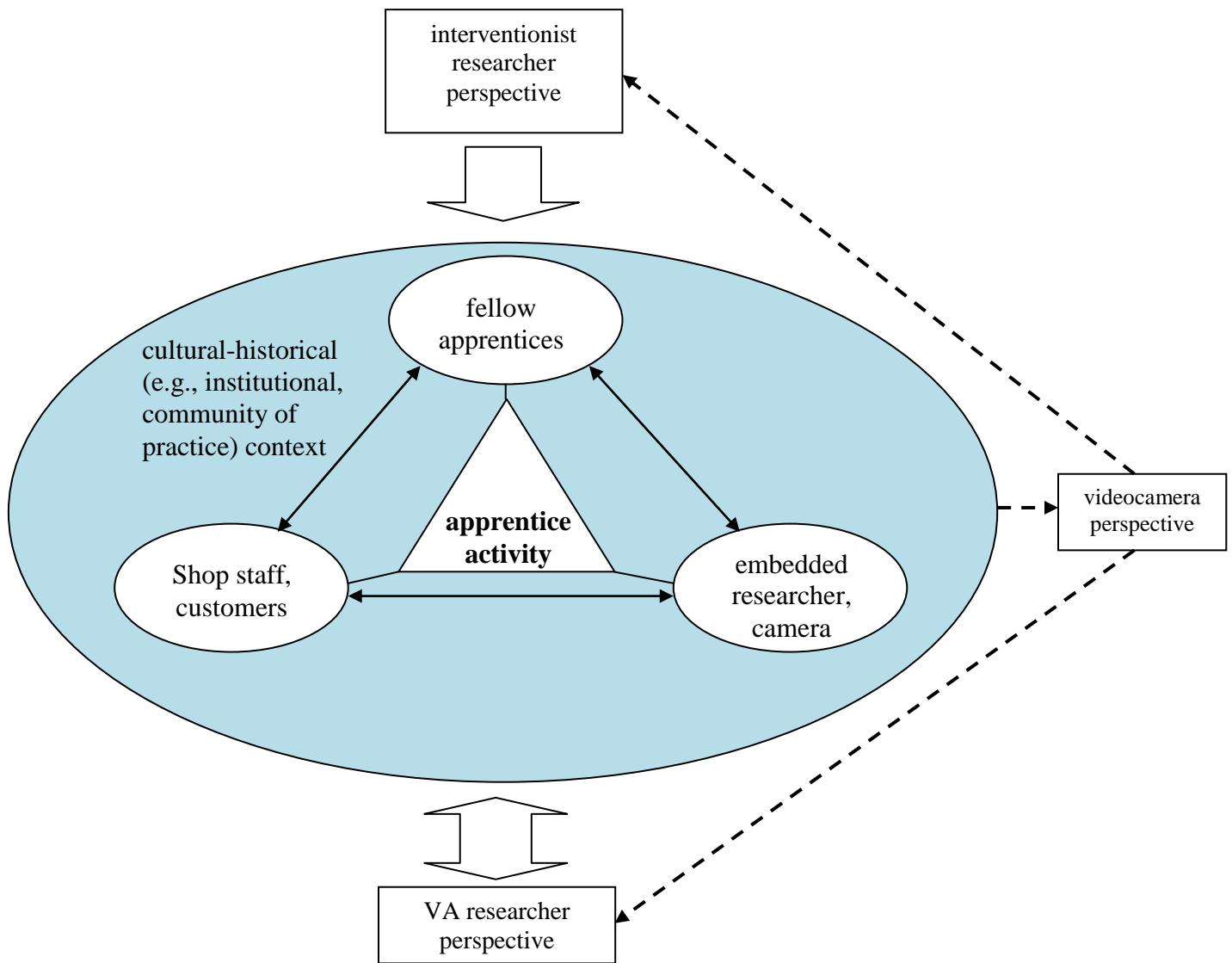
5.3.3 Critical analysis of VA methods

A fundamental precept of VA is to critically examine the assumptions, interactions, and relations in the specific cases in which VA is used. Based on the social practice framework of this study, apprentice activity is the main unit of analysis, supplanting the more traditional unit of disciplinary content learning traditionally used in learning and cognition studies of middle school and high school learners. Figure 5-1 illustrates the basic interactions and relationships that were necessary to consider in analyzing the VA method in use.

Each perspective designated in Figure 5-1 constitutes a different relationship with the researcher including the researcher’s relationship with himself when he examines the phenomenon from an embedded researcher-instructor perspective. The videocamera provides an accurate record of the phenomenon within the camera’s field of view. But the field of view is controlled by the researcher or other camera operator. Each of the possible relationships between actors in the shop community of practice is reviewed and integrated into the researcher perspective during the data analysis process.

Figure 5-1. Scheme of perspectives, interrelationships, and information flow. Large block arrows indicate power relationships. Solid lines and arrows indicate actor interrelationships. Dotted arrows indicate information flow.

5.3.4 Fitting the methodology to the research questions



There is a strong advantage to adopting an “activity” unit of analysis rather than the traditional cognitive unit of individual conceptual change or individual learning. That analysis does not face the insuperable challenge of needing to find out what is inside people’s minds. Activity manifests learning, by definition within the participationist learning paradigm. As illustrated in Chapter 5, an episode of brake repair activity can indicate the degree of learning better than a verbal interview or testing scenario. In this situation, activity is defined as what a person does in the form of actions organized around a unifying purpose. This definition includes the physical, social, and psychological activity involved in the cultural practices of discourse, work, play, survival, and so on.

Such a definition may appear all-encompassing and may prompt the question “What does ‘activity’ not include?” The absence of activity is stasis. So, the analysis of a learning session uses observation of activity to determine not only the nature of learning but also the extent of learning for the purposes of learning assessment.

As explained in the previous chapter, practice-based theory assumes that knowing and intelligence is extensively distributed across the social and physical environment. In the case of bicycle repair, this means that while some of an apprentice's knowledge of a repair procedure exists within the individual apprentice's cognitive memory of steps in a repair procedure and mental image of how the repaired bicycle should appear after the repair work, much of it—and probably most of the apprentice's knowledge and cognition—exists external to the apprentice's cognition, in the shop environment, in the design of the overall bicycle and the specific bicycle parts that the apprentice is repairing, in the hand tools that the apprentice will use to effect the repair, in the verbal shop banter between the apprentice and fellow apprentices, and in the bodily actions that the apprentice will use to address the repair problem and accomplish the repair. This distributed knowledge, moreover, does not so much exist as a cognitive substance within the apprentice's mind or in the environmental artifacts but rather unfolds in a process of coming to know by becoming a more central participant in the practice of bicycle repair. When knowing and learning are thus defined, how exactly does one study such a seemingly diffusely distributed phenomenon?

5.4 Setting

A principal claim in the previous chapter argued that framing practice-based learning theories as “situative” contributes to the widespread misconception that the best way to implement educational reforms based on social practice research is to emphasize the practical context of disciplinary domains such as mathematics and physics. This focus on the situated quality of social practice theory at the expense of that theory's other principal components—the participationist quality of learning and the activity-based nature of knowing—has contributed to the incomplete perception among teachers of the true nature of practice-based theories and the research-based reforms that attempt to harness that theoretical work.

That argument might seem ironic considering that this study revolves primarily around the unusual setting of the educational bicycle shop and the opportunities for learning that that setting provides. The bike shop setting does anchor many of the principal claims, but it does so because it embodies the epistemology of knowing as participation in a community of practice. It also encourages the perspective that knowing is best considered as activity rather than a thing to be acquired.

Such a radical standpoint makes conventional learning studies irrelevant. Instead of asking “How much disciplinary ‘content’ was learned?” the key research questions are framed in terms of “what kinds of social engagements provide productive contexts for learning to take place? (Lave & Wenger, 1991)”

The majority of practice-based learning studies have assessed the relationship between varying learning activities and the degree or quality of learning, consequently activities tend to serve as the independent variable. Even though the principal research question in this study asks about the relationship between physical activity and learning, it is the setting of the educational bicycle shop—rather than any other intrinsic characteristic of the activity—that principally shapes the activity. Such an analytic frame assumes, then, that setting is an intrinsic characteristic of activity and that it distinguishes these activities that take place in the educational bike shop from those that take place elsewhere.

The focus on “physical” activities as opposed to non-physical activities is a way of further elaborating the nature of the educational bike shop setting. It is not intended to distinguish between physical and non-physical activities because the theoretical framework of

this study avoids making such a distinction and suggests that such a distinction is not possible given the strong identity between physical and mental activity.

5.4.1 *The Exploratory Bicycle Shop*

A detailed cultural and political history of the exploratory bike shop phenomenon was provided in Chapter 3. This section provides details about the physical shop features. The work incentive aspect of this alternative learning program was called “earn-a-bike”, but it soon appeared that the strongest motivation for academically underperforming youth to participate resulted from the desire to belong to a thriving community institution, the “neighborhood bike shop,” and its intergenerational community of practice. The lure of the setting—the tools, equipment, and all of its social and cultural appurtenances—appeared to be greater than the reward of earning a bicycle.

Physical components of the bike shop. Educational bike shops in this study range in size from about 500 square feet to 1500 square feet for the main educational space (see Table 1 for basic characteristics of the three study sites). The educational space consists of an open area where professional bicycle workstands are spaced apart far enough to allow bicycles to be moved around and mounted in the workstands without too much congestion and workbench space which is typically mounted against the walls. The industry standard professional Park double workstand consists of a 5-foot long vertical post mounted on a ½-inch thick, 4-foot wide steel base that weighs over 150 pounds. Across the top of the central post are two opposing arms equipped with heavy duty bicycle frame clamps that swivel 360 degrees allowing bicycles to be positioned at ergonomically optimum work levels and angles. The heavy base allows either single or double mounting of bicycles, which typically weigh 20-50 pounds, without compromising the stability of the work stand.

Workbenches are equipped with board-mounted tool sets featuring an array of metric combination (open-end-box-end) wrenches, screwdrivers, hammer, rubber mallet, pliers, and various specialized bicycle repair tools including thin cone wrenches, bottom bracket wrenches, headset wrenches, Allen keys, chain tool, cable cutters, spoke wrenches, pin spanners, metal files, hacksaw, ruler, micrometer caliper, 8-9-10 mm socket Y-wrench, and assorted mechanical remover/separators devices. That list covers the basic apprentice tool set, and most of these tools are invariably mounted on hooks hanging from large boards on which the outline of each tool has been traced with a thick marker.

The tool tracings along with clear labels on drawers for additional tools, new and used parts, and supplies illustrate just two instances of the constructivist “find it yourself” or “explore and discover” educational philosophies that seem to be inherent to educational bike shops. As explained in a subsequent section, the degree of constructivist pedagogical practice varies to some degree across the hundreds of educational bike shops in the world, yet something in the physical nature of bicycles and something about the developmentally appropriate fit between bicycle repair activity and older children and adolescents drives an intrinsically constructivist attitude among the staff. The educational bike shop phenomenon seems to generate a disdain for didactic pedagogy and a general embrace of constructivist inquiry-based learning approaches. This observation is not meant to suggest that all educational bike shops are highly successful in maintaining productive, high-motivation learning opportunities for participants. But the strong positive correlation between the educational bike shop setting and the inherent tendency to teach using inquiry methods does result in a grassroots-level spread of constructivist pedagogy.

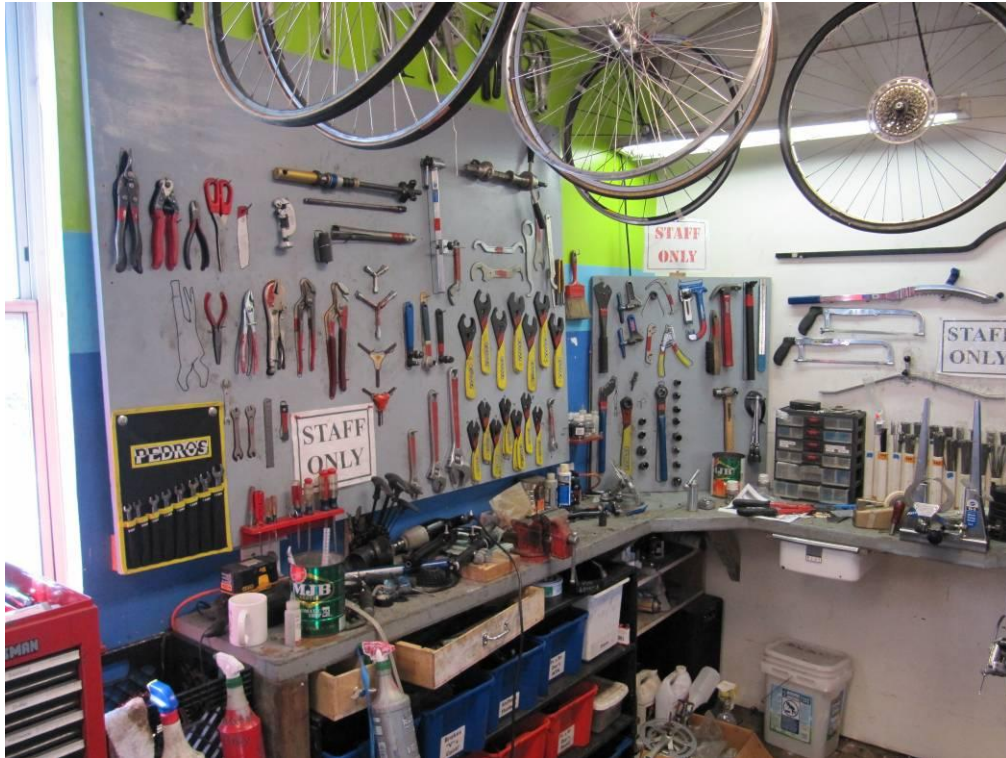


Figure 5-2. The pro mechanic’s tool board at Sierra used by both expert mechanics and advanced students. The numerous signs restricting access to “staff” are intended to keep participants in Sierra’s community fix-it-yourself sessions from using tools they are not adequately familiar with.

A large, heavy bench vise is firmly mounted on the workbench or on a dedicated stand. Most educational bike shops have an electric-powered air compressor in addition to hand-operated air pumps. Few power tools exist in the educational bike shop due to safety concerns about mixing power tools and children. But even fully equipped professional bike mechanics use many other standard and specialized tools and depending on the shop floor plan, a professional mechanic’s tool board and work area will either be integrated with the apprentice work area, adjacent to it, or entirely separate from it.

Table 5-3. Basic economic, physical, and geographic characteristics of the three study sites

	Avg annual budget/ number of employees	Educational work space	Neighborhood economy	Neighborhood type
Heartland Community Bike Shop	\$32,000/ 3 part-time	500 square foot room in a large, gothic Protestant church	low-income residential, low-end commercial	at center of an expansive residential area including many residential neighborhoods
Cascade Community Bike Shop	\$400,000/ 10 full-time, 5 part-time	1500 square feet in several rooms in a converted two-story home	low-income residential, mixed commercial	at edge of a low-density commercial district within a large residential zone undergoing gentrification

Sierra Community Bike Shop	\$230,000/ 2 full-time, 7 part-time	dedicated 1200 square foot building on a small campus of park buildings	low-income residential, light and heavy industrial	in a city park at the border between an industrial zone and a residential area
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5.4.2 *The bicycle: A developmentally accessible technology for study*

The bicycle supplies the inquiring middle school or high school student mind with something very useful: a simple, self-contained technological system that can be safely and effectively examined, taken apart, altered, and maintained by young humans who are peripheral participants in the adult-dominated world. The bicycle is an exceptionally simple mechanical machine that is powered solely by direct human energy. It consists of five main interconnected subsystems (see Table 5-3) that channel human energy from a two-armed foot-operated crank via a chain drive to a pneumatically cushioned wheel. A second wheel, frame, and control subsystems add to this power system the capabilities of speed and directional control. For those readers from severely isolated cultures or regions of the planet, illustrations of the basic bicycle are provided in Figures 5-2 and 5-3.

Figure 5-2. Bicycle: a) left, a historic bicycle from the early twentieth century has all the basic technological features of the contemporary bicycle including pneumatic tires, chain drive, and metal frame; b) right, a contemporary image of the bicycle from bicas, a social action, education, and art collective in Tucson.

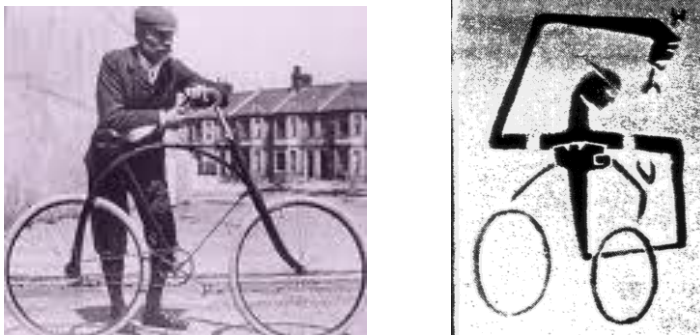


Figure 3-3. Bicycle, a child’s image: print made from an inner-tube rubber stamp by Fernando Seeley, a student at the bicas collective in Tucson.



Table 5-4. Bicycle subsystems and some biological analogs

Subsystem	Components	Function/biological analog
Frame	Main frame, fork, handlebars/stem, saddle (seat),	Structural support/skeletal system
Drive train	Pedals, cranks, chainwheel, chain, rear cog/cluster	Power transfer/muscular system
Wheels	Hub, spokes, rim, tube, tire	Locomotion
Brakes	Brake pads, calipers or arms, cables and housing, brake levers	Speed control
Gears	Front and/or rear derailleur, cables and housing, shifter levers	Cadence and efficiency control

Each main subsystem has a finite number of subordinate subsystems. Educational bicycle shops exploit this “built-in” lesson in systems design to help students acclimate to thinking in a systems framework that is applicable to any discipline, from technology and mathematics to the social sciences and even language arts. Often, bike shop instructors use some of the obvious biosystems analogies to give students a comparative perspective on systems thinking.

Researchers have endorsed (Resnick, 1987; SCANS, 1991) a systems foundation to learning as an effective approach to preparing students for the technological work force. Even aside from such “social reproduction” interpretations (Kliebard, 2004), however, the bicycle has broad instructional utility because reverse engineering the design of such a simple machine—as students do in the shop—predisposes them to apply the same analysis and perspective to understanding the structures and mechanisms of the social world. At least, that is one working hypothesis that motivated this study and underlies its methodological design.

5.5 Participants

While the study focuses primarily on the actions and dialogue of focal students engaged in bicycle repair activities, adult instructors perform a substantial role in the learning activities. Finally, I am a third participant type in the roles of assistant instructor, researcher, and camera operator. In general, educational bike shop students also interact with non-focal students, other bike shop staff members, and bike shop customers. Except as noted below, such interactions

were very minimal, constituting less than one percent of the students' in-shop time, and thus peripheral to the study.

The student pool consisted of middle school and high school students enrolled in educational bicycle shops in three urban locations, one in Northern California (Sierra), one in the Pacific Northwest (Cascade) and one in the Midwest (Heartland). All three sites have small instructional staffs composed of a paid lead instructor and various paid or volunteer assistant instructors. Over 90 percent of the videotaped learning activity sessions focused on interactions with the lead instructor or myself. Lead instructors typically had close relationships with their students since the students self-selected their participation in the shop activities and were therefore well motivated to engage in focal tasks and to avoid distractions. Nevertheless, many students had developed strong aversions to formal learning and thinking tasks or any activities that resembled formal school learning and therefore presented instructional challenges. Also some students had strongly established oppositional behaviors in relation to organized learning activities that also contributed to the instructional challenge.

My relationships with some of the students at the Sierra and Heartland sites involved short social histories of working together in the shop for a period ranging from several months up to two years. My relationships with the Cascade students were spontaneous, without any previous instructional or social contact. Because I was usually not performing the role of lead instructor, I had some opportunities to develop a more collegial relationship with the students.

I chose those three educational bicycle shop sites out of a pool of over 100 on the basis of three criteria. The focal sites were required to be located in major urban centers that had ethnically and socioeconomically diverse general populations. Selected sites also had a combination of neighborhood and citywide service orientations, not just one or the other. Finally, sites had to have a track record of at least two years of delivering high quality learning opportunities and progressive instructional methods to students. Educational bicycle shops across the U.S. vary widely in the quality of educational services. The three selected are among the top five in educational quality in the nation. Two other top-level educational bicycle shops are located in Boston and New York, respectively, but travel logistics favored the Heartland and the two West Coast site locations.

5.5.1 Student sampling

The number of entry-level students in educational bicycle shops nationwide averages between 30 and 100 per year, which equates to an active enrollment of 10-25 students at any one point. In contrast, the number of advanced students who have graduated from the beginning level of instruction is much smaller. Active enrollment of advanced students in each of the three focal sites ranged from two to 11. Actual enrollment during the period of this study, however, diverged at all three sites from the national averages. Enrollment at the two younger organizations was below average. At Cascade, the oldest of the three shops, enrollment far exceeded the average. Table 5-6 shows the overall number of enrollments at all three shops.

Despite having a large pool of potential participants as indicated in Table 5-6, the main determining factor for selection of students was participants' willingness to complete the parent permission forms. Because only 12 students submitted completed parent permission forms, all 12 were selected for the study. Two of those students were removed from the study due to irregular attendance, leaving ten students for full participation in both Phases I and II. The population had the following demographic characteristics:

Table 5-5. Demographic distribution of participant sample

Male	77 %
Female	23 %
African-American	35 %
Hispanic	28 %
Asian	14 %
Caucasian	14 %
Mixed race and other	9 %
Families receiving public assistance	78 %

5.6 Data Collection

This study examines two kinds of data, *naturalistic* (ethnographic) and *interventionist* (controlled, quasi-experimental). These two main data classes mirror each other in a redundancy that facilitates triangulation. Both types of data capture a) student actions and b) the relations between students and their physical and social environments as they tackle work tasks in an educational bike shop. Figure 5-4 illustrates these two general classes of data and the three specific data collection techniques that are combined in this study.

Table 5-6 compares student enrollment and participation data across sites. Further details about data collection for each phase are provided below.

	Sierra	Cascade	Heartland
Number of students enrolled in Shop overall, all levels	21	62	12
Number of students participating in Phase I	8	14	4
Number of students participating in Phase II	3	6	1
Age range of participants	12-18 years	9-16 years	8-16 years
Phase I videotaping dates, mm/yyyy	10/2009 – 03/2010	02/2010, 05/2010	01/2010, 02/2010
Phase II videotaping dates, mm/yyyy	02/2010 – 07/2010	05/2010, 07/2010	04/2010
Phase III videotaping dates, mm/yyyy	03/2010 – 05/2010	02/2010, 07/2010	not applicable

Table 5-6. Participant enrollment and data collection time frames

5.6.1 Phase I Protocol

The goal of the Phase I protocol was to capture the activities that take place regularly in the educational program facilities of the three focal shops in a form as close as possible to their natural state. More than just a record of work activity, however, this observational video record is also intended to capture the social register, the emotions and the motives of stakeholders and any other aspects of the exploratory bike shop culture. Once collected, this corpus of observational videotape data is then analyzed to determine the most significant themes for investigating further using the more focused data collection interventions in Phase II.

Videotaping during this initial phase is aimed at recording a variety of stakeholder perspectives on all the core educational activities that occur in the shops.

Table 5-7. Types and total amounts of video data collected at each site during Phases I and II.

Video type	Sierra	Cascade	Heartland
Long shot, wide angle	6 hours	2 hours	1 hour
Work-group focus	22 hours	13 hours	6 hours
Close shot, interview	3 hours	9 hours	2 hours

To accomplish this goal, I used several different approaches to videotaping (see Table 5-5). I recorded at least 45 minutes of *long-shot* video showing the variety of interactions that occur in all aspects of shop operation, from educational to retail activities. For long shots, I positioned the video camera in the most remote spot possible inside the shop and let it run unattended to maximize naturalism. I circulated through the shop as a guest volunteer instructor and researcher, although I tried to foreground my instructor identity and keep my research identity in the background. Other than operating the video camera, and conducting interviews at the end of my time visiting the study sites, my activities with students involved monitoring their work and discussing bicycle repair problems with them as appropriate.

Most of the video collected in the shop consisted of *work-group* video in which a small number of students, between one and four, were taped as they completed a repair procedure. Because the purpose was to record naturally occurring activity, the *work-group* video segments were captured spontaneously, as the activity unfolded, without any suggestions or interventions by the researcher other than assisting in answering occasional technical questions on bike repair.

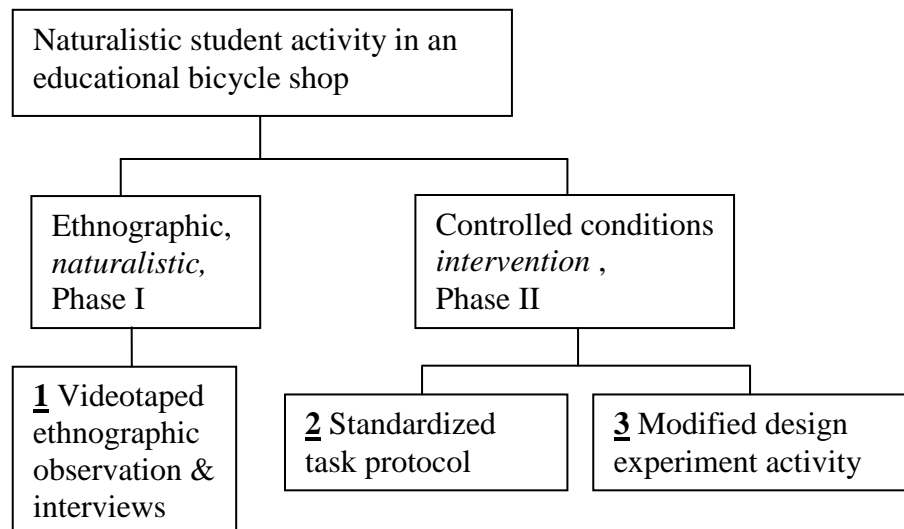


Figure 5-4. Protocol tree diagram showing the study's two approaches, ethnographic and controlled intervention, which result in three modes of data collection activity.

5.6.2 Varieties of Videotaping Technique

For capturing the most naturalistic perspective on informants' activity, I placed a compact, tripod-mounted video camera in a corner of a shop and let it run continuously with little to no adjustment of camera angle. Long shot video such as this accounted for about 30 percent of the total video data collected. Details of apprentice's manual activities were sometimes hard to discern in this data, but the wider angle captured more of the ongoing activities in the larger shop environment, and informants tended to forget the camera's presence more readily. The mini-DV tapes had a capacity of 60 minutes of high-quality, short-play video and had to be changed only once or twice during a two- or three-hour work session. The usual two-hour or 2.5-hour shop work sessions normally used two tapes. During most work sessions I used a combination of long-shot focus and work-group focus.

The bulk of the ethnographic video data, about 50 or 60 percent, focused on a single work group of one to four students, mostly in tripod mode but with a few handheld mode segments. At this close range, the video record provides excellent detail of manual activities, facial expressions, and other fine motions and sounds. The video camera was more intrusive at this distance from the informants, so some degree of naturalism is sacrificed as demonstrated by a small number of students who peered into the camera lens or gave momentary 2-second performances. I tended the video camera during most of the taping, but only to pan the camera to follow an activity whenever it migrated off-camera for more than 15 seconds or so. The remaining 10-20 percent of the video data consisted of stationary head shot interviews, both individual and small focus group. Following the completion of Phase I data collection, I performed a preliminary data analysis to identify key themes and to form follow-up research questions.

5.8 Phase II Protocol— Controlled Intervention Studies

Phases II-A and II-B: Standard task comparison and self-evaluative video interviews

Eight students representing all three sites (one each of Sierra and Heartland; six from Cascade) participated in Phase II-A, a comparison of students' performance on one of two standard bicycle repair tasks. Participants chose between two repair procedures: a) tire repair, a basic-level task and b) brake repair, an intermediate-level repair task. Six students chose to do the tire repair; two advanced students selected the brake repair. Seven of the eight students also completed the Phase II-B video follow-up interviews in which they viewed themselves on video performing the standard task, and they discussed their performance with the researcher.

Due to the large number of students available, at the Cascade site, some spontaneous additions to the protocol occurred. I had initially designed this portion of the study to focus on the physical aspects of individual students' interactions with their environment rather than on the social aspects. However, two pairs of students agreed to perform standard tasks together, which allowed both examination of social interactions between participants and comparison between individual participants and participant pairs. Emily and Donte performed a brake repair together. Donte and Dennis performed a headset adjustment together. These participants pairs resemble two-member work groups that were observed during Phase I, but Phase I work groups formed spontaneously as opposed to the intentional pairings that I made in Phase II-A. Likewise I specified the tasks performed in Phase II-A, whereas all tasks performed in Phase I occurred independently of my planned actions.

Phases II-C and II-D: Follow-up work-group task and interview

The intermediate-level research questions (see Table 3-1) generated by Phase I analysis formed the structure for Phase II visual analysis and in-depth case studies. The two final parts of Phase II (II-C and II-D) were designed to integrate all preliminary findings up to that point to generate a final round of data collection that would help address research questions as they had developed to that point. In a sense, this stage of research questions and data collection reflects the researcher's own learning progression.

Preliminary analysis of data from previous stages of the study suggested the following:

- what defines learning, knowing, and competence in the bike shop depends less on the learning of procedures because knowing encompasses more than factual knowing,
- development of the student's identity as knowledge authority (Engle, 2006) plays a key role in the learner's development of legitimacy as a "peripheral participant", and
- ways of seeing plays a central role in students' ability to solve problems.

5.9 Data Analysis

Once recorded, videotaped observational sessions, intervention sessions, and interviews were inventoried, then content logged. A content log provides an annotated synopsis of actions and events during a data collection session. By making a complete written, time-stamped array of episodes of student thinking, doing, and learning, it provides an index to potentially important episodes of interest. Sections of the video that need to be viewed more carefully can then be fully transcribed and replayed as necessary for more detailed analysis.

The analytic method resembles traditional techniques of cognitivist-constructivist discourse analysis in many ways. However, just as visual methodologies diverges strongly in the data collection process, visual anthropology also departs from the analytic techniques at this point. The case of Sierra apprentice Marcus is presented below to illustrate the analytic techniques used.

5.7.1 Student case: The spontaneous planar geometry lesson

The video record from which the following activity segment was excerpted was part of the naturalistic data set. Yet it demonstrates how easily naturalistic activities in the educational bike shop can be adapted to the experimental, generated form of data. Moreover, the considerable extent and nature of instructional scaffolding that I provided as a participant-observer-cameraman in this episode blurred the line between naturalistic and generated data.

Marcus was a 14 year old intern who had logged in about 20 hours of shop-based on-the-job learning at the time of this videotaped episode. Like other students in the shop that day, Marcus was working on a bicycle that was being prepared for sale at an upcoming holiday celebration event. Patrick was the adult lead instructor, and I was circulating between the two students in the shop at the time as an assistant instructor. My role as cameraman was also quite active since I shot much of the episode in hand-held camera mode to capture some of the less overt aspects of the activity.

Mastering the Derailleur Hanger Alignment Tool. In the video clip described here, Patrick instructed Marcus to straighten the bent rear derailleur hanger using a hanger alignment tool. Because Patrick used a discovery learning type of pedagogy in most of his work sessions, his instructions to Marcus were minimal. He simply told Marcus to screw the tool into the hanger threads and straighten the hanger, leaving the details of those actions to be reasoned out by Marcus through rational analysis, trial and error, or other approaches.

This was a minimalist version of instructional protocol 7 (see Appendix A), which suggests using a monitored discovery approach to letting students explore and gain competence in using dropout alignment tools. Both dropout alignment tools and the derailleur hanger tool are basically levers that attach securely to a frame part in order to bend it in various directions to achieve alignment (see Figure 3-5).

Learning progressions

However, in the parlance of distributed cognition, the derailleur hanger alignment tool has a high degree of “working intelligence” built into its design as compared to the dropout alignment tools which are glorified adjustable wrenches. The hanger alignment tool has a pivot joint at the hanger end that allows turning around a full 360-degree arc. It also features a sliding indicator rod at the opposite end that allows accurate reading of alignment variance at any position along the arc despite the eccentric relation of the tool arc to the circle of the rear wheel which serves as the index plane. This eccentricity combined with the planar geometry of frame alignment constitutes an underlying level of geometric complexity beyond the level of tool “intelligence”.

Figure 5-5. Marcus experiments with the derailleur hanger alignment tool in a way that resembles how most students approach the problem of reverse engineering the design of any machine or social “black box” to better understand its intended function.



Figure 5-6. Marcus explores the geometry of parallel planes in advance of discovering the relationship between a misaligned derailleur hanger and derailleur dysfunction.



Multiple levels of complexity in a work task or other unit of learning constitute what the literature has recently called a *learning progression* (Collins et al, 2004). In this case, the learning progression for mastery of the derailleur hanger alignment tool consists of at least four levels:

1. Basic understanding of how to install the tool and use it to leverage the hanger into a rough “eyeball” degree of alignment.
2. A more advanced understanding of how the tool design provides a “working intelligence” in its ability to precisely gauge variance from coplanarity through the use of a pivoting arm and sliding indicator rod. Figure 5-7 shows a straight on view of the rear of a completely stripped bicycle frame and the location of the derailleur hanger.
3. An understanding of the underlying planar geometry of frame alignment and its relation to effective derailleur shifting plus an understanding of how the rim of the rear wheel provides a coplanarity index for the hanger and how the sliding feature of the tool’s indicator rod resolves the problem of eccentricity between the wheel rim index and the pivot arm’s arc of travel.
4. Mastery of tool use which integrates conceptual understanding of tool design and underlying structural geometry with the performative aspect of physically using a tool to achieve a precise measurement and alignment outcome within a commercially efficient period of time.

Figure 5-7. Rear view of a stripped bicycle frame (in gold. Disregard the hands and the frame alignment gauge they are holding.) The derailleur hanger is located on the right (drive) side of the frame and appears as a small protrusion at the right bottom of the frame (a).



In most instances of learning progressions being used to assess student learning, the students are expected to advance through progressively more complex levels of understanding of a big picture concept over a period of months or years. My use of learning progressions here is on a much smaller scale, but the method appears to be just as useful in helping to describe the development of Marcus's conceptual learning over time. The extraordinarily simple technology of bicycles can be analyzed to an exhaustive level of detail. What is important, though, is not how much can be analyzed and written about bicycle repair but how analogous this simple machine and its finite number of subsystems can be to larger, more complex mechanical systems and social structures as mentioned earlier. To the extent that that analogy works, learning about bicycle systems can serve as a prototypical model for the learning of other ecological systems, both material and social ones.

Types of data: knowledge, activity, inquiry, narrative, and other learning episodes

An initial look at the videotapes, the content logs, and the interview transcripts revealed various types of learning episodes in the educational bike shop apprentice work sessions. In addition to the original phenomenon and the researcher's videotape record of the work activity, the self-retrospective interviews provide the informant's perspective on his or her own activity. The finished repair job stands as an inscription of the apprentice's skill. That final inscription, then, is subject to evaluation by a shop supervisor or, ultimately, a customer/end-user. Even the end-user's assessment can be subdivided into an initial impression based on visual examination and initial road test as compared with an extensive road test over various conditions and an extended period or number of trials. Each of these versions of assessment of the mechanic's work ability and disciplinary knowledge is likely to offer a slightly different perspective.

Table 5-8. Catalogue of episodes of knowing and doing in the bike shop.

Activity/Concept	Visual	Combined	Verbal
Brake repair, caliper, cable replacement or	032510b Deon demonstrating manual facility with cable replacement.	032510b Deon directing Emily in loosening cable adjustment at time 32:42. Deon and Emily jointly	052610 Brad trying to find alternate adjustment points for brake cable. Mechanics of barrel

adjustment	032510b Deon isolates fault in caliper brakes to levers	diagnose brake centering problem as lack of wheel trueness. They collaborate on balancing caliper width adjustment with spring centering and wheel alignment.	adjuster-housing-cable-brake-width relationships starting at time 20:30.
Mechanics of flexible-cable brake actuation			052610 Brad discusses with CH the mechanics of adjusting cable actuated brakes
Brake repair, cantilever, replacement, adjustment		052610 Brad, working under CP's instruction, struggles to coordinate Allen wrench and combination wrench opposing torques to facilitate brake shoe adjustment. CP instructing Brad in centering of brakes at time 18:10.	

Sample data analysis of Marcus's tool mastery episode

The method for examining Marcus's first encounter with the hanger alignment tool starts with perusal of the 3-page content log for the 52-minute videotape containing the hanger alignment tool episode. The following content log excerpts illustrate how this summary of Marcus's actions is used to focus in on video segments of interest. The numbers in boldface indicate the videotape time stamp in hours:minutes:seconds. The complete content log for this videotape is provided in the Appendix.

Content Log: CL120209a

00:06:49 – 00:08:14. As Marcus contemplates the tool inserted into the hanger, Charles prompts him to explain how he thinks the tool is designed to work. Charles demonstrates lining up indicator rod at point of maximum rim deflection. Marcus experiments with levering the tool to bend the hanger but seems baffled by use of the indicator.

00:09:00 – 00:11:02. Marcus identifies gap at 9 o'clock, tests movement action of indicator rod and chassis, seems unsure of how to accommodate the eccentric movement of indicator due to the tool's pivot around a center offset from the center of the rear wheel. Charles queries Marcus about the meaning of the variation in indicator gap size and tries to get him to correlate gap size with coplanarity of hanger and wheel.

Within the short time span of about 24 minutes, some interesting changes appear to emerge in Marcus's actions and speech that possibly indicate a shift in his way of seeing the hanger alignment tool and the mechanical problems it is designed to correct. Rather than interpret this as a potential instance of conceptual change, as standard constructivist analysis would suggest, however, I tag certain segments within this video clip as visually distinct actions

indicating possible episodes perceptual change. Only after tabulating this data into a matrix that lays out actions, potential competencies, and interpretations and then looking for regularities do I try to shape these data into preliminary findings. Table 5-9 demonstrates the outcome of this analytic method.

Table 5-9. A sample analysis of selected episodes produces a matrix of environmental interactions and student competencies.

	Actions and interactions	Ways of seeing and potential competencies
Episode 1 CL120209, 00:06:49 – 00:08:14	Marcus experiments with function of the indicator on the hanger tool.	Understanding of the relationship between the mathematical concept of parallel planes and the minimization of friction in linked mechanical systems
Episode 2 CL120209, 00:11:02 – 00:11:50	Marcus starts to take hanger tool apart in effort to understand its function. CH advises him not to.	Marcus switches from “trial and error” solution path to “take it apart” approach in attempt to understand tool function.
Episode 3 CL120209, 00:11:50 – 00:12:51	Marcus seems to fumble with indicator rather than use it effectively to measure coplanarity	Repeated fumbling with indicator signals unachieved competency in tool use.

The brief analytic excerpt in Table 5-8 describes repeated instances of Marcus appearing not to use the tool in a canonical manner to test coplanarity of wheel and hanger as the tool was designed to do. Despite this apparent absence of understanding, which continues for the next 12 minutes, at about 13 minutes after the start of these analytic episodes, Marcus does clearly demonstrate deep understanding of the tool and effective use. This prompts the question “What changed in Marcus’s actions and interactions during a 13 minute period to produce the competency outcome?” Are there visual clues in the episodes that appear to show lack of understanding of the tool? This question prompts a careful review of Marcus’s actions during that segment of the videotape.

This first iteration of data analysis of a few minutes of the video record prompts a wealth of other questions that need to be considered after a vetting. After review, these questions then become part of the process of further analysis followed by designing the next iteration of quasi-experimental interventions in a subsequent work session with Marcus or other students. Some of those questions include the following.

- What does Marcus’s several minutes of apparent fumbling with the indicator signal?
- How does this approach to solving the question of tool function compare with Marcus’s problem solving strategies in similar situations? ...in contrasting situations?
- Does this apparent fumbling resemble other instances of Marcus exploring a complex tool or mechanism before being instructed in its canonical use or function?
- What other evidence of prolonged exploration of a tool exists in the videorecord?

- What differences are evident in Marcus's explorations of tool use after instructor Patrick demonstrates and carefully explains the rationale behind canonical tool use procedures and techniques?

5.10 Problem Arc

To illustrate the research design and analytic techniques used this chapter presents detailed descriptions of methodology and several examples of data analysis. The bulk of data analysis is presented in Chapter 6, but portions are presented here.

- **Problem Arc 6.** The grounded-theory, emergent-problem process has so far produced two main study branches and several methodological questions and findings. How will the process evolve from this point? What did the VA methods used so far reveal in response to the research questions?
- **Solution Strategy.** Based on the combined methodology study design, and the variety of data collected and given a preliminary analysis, I decided to generate the next iteration of research questions and answer them using VA methods alone.

The two study branches that emerged were a) the centrality of assessment and competence issues to the relationship between setting and thinking practices and b) a focus on how hand tools both mediate actions and coordinate thinking practices. The latter branch emerged from two sources: the discussion relating tool use to Hutchins's (1995) theory of distributed cognition and Cobb's (2000) theory of symbolizing practices. The next chapter will attempt to synthesize these elements into the final iterations of the study process.

Chapter 6: Formal Assessment in the Social Practice Model of Learning

This chapter continues analysis of the video data, but at a more detailed level. It examines specific episodes of activity that illustrate examples of competent participation, learning, or ways of seeing. The goal of the chapter is to further refine a model of learning that is flexible enough to accommodate the diverse ways of knowing that proliferate in dynamic cultures.

6.1 The Vocabulary of Visual Analysis

Much of the analytic terminology used in visual analysis originated with Goodwin (1994, 1995). Several of his constructs used for distinguishing ways of seeing and the learning associated with them are described below. In this chapter I use Goodwin's constructs to help explain the interactions among students and between students and their physical environment. I also use analytic terms established by Stevens and Hall (1998). Visual grammar is a visual analytic term that has received little attention. It refers to the nonverbal symbolizing used to communicate, particular in manual activity environments and has proved useful for explaining processes occurring in the exploratory bike shop environment.

6.1.1 Reflexivity

Reflexivity goes beyond explaining the researcher's approach to examining his or her own perspective. It is a comprehensive level of examination of the researcher-informant relationship, how the positionality of that relationship was established and how it resulted in producing understanding during the fieldwork.

Collaboration

In the VA context collaboration refers to a quality of the researcher-informant relationship in which the two entities work with and negotiate with each other to reach a mutual understanding and to enable the researcher to represent the point of view and the experiences of the informant. A collaborative approach demonstrates how many aspects of experience knowledge are not visible. It recognizes the intersubjectivity that underlies any social encounter.

Naturalism

Methodological naturalism refers to a level of collaboration and symmetric relations between researcher and informants that reduces the interventionist quality of conventional research thus reducing the artificiality of the relationship. It is the principle that endows VA methodology with greater validity than interventionist methods because of the more genuine level of researcher-informant interaction.

Naturalism in VA methodology should not be confused with the "unobtrusive research" methods of Emmison and Smith. Those researchers covertly record informants' reactions to specific provocations or interventions in an attempt to capture observational data of greater reliability. Their method neglects the negative effect that their interventionist technique has on data reliability. The method presumes that increasing observational reliability effectively

captures the informants' genuine point of view without realizing that the asymmetric power relationship inherent in their interventionist approach skews the reliability of those data.

Highlighting

Goodwin (1994) developed the notion of highlighting to describe the way a master directs the apprentice's attention to a particular detail of seeing or channels the apprentice's observation processes in particular direction.

6.2 Assessment and the Social Practice Definition of Knowing and Learning

Assessment, which relies on an explicit (although not necessarily specific or quantifiable) definition of learning, itself remains poorly defined within the social practice context, even by Lave and Wenger (1991) and Wenger (1998). Part of the problem seems to be that no one has yet approached assessment from the perspective of the production manager, the entity that directly runs the work operation.

In the history of schooling, the work and the purpose of assessment has been appropriated from the hands of the teacher into the domain of the policy makers as a means of shifting control over what and how children are taught to a more centralized source of authority. Removing responsibility for assessment to a further distance from the learning activity increases the chances that the purpose of assessment will be used for political rather than educational purposes.

6.2.1 Role of Assessment in the Exploratory Bicycle Shop

The exploratory bike shop uses assessment in a direct manner for strictly educational purposes, that is, to determine how well the apprentices are learning. However, since learning in a social practice context does not supply easily measurable units, the degree of an apprentice's competence has to be assessed in a fundamentally different way.

In a commercial bike shop context, new employees usually enter the community pre-assessed. But because bicycle repair is so technologically simple compared to the servicing of other machinery like automobiles (Dant, 2004) or photocopiers (Orr, 1996) some employees are hired on as apprentices. The appeal of hiring a less experienced mechanic to join a shop's existing community of mechanics is that a novice can be enculturated more easily into the existing shop's particular style of practice. The disadvantage is that it takes longer to bring the apprentice up to full production speed.

Compared to an experienced mechanic, the apprentice will also require more continuous assessment of his or her learning progress. Similar to Lave and Wenger's (1991) case of Liberian tailor apprentices who work their way up through progressively more challenging work tasks according to clothing item, apprentice bike mechanics are given increasingly difficult repair procedures. But whereas the tailor apprentice's degree of competence can be measured on a scale of less difficult to more difficult items to produce from raw materials into a finished product, the scale of competency in a bike repair shop depends not just on the finished repair, but all the contingent related repairs that may or may not be needed. The ecological interrelations of subsystems in the bicycle require that each particular bike repair job is carefully pre-assessed in order to it to effectively index the apprentice's competence in finishing the job. Otherwise a brake repair job given to an apprentice, for example, might indicate a much higher level of

competence than the standard brake repair job because of underlying complicating conditions not readily apparent in a quick pre-assessment of the repair.

Examples of common underlying conditions that would vastly alter the level of competence needed to complete a repair wheel trueness, wheel dish, axle cone spacing symmetry, and frame alignment. All of these conditions are distinct from brake operation, yet all of them directly affect the ideal level of a brake's ability to effectively stop the bicycle. The need to pre-assess a bicycle repair task carefully points to an interesting difference between bike repair activity and production activities such as tailoring and other manufacturing activities. In the bike shop case, the work of assessing the apprentice's competence is transferred to pre-assessment of the repair task so that task completion can serve to index the apprentice's competence. In the case of Liberian tailors, the work of assessing competence is wholly built into the design of the specific clothing item eliminating the need for any pre-assessment.

If the bike shop manager were to use an apprentice's ability to repair a brake as a standard method of assessing the apprentice's readiness to advance to fuller participation or more advanced work tasks (see Table 6-1), then the brake repair task would have to be pre-assessed as a standard task to be accurate.

Table 6-1. Comparison of tailor apprentice and exploratory bike shop apprentice product-based and task-based competency benchmarks

Level of competence and participation in community of practice	Liberian tailor apprentice finished products and practices⁸	Exploratory bike shop apprentice completed tasks
1) beginner, peripheral participation	hats, men's undershorts, informal and intimate garments for children, hand-sewn	tire repair, wheel installation and removal, brake cable replacement
2) intermediate	Cutting and machine-sewing of increasingly external and formal items	headset, bottom bracket, and hub overhaul, brake centering
3) advanced participation	dresses and shirts	chain replacement, gear adjustment, wheel truing
4) full participation (journeyman)	Higher Heights suit	frame alignment, wheel building

One useful finding from this analysis is the analogy between conceptual understanding and effective repair activity. Bike shop managers use the analogy to substitute physical repair activity for conceptual understanding in the apprentice assessment process. But the analogy also carries over into other aspects of communication and interaction in the exploratory bike shop setting. [Does this conclusion move the analysis toward Sfard's commognitive theory?] It also raises a question for the visual analysis process: do actors in the shop setting use a physical action vocabulary to communication and think on a regular basis? The answer seems to be yes, but that needs to be confirmed through the visual analysis.

⁸ Compiled from Lave (1977) and Lave & Wenger (1991).

5.2.2 *Envisioning conceptual understanding*

In agreement with Dant's (1998) visual analysis of car mechanics' repair activity in England, a relationship between apprentices' physical actions, the "habitus" of the shop, and the apprentices' cognitive understanding of problem situations appears to emerge in the 30 hours of exploratory bicycle shops videotapes. My analysis detects evidence for a kind of action-based vocabulary and visual grammar that substitutes for much of the verbal communication normally used in contemporary work situations.

Dant, a sociologist, focused on the relationship between the shop habitus and the cognitive aspects of the auto repair work. Surprisingly, he found that the cognitive component of solving the particular repair problem he studied, replacement of a worn out windshield wiper motor assembly, had less to do with knowing a generalized procedure than with the local, spontaneous problem solving required to fit this particular unit into the engine compartment of this particular car. The same kind of localized, contingent thinking occurs in the exploratory bike shop since it, like the auto repair shop, frequently encounters installation of new parts onto older, nonstandard bicycles. In some cases, the contingent problem solving required in the bike shop ratchets up a notch higher than the conventional bike shop or auto repair shop because apprentices and their instructors sometimes adapt recycled parts to the repair of a used bicycle. As one conventional bike shop mechanic recently observed while volunteering in the Heartland shop, "You guys are the real mechanics. All I do is tighten pre-assembled components into place on newer bicycles. You shape metal, improvise new designs, and solve stubborn problems."

All accolades aside, the bicycle still consists of the simplest transportation technology in existence other than a pair of sandals. That simplicity makes it ideal as a vehicle for work-based learning among children and adolescents, and it greatly facilitates the visual analysis of learning in the exploratory bike shop. A cataloging of basic bicycle repair procedures produced a total of 72 procedures organized into five subsystem categories (see Table 3-2). By comparison, an auto repair shop uses many hundreds of procedures, and a catalog of medical procedures runs into the thousands.

On the surface, academic communities of practice appear to share a product in common with exploratory bike shops: trained workers. However, the "product" differs in many qualitative respects, not to mention the vastly greater numbers of workers trained in schools as compared with exploratory bike shops or similar hybrid production-educational enterprises. Because public school systems mass produce trained workers by definition, the in-process students must be regarded to some degree as raw material for the manufacture of trained workers and as production units. The school-based assessment system, even before the current era of high-stakes testing, reflects this mass production attitude. The bureaucracy has no capacity, by definition once again, for any attitude toward student units other than viewing them as products to be ranked and distributed within the economic system. Individual teachers and counselors usually develop individual relations with students at the classroom level, but the bureaucracy has no choice other than to see students mainly as numbers. In that system, assessment assumes the purpose of organizing the human capital for mass distribution. Both the bureaucratic and the social reproductive structures of the school system reinforce this relationship with students and with the process of assessment.

Assessment is one of the key themes that emerges from the visual analysis of the videotape data across all study sites. Other key across-site commonalities include the standard practice of peer instruction, and several related progressive education themes such as learning from mistakes, encouraging exploration and mistake-producing risk-taking. Site-specific findings

include the uniquely structured peer tutoring system at Cascade and the students-with-serious-disabilities populations served by Heartland and Sierra.

6.3 Reading Competence in Apprentice Work Videos

6.3.1 *Ways of Seeing Competently*

Much of the work of becoming a more central participant involves being able to see details in the unfolding production process in a way that approximates the masters' way of seeing, that indicates a high quality product.

Transcripts and Other Data Excerpting Conventions

Two different styles of data excerpts appear in this chapter. Transcript excerpts of formal interviews follow the customary stylistic convention of using individual line numbers to reference specific text. Most of the data excerpts, however, are taken from time-stamped "enhanced content logs"—essentially video transcripts—of ethnographic episodes that contain descriptive notations often with little dialogue. Excerpts of video transcripts appear in this chapter as three-column enclosed boxes with time values in the far left column. References to specific video transcript items are given in time values rather than line numbers. Orienting notes about location or to the larger off-camera context are included in square brackets.

6.3.2 *Standard task performance analysis*

The purpose of the standard task activity in the lineup of research methods used in this study is to help guide the emerging, increasingly narrow focus of the research questions. Given the broad scope of the original question, which sought the nature of the relationship between the learning process and its setting and which helped define the broad scope of the initial phase ethnography, a method was needed identify themes in the ethnography worth pursuing in greater depth. The standard task activity was one of those methods used. Unfortunately, this activity was executed prematurely, before preliminary results from the ethnography were available to make logical decisions about which study parameters to compare for greatest analytic effect.

Before results from the many hours of naturalistic observation videotapes had been analyzed or even carefully examined, I decided to give students the choice between two possible standard repair tasks, tire repair or brake repair. The eight students in this second phase of the study chose a task and performed it under conditions controlled for direct comparison. In other words, the task conditions were made as uniform as possible, which would allow for comparison of task performance across students and, if desired, also across study sites.

Six students chose the tire repair task and two chose brake repair. About one month after that data was collected, preliminary analysis of the Phase I videos suggested further examination of a repair activity that involved a) a fair degree of conceptual complexity and b) a finely tuned "way of seeing" that would index a learner's expertise. On the surface, at least, tire repair in all its mundane simplicity and brute force technique did not fit either of these criteria. Nevertheless the standard task component did generate some interesting findings as described below, both in the tire repair and brake repair tasks. The repair task that did fit the two criteria was hub adjustment, and the follow-up comparison study of that task is described in the last section of this chapter.

Tire repair task

Fixing flats is the unglorified ground-level repair job that virtually all bike mechanics learn first, often before they ever receive any formal training. Because tire repair technique is so frequently disseminated child-to-child in an informal context, it is subject to the imprecision that characterizes folk wisdom. Many inaccurate myths about effective technique exist. Adding to the uncertainty is the ethereal composition of tires. In sharp contrast to the bicycle's structural and dynamic metal components that fit together precisely, tires are composed of flexible rubber and about 80 percent air by volume, hardly the stuff of precise manipulations. Also, the logic of tire size standards can be elusive. For example, a 26 x 1.75 tire is not interchangeable with a 26 x 1 ¾ tire.

Nevertheless, tire repair is, by itself, a highly standardized task with virtually no variation in procedure among the millions of tires in use. Pry the tire off of the rim. Test the tube inside and, if necessary, patch it. Reinstall the tube and tire on the rim. Finally, reinstall the entire wheel on the bicycle and align it. There are two possible variations in the sequence of reinstalling the tube and tire; otherwise bicycle mechanics the world over use exactly the same procedure, making it a good candidate for this standard task comparison.

Yet, like all procedures involving used bicycles, unanticipated problems tend to arise. Because all students ultimately completed the task within a reasonable time, the first three criteria for task completion in Table 6-3 are described in terms of difficulty encountered, not completion, while the last two criteria are listed as subtasks that were or were not performed. These last two task criteria are deceptively subtle points of repair that carry considerable weight as indicators of skill mastery. Neither valve straightening nor proper tire seating is typically emphasized in the beginning shop curriculum. But these two simple checks are performed by most advanced mechanics and are strong indicators of a well developed sense of how a well repaired tire should look and feel.

Table 6-3. Tire repair standard task comparison across students.

Student, age (study site)	Problem with tire removal?	Problem with tube testing/patching?	Problem with tire reinstallation?	Straightened valve?	Checked for proper tire seating?	Comments
Emily, 10 (Cascade)	no	no	yes	not observable	not observable	used tools to reinstall tire
Dennis, 10 (Cascade)	no	no	yes	yes	no	tube too full to reinstall tire
Carl, 15 (Cascade)	no	no	no	yes	yes	flawless performance
Debra, 15 (Cascade)	no	no	yes	not observable	not observable	unfamiliar with rim strip
Marcus, 14 (Sierra)	no	no	yes	not observable	not observable	unfamiliar w/ one bead rule?
Colin, 15 (Heartland)	no	no	no	yes	yes	removed tire bead without tool

Among the four students from Cascade, none encountered any problems with tire removal or tube testing and patching. However, all except Carl did have some difficulty with tire reinstallation. One interesting aspect of this distribution for this particular criterion is that it

correlates positively with the extent of bike repair experience. Carl is both much older and more experienced than Dennis and Emily. Carl is the same age as Debra, but Debra is new to the world of bicycle repair, and her task performance was hindered both by difficulty reinstalling the tire and her unfamiliarity with the rim strip, a standard protective strip of rubber, plastic, or cloth that lies between the tube and the spoke ends on all wheels. Evidently she simply had not noticed the rim strip on the previous two or three tires she had repaired.

Especially notable in the distribution of performance results in Table 6-3 is the difficulty Marcus at the Sierra site had with tire reinstallation. Not only is Marcus one of the older students in this study sample but also he is one of the more experienced bike mechanics at Sierra, at least in terms of shop hours accumulated and the individual attention he has received from instructors over the previous eight months. Marcus has demonstrated his ability to do certain advanced skills such as wheel truing and even wheel building. Yet, his understanding of effective tire repair procedures appears not to be strong. Video of Marcus repairing tires under naturalistic conditions corroborates the results of this intervention study.

Several factors could help explain this paradox of an advanced mechanic who has difficulty with the basic task of installing tires. One age-related factor involves hand strength, which was a factor with the two 10-year old students at Cascade who had difficulty reinstalling a tire. But at age 14, Marcus should have developed enough hand strength to muscle a tire onto a rim.

The fact that Marcus was working on a more challenging high pressure-rated tire as opposed to the smaller, low-pressure tires that the Cascade students were working on could also help explain his difficulty. However, the video shows that neither this nor the hand strength factor accounted for Marcus's main problem, which was that he did not follow, and therefore seemed not to know, the fundamental one-bead-on rule for installing tires. It is impossible to install the proper size tire onto a rim unless one of the two tire beads, the rigid edges of the tire, is fit all the way onto the rim first. One bead is entirely on the rim, the other bead is entirely off. Only then can the second bead be pressed onto the rim. Unfamiliarity with this fundamental principle is what made the procedure difficult for Marcus.

Considering this situation from a social practice perspective the question then arises, "How can Marcus, who has become so central to Sierra's community of practice that he recently joined the staff there as a paid intern, be so peripheral with respect to familiarity with this principle and performance of this basic task? Marcus's case seems to challenge the logical integrity of the social practice definition of learning. One way to approach this problem is from the standpoint of the *legitimacy* component of the *legitimate peripheral participation* construct. The school or apprentice situation extends a special "learner's permit" of legitimacy, which allows the apprentice to participate in full or nearly full-participation activities under the condition of proper supervision. This special hybrid status is what creates the cultural space for learning within the community of practice. In Marcus's case, he is participating in near-full activities with respect to advanced tasks such as wheel truing and wheel building, but that does not mean that he has mastered all of the more fundamental tasks. Unlike tailoring in which skill mastery must follow a specific sequence, bicycle repair leaves more room for out-of-sequence mastering of skills.

Unfamiliarity with a fundamental procedure of tire repair and the procedural rule behind it could account for much of Marcus's difficulty with the tire repair task. But other factors likely contribute to Marcus's diminished performance on the tire repair task. One stems from his aversion to test situations. Compared to the spontaneous atmosphere in all of the naturalistic

video situations, the standard task video activity resembles a test situation. Several other students also exhibit varying degrees of test aversion.

Marcus does not thrive in certain test situations. A dramatic example of his test aversion is a video episode that occurs at the end of my initial interview with Marcus. I asked Marcus to demonstrate his ability to adjust a hub that was too loose. Hub adjustment, as shown in Table 6-1, is an intermediate-level activity, not so basic as tire repair, but still one of the earlier skills to be mastered. Marcus appeared to be lost at several stages of this procedure.

Several of the ethnographic videos of Marcus competently performing both simple and complex repair tasks corroborate the role of test aversion in this situation. Marcus's adeptness at wheel truing illustrates his ability to master a complex task. The following ethnographic video and dialogue excerpts are from a spontaneous work episode late in the study. CP is the lead instructor at Sierra.

00:35:38 – 36:48	The wheel is mounted in the truing stand. Marcus carefully tests the spoke wrenches for a snug fit, rejecting his first two tries. While Marcus is hunting for another spoke wrench, CP steps up to the truing stand (...)
00:36:49 – 38:59	Marcus: I can't find the right spoke wrench. CP tries the wrench and finds it too tight. He suggests that Marcus try the red wrench. (...) the red spoke wrench fits well. Marcus starts spinning the wheel.
00:39:00 – 40:55	Marcus demonstrates what appears to be impeccable form in truing a wheel in the truing stand. He locates a target trouble area in the vicinity of 1-5 spokes using a combination of auditory, visual, and haptic cues. He tests the spoke tension of the spokes he is about to adjust. He very carefully positions the spoke wrench onto the nipples to avoid nipple damage. He turns the spoke wrench in the correct direction to achieve the loosening or tightening desired. He then restarts the testing-adjustment cycle, occasionally adjusting the indicator arms on the truing stand or taking a long perspective on this close-range work.
00:40:56 – 43:49	CP asks if Marcus is making progress. Marcus answers affirmatively. Marcus continues the truing process competently.

As this excerpt indicates, Marcus demonstrates several key aspects of highly competent wheel truing technique. At time 35:38 Marcus's care in finding the correct size spoke wrench indicates not just good work habits in finding the right tool for the job, but also indicates an awareness of what can easily happen when a slightly loose fitting spoke wrench is used to turn the softer brass metal of the spoke nipple: a stripped spoke nipple. Stripped spoke nipples are one of the bike mechanic's bigger headaches. One reason is because they can be difficult to remedy. Another reason is that when they are discovered on a used bike, they indicate the previous work of a sloppy or incompetent mechanic who may have left other surprises that are waiting to be discovered.

A few minutes later in the same work session, Marcus encounters spoke nipples with frozen (i.e. corroded or oxidized) threads, a condition which further increases the risk of stripped nipples. He asks CP what a stripped nipple looks like, indicating that he does not have enough experience to have encountered the problem, but he is aware of the seriousness of the problem.

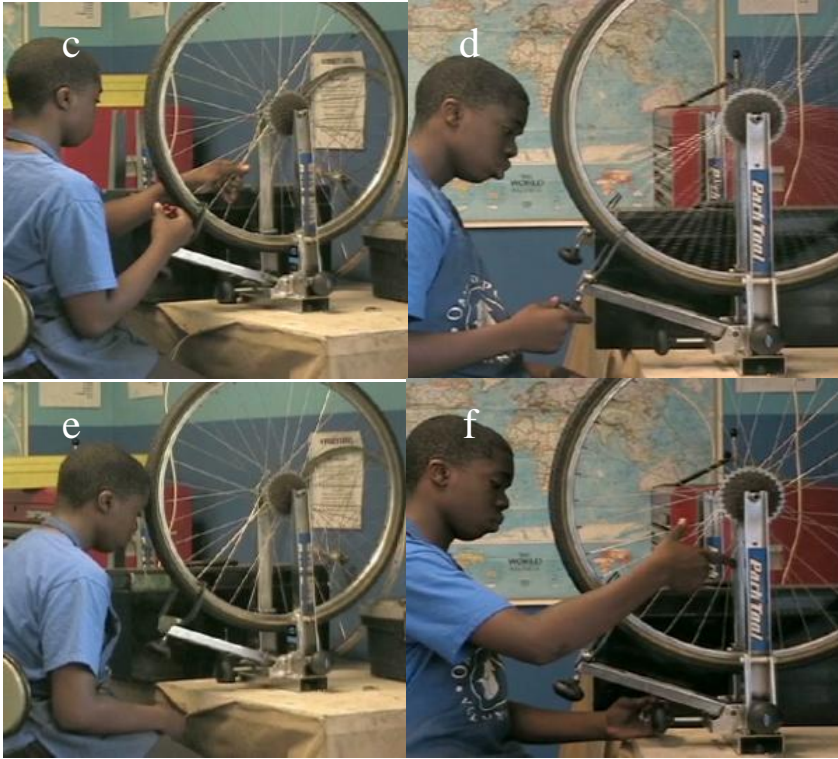
At time 39:00 Marcus shows more signs of advanced competence at wheel truing. He uses both the visual cues as he watches the widening and narrowing gap between the spinning

wheel and the truing stand's indicator arms and the auditory cues as the wheel actually touches the indicator arms making a sharp grating sound. Most impressive, however, is his practice of feeling the tension of spokes before making an adjustment. Wheel truing is a procedure that involves bringing three dimensions—horizontal variance, out-of-roundness, and spoke tension—into the best possible balance considering that structural stresses caused by rim damage would make a perfect balance impossible. Spoke tension is usually the last of three dimensions that a mechanic learns to monitor during this complex balancing act. It is also the hardest to sense by touch, which is why some mechanics use tensiometers. But Marcus demonstrates that he knows how to judge an adjustment based on his sense of spoke tension (see Figure 6-2.)

Figure 6-1. Marcus truing a wheel at the truing stand: (a,b) a sequence showing the subtle movement of Marcus's left hand downward along a spoke indicating his careful technique intended to avoid stripping spoke nipples.



Figure 6-2. A longer video sequence (about 12 minutes) of Marcus truing a wheel: a) delicately moving the wheel back and forth to find the area needing truing adjustments; b) squeezing two adjacent spokes together to feel spoke tension; c) a combination of fatigue and consternation at discovering stripped nipples prompt Marcus to take a momentary break; and d) adjusting the indicator arms on the truing stand.



Marcus's difficulty in performing the hub adjustment task is further discussed in section 5.4.2 of this chapter, where his performance is examined in the context of competency assessment.

Brake Repair Task

Two of the more advanced students chose the brake repair standard task: Donte and Sam, both at the Cascade shop. Brake levers transfer the closing motion of the cyclist's hand to a steel cable that actuates any of several types of brake arms that clamp the wheel rim between two rubber brake pads, bringing the wheel to a stop. When not in use the brake arms are held away from the rim by springs. The cable is routed between the lever and the brake arms by cable housing and various frame-mounted cable guides.

Donte and Sam both completed this standard task. However, Donte's performance falls into a unique category of expertise. At age 13, Donte is recognized as the top apprentice mechanic in the Cascade community. While other apprentices are still exploring the function of bicycle components and building their conceptual understanding, Donte seems to be finished with that part of learning and focused instead on refining his repair technique. There is less of the excitement of discovery in his calm demeanor and more of the satisfaction of effective, efficient craftsmanship.

While there is little else to compare between Donte's and Sam's performance, there is an interesting contrast between their general approach to work and learning and the approach of Brad, a precocious ten year old student at the Sierra shop. In the ethnographic video excerpt below, Brad is trying to adjust the spread of the brake arms by turning the barrel adjuster at one end of the brake cable. The barrel adjuster effectively lengthens or shortens the cable housing which has the opposite effect on the cable that travels inside the housing. So, to lengthen the cable which opens the brake arms wider, Brad should shorten the housing (relative to the inner

cable) by screwing the barrel adjuster further toward the nearest end of the cable. If this description seems unclear, it is because that is the point I am trying to make. Any verbal description, no matter how precise, seems to obscure the situation. Video, alone, clarifies the situation. Even then, Brad’s hypothetical inquisitiveness unnecessarily prolonged the semantic ambiguities and the mechanical conundrum.

The point to take from this example is illustrated at time 28:02 when I advise Brad to stop trying to resolve the question with visual images and instead take advantage of the concrete object that can be tested in its various positions to determine what adjusting barrel action produces brake arm widening and what action narrows the distance between the arms. Whatever Brad’s motives were, his discursive practices led him to seek the abstract, general answer because that approach is more highly valued in the academic community than concrete answers. With a mechanical situation such as this one, however, Brad needed to recognize that that the concrete solution yielding local knowledge would have best served the purpose. I have always observed students using trial and error on the adjusting barrel rather than trying to analyze the general behavior of the cable-and-housing system using mental images. The difference between Donte and Brad on this point strengthens Bourdieu’s (1977) notion about dispositions of the privileged classes toward abstract, generalizable ways of knowing.

00:23:36	CH asks B what effect CP’s request to tighten the barrel all the way down achieved. Both of them discuss the dynamics of barrel adjustment and cable length for several minutes. CP listens peripherally, then joins the discussion by demonstrating with a spare cable and housing example.
00:26:36	CH explains the paradox of CP adjusting the barrel all the way down which opened up the brake adjustment, yet the brakes are now tighter. B acknowledged that he made the adjustment tighter after CP’s barrel adjustment when B moved the R shoe in farther.
00:28:02	B continues to try to reason about the relation between barrel adjustment and cable length. CH tries to advise B simply to move the barrel adjuster to see how it affects brake tightness, but B continues to speculate abstractly. B’s attempts to predict barrel adjustment effect becomes ambiguous as he says “tighten this” and it’s not clear whether tighten the barrel refers to screwing it down or up.
00:30:40	After more ambiguous attempts by B to explain the barrel-cable relationship, CH asks B what he is trying to accomplish now and what his plan of action is. B: “Eliminate the drag on the wheel. And to do that, I (2) need to (3) adjust the pads.” CH advises finding points of adjustment other than the time-consuming brake shoe adjustment. B: “Could it be somehow loosening the cable?” CH observes that the rear adjusting barrel is already maxed out. B traces the cable to the front of the bike and looks at the brake lever adjusting barrel. CH commends B for finding that adjustment point. B runs the barrel in to the max, but the loosening effect is not perceptible because the barrel was almost maxed to begin with.
00:33:20	CH suggests that there are two more cable adjustment points. B points to the anchor bolts on the straddle cable and the R side of the straddle

cable. B suggests making some sort of adjustment that would give the straddle cable more “play”. But then he gets skeptical that that would make any difference in the overall cable length. Eventually he claims to understand how allowing more cable to pass through the straddle cable.

6.3.3 Self-evaluative Video Replay Analysis

The self-evaluative video component accomplishes two goals. First, it elevates the participant’s voice to the level of the researcher’s with respect to assessing the participant’s performance on the work task. That accomplishment also enhances the student’s sense of knowledge authority. Second, it brings the researcher’s way of seeing closer to the informant’s. When the informant and researcher discuss the informant’s work performance together, the researcher has an opportunity to clarify any misunderstandings about the informant’s thoughts, intentions, and actions.

However, the collaborative watching of one’s own work performance did not add as much to students’ assessment of their own knowledge and competence as the spontaneous ethnographic videos. Dennis (Cascade), for example, used the video self-examination to defend a technique that received criticism from both myself and Emily (Cascade) who joined the last few minutes of the interview. The non-protocol exchange that developed between Emily and Dennis took the form of trading war-story narratives about bike repair experiences similar to the narrative discursive medium that Orr (1996) observed among photocopier technicians. In the following section self-assessment emerges as a discursive practice that originates in the culture of the work place and representational infrastructure that supports both the perpetuation and the dynamic change of that culture.

6.4 The Development of Competence Through Work Practice

6.4.1 Professional Vision and Culture of Self-assessment: The Case of Emily and Josh

Emily and Josh, both participants at the Cascade shop, provide an example of effective peer instruction. Josh is a 15-year old apprentice who has completed the advanced bike mechanics course, is a sensitive youth mentor and intuitive teacher, and at mid-adolescence positively exudes self-confidence and a fair measure of exhibitionism. Emily is a 10-year old student with an attentive, composed demeanor who warms up socially to Josh whom she has never before met in the episode described below. While this learning interaction illustrates skillful peer instruction by Josh, it also reveals some pivotal characteristics of the exploratory bike shop experience.

Emily is assigned to a work station to continue work on a bicycle that she is close to “earning”. She performed some work on it during the previous week. The earning of her bike culminates her beginning level course in bicycle mechanics. The shift supervisor—in this instance Tori, the Program Director at Cascade—has assigned Josh to be her mentor on this shift. Prior to the exchange below, the bicycle has been clamped into the work stand and the rear wheel has been removed. Josh proceeds to guide Emily through a hub overhaul procedure on the rear wheel, a procedure Emily has performed once previously on a different bicycle. The first step in overhauling the hub on a rear wheel with a multi-cog freewheel is to remove the freewheel to allow access to the hub interior.

00:07:15 -08:19	Meanwhile Josh has placed the wheel onto the freewheel removal tool and has asked Emily to turn the wheel counterclockwise. Emily pushes the wheel in the proper direction without effect. Josh adds a little push to break the threads. Emily continues turning, on Josh's instructions. Josh determines that the hub is free from the freewheel, and he asks Emily to pick the wheel up. Emily grabs the wheel by the spokes from underneath, but does not pick up the wheel. Josh repeats his request several times without any change in Emily's actions. Josh struggles for a few seconds to loosen the vise, Emily lifts the wheel off the vise. Josh hands Emily the freewheel, "There you go."
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Figure 6-1. Emily and Josh in the Cascade shop discuss a strategy for overhauling a rear wheel, which Josh is holding in his right hand. The first step involves removing the freewheel, a cluster of cogs visible at the center of the wheel.

Josh and Emily had to move to a different work station with more tools to finish the above procedure. Back at their own work station, Josh gets Emily started on removing the axle and ball bearings for cleaning.

00:08:20 -09:14	[At the green station.] Josh: "Now, we're gonna work on the non-drive side." Emily turns the wheel over. Josh: And now it's just like your regular hub overhaul. Joshua's demeanor is calm and patient. He guides Emily gently, making suggestions only when necessary about which tools to use and which actions to effect.
00:09:15 -09:37	Josh: "All right. So, which way do you turn to loosen? (5) And then here's another good spot to use the hand trick. You put the two wrenches right next to each other like this. And then you just squeeze your hands together. There you go."

Josh uses precise technical language probably for several reasons. It supports his knowledge authority among peers. It habituates participants whom he is mentoring to the technical jargon of the shop thereby enculturating them further into the community of practice. Use of technical language also habituates himself to the symbolic relationship between the language and the conceptual understanding the language represents. Finally, practicing precise technical language solidifies his own technical language skill since he is still a learner, still on a trajectory to becoming a more central participant in the shop's community of practice.

Precise technical language is not the only option available to instructors. Sierra's lead adult instructor uses vivid imagistic and often metaphorical language to communicate subtle physical actions or mechanical concepts to his students due largely to his background in industrial design. He uses proper tool names and bike part names, but instead of referring to the "non-drive" side of the hub, he might simply call it the "other" side when working with a student. Likewise, the lead instructor at the Heartland shop combines a street vernacular with a no-nonsense linguistic style which sometimes results in lexical transformations or neologisms. "Non-drive side of the hub" is an unusually technical way for a 15-year old to communicate with a ten-year old, but it worked well in this instance.

At time stamp 09:15 in the above excerpt, Josh deftly turns a corrective instruction into a question. Instead of telling Emily that she was turning the wrench the wrong way, he prompts her to think about her action by asking which direction of turn results in loosening. The technology of threaded joints—e.g. the common hex nut that Emily loosens to remove a wheel, or in this case, an axle—is central to the construction and fine tuning adjustment of the bicycle. Threaded joints translate rotational motion into a disproportionately small lateral motion along an axis orthogonal to the rotational plane. The asymmetry between rotational versus lateral motion also concentrates force along the lateral vector. This characteristic allows nuts and bolts to clamp metal parts together with great force, a phenomenon which has held together much of the modern industrial world for over a century. The high rotational-to-lateral motion ratio is also essential to making periodic infinitesimal tightening adjustments to ball bearing joints that have worn down a hundred microns or more from normal use. As Emily is about to learn, turning a wrench through a 40 degree arc will close about a 100 micron gap between bearings and their races. Only, bike mechanics do not use the micron unit of measure or degrees of arc, and instead use "quarter-turn" or smaller fractions to describe rotational motion.

While the geometry and physics of threaded joints can be fascinating to mathematicians and mechanical engineers, they are essentially irrelevant to most professional and apprentice bike mechanics because of their ubiquity in the material world and their fundamental simplicity of operation. Turning a nut one way tightens it; the other way loosens. That is as deep as understanding needs to go for most mechanics and for virtually all apprentice mechanics⁹.

⁹ Many pragmatic professional bicycle mechanics never go deeper than that level in their understanding of the underlying technology simply because it is unnecessary. Young students exploring the mechanics of bicycles inevitably gloss the details of nuts and other threaded joints because what threaded joints accomplish is so much more consequential than how they accomplish it. Such a triumph of pragmatism over theoretical curiosity and analysis is in some ways emblematic of the cultural tension in U.S. society between unreflective users of technology and the geeks who make technology happen. How that translates into the pedagogical and learning debates over concrete learning versus abstract learning is one of the questions guiding this inquiry.

One last note on the videotape excerpt above: Josh clues Emily in to an important hand tool technique that many beginning mechanics, especially young ones, do not learn until after a year or several years of experience. He had shown Emily once before, during wheel removal, this technique that allows a mechanic to break a tight nut loose without scraping skin off in the follow-through motion. This time, Emily tries the technique herself and successfully executes it (see Figure 6-2). This kind of hand tool use custom that is common to mechanics in shops across all cultural variables illustrates the relation between setting and professional practice that Dant (1998) identified in his study of auto repair shops.

Once Emily has taken the internal parts out of the hub and cleaned them, she replaces them in the hub and adds fresh grease to the bearing races. The critical part of the hub overhaul procedure is to tighten the bearing races onto the ball bearings so that the surfaces barely touch each other, which minimizes friction, and so that there is no gap between bearings and races. This adjustment is made by tightening an adjustable race, called the cone, to a perfect fit against the bearings, then tightening a locknut against the cone to keep it stationary under the stress of road vibration. This is where a quarter-turn or an eighth of a turn of the adjusting cone can result in excess friction (palpable grinding sensation or visibly unsmooth axle turning) or a gap (call “play”).

Embodied Thinking: The Eclipse of the Cognitive

None of the geometry of threaded joints or the conceptual mechanics of closing a 40 micron gap is ever verbalized by a mechanic or even a bike mechanics instructor. Threaded joint orthogonal-translation geometry is so deeply embedded in contemporary U.S. culture, since virtually everyone at some point in his or her post-infancy life has had to turn a screw to tighten it, that the cone adjustment procedure is performed intuitively, by feeling for excess friction or play and turning the cone accordingly. The interaction between Josh and Emily at this stage of their work session illustrates the non-verbal, intuitive, and non-conceptual aspects of this activity. The repetitive trial-and-error nature of this activity results in Emily and Josh spending the next 15 minutes getting this simple mechanism perfectly adjusted.

As the following video transcript excerpts show, however, such a seemingly simple task does not always unfold in a straightforward manner. The various detours and interruptions that occur over the ensuing 15 minutes illustrate a work environment richly interwoven with multiple levels of interaction and activity.

00:27:14 -28:43	Josh: All right. You remember the procedure, right? Tighten it down all the way by hand, then back it off a quarter turn? [No clear response verbally or bodily from E as she continues threading a locknut on. There is the slightest hint of a nod.]
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Emily’s atypical lack of responsiveness in this exchange could manifest simply her occasional reticence. More likely, though, she is displaying annoyance at Josh’s questioning of her procedural knowledge. During the ten minutes leading up to this exchange, she and Josh engaged in a lively dialogue, both task-related and social in nature, culminating in an embarrassing moment for Emily when she gave up trying to screw a cone back onto the axle

because she could not engage the threads. Josh eventually engaged the threads for her, and she finished the hub reassembly herself.

Up to this particular moment, Emily had demonstrated faultless competence. She smiled at her inability to complete this most fundamental of skills—screwing on a hub cone, which is equivalent to screwing on a nut—but a self-lamenting shake of her head accompanied the smile. When Josh capped this embarrassing moment by asking a question about her knowledge, Emily probably interpreted it defensively as a challenge to her knowledge level.

00:29:40 -30:19	Tina calls out for advanced apprentices to announce themselves to the rest of the group. Then she explains to the whole shop that beginning students who have questions they cannot resolve themselves or with their partner must go to one of the four advanced apprentices who have just identified themselves.
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Roughly one half hour into this work session at Cascade, the Program Director, Tori, reminds all students about the policy, sometimes only loosely enforced, that requires beginning students to refer all questions first to a fellow novice or to their more advanced work station partner, and then if necessary to the designated advanced apprentices. Only after the resources of this knowledge hierarchy have been exhausted are students then allowed to bring a question to one of the adult staff.

The only policy of its kind among the three study sites and apparently throughout the national exploratory bike shop community, this policy is remarkable in multiple respects. First, it defines a participation structure in which knowledge authority is decentralized and redistributed down to the level of the most peripheral participant. Although the participation structure is organized hierarchically, the ultimate effect is to support the legitimacy of the most inexperienced beginner as an incipient authority, not just a participant, within the shop community. The participation structure also provides a striking example of a well-conceived representational infrastructure (Hall & Greeno, 2008) and how that infrastructure supports learning. Part of its effectiveness seems to result from its low visibility. Clearly, program director Tori is drawing attention to it in this instance, but is normally enforced in a more subtle, relaxed, sometimes even irregular manner. Adult staff members occasionally remind the designated advanced apprentices, and apprentices support the policy by practicing it themselves and subtly guiding novice students by example and sometimes a reminder. Despite occasional lapses in enforcement, however, the policy is firm and taken seriously. Such absence of rigidity in enforcement possibly helps keep the policy enforceable and effective.

Second, the policy results in a highly efficient operation in which a single adult staff member can easily and effectively supervise a shop full of 20 or more energized young learner-explorers.

Third, the history of this policy is remarkable in itself. As program director Tori explained in a later interview, it emerged about a year earlier after the discrete student participation levels had been thoroughly defined. It is quite common for large human service organizations that have well-defined hierarchical participation structures, as most schools do, to develop an organizational culture that restricts access to higher knowledge authority levels. But, among small organizations like exploratory bike shops such restriction is rare. The reason for scarcity has much to do with the “godhead complex”, which is common issue among start-up exploratory bike shops when policies are less formal and the temptation to cultivate dependence

of students on adult staff and the reverence that accompanies that dependence is strong. The Cascade organization has developed far enough that its program director, Tori, understood not only the management value but the tremendous educational value of redistributing the adults' customary knowledge authority in a democratic manner.

Figure 6-3. Emily and Josh in hub cone adjustment episode: a) Emily finishes assembling hub, b) and makes an initial adjustment. c) Emily: You're disagreeing with me? Josh: Very much so; and d) conflict resolves.



00:30:20 -31:19	Emily uses a cone wrench to back off the cone by a quarter turn. J stops her and asks her to retighten the cone all the way by hand. After she turns it several times, apparently not having completely tightened it before, J checks for tightness, then OKs her to retry turning the cone wrench a quarter-turn back.
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Emily completes the procedure even though Josh’s attention wanders across the shop into conversations with other students. Josh returns to Emily’s work bench after a minute. Emily informs him that the adjustment is too tight. Josh asks her to make the adjustment once more. Emily complies, then tests the adjustment by feel and judges it too tight. Josh agrees. In the long excerpt below, Josh interrupts Emily’s work and tries making the adjustment himself.

00:33:24 -35:24	<p>Josh: [Holding the axle steady while Emily breaks the locknut free.] Don’t kill me. [Emily laughs.]</p> <p>Noticing an unexpected problem, apparently a loose cone on the other side of the hub, Josh grabs both cones with cone wrenches and asks Emily to tighten a locknut.</p>
00:36:30 -38:34	<p>Josh continues to adjust the hub cones.</p> <p>Josh: “All right. It looks like no matter what, it’s going to be a little grindy. Now, tell me if there’s play.”</p> <p>Emily grabs the axle and shakes it lightly.</p> <p>Emily: Yes. Josh: Is there play? Emily: Yeah. Josh: You sure? Emily: [Shakes axle again, back and forth sideways, and answers in a muffled tone.] Yes. Josh: You sure? Is there play? Does the axle... [Josh models a more forceful shaking of the axle in two dimensions, both side-to-side and in-and-out] does it feel like there’s play in the axle? Emily: What do you mean by play? Josh: Like, is there room for it to move back and forth? Emily: [Shaking the axle.] No. Josh: Really? Sure? Like up and down. Emily: Oh. [Pushes hard on axle up and down.] No. Josh: [Demonstrating the desired motion.] Push in and go up and down. Emily: [Tries again.] No. Josh: Really? CH: Are you hallucinating? Emily: Are you disagreeing with me? Josh: Very, very much so. Feel it right there. Emily: [Pushes on the axle.] I don’t... Oh. That’s like the slightest bit.</p>
00:37:33 -38:34	<p>Josh: Yeah, well, better none than some. Break it loose. [He screams in mock agony as Emily loosens the locknut. Then Josh readjusts the hub.] “OK. Don’t kill it. Kill it, kill it, kill it. Kill it, kill it, kill it. Lock it down all the way as hard as you can.</p> <p>Emily wrenches the locknut tight. She grabs the wheel with her left arm</p>

	<p>and puts her body into wrenching with her right arm while J is coaxing her.</p> <p>Josh: “Harder, harder, harder. Don’t kill me. Don’t kill me. You got it.”</p> <p>Emily laughs. She feels the adjustment again and nods affirmatively. Josh feels the axle carefully for several seconds.</p>
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At the beginning of the above excerpt, Josh has taken over the hub adjustment task to minimize time spent on an unexpected problem. Unexpected problems appear frequently in the context of bicycle repair work on old, used, recycled bicycles that are more likely to have been improperly repaired by a backyard mechanic or an inexperienced end-user. Normally unexpected problems provide opportunities for learning both the skills necessary to address problems spontaneously—a key attribute for mechanics who work on older bikes—and an unplanned curriculum procedure that may or may not typically appear in combination with the planned procedure. In this case Josh makes a good decision to avoid a detour and quickly solve the minor problem himself in order to sustain the flow of the learning exploration with Emily. Even though Emily appears to be a quick learner, Josh decides not to dwell on this side issue. As will be shown now, Josh has in mind other key concepts that he wants Emily to focus on.

At time 36:30, Josh finishes readjusting the hub cones himself. He tests the adjustment by feel and declares that it is not going to be possible to get a perfect adjustment, i.e. not too tight (rough feel when turning) and not too loose (play). He then asks Emily to test for play. Emily appears to know what to do since she grabs the axle and gently shakes it. Josh, however, judges by the gentleness of her shaking that she does not really understand what “play” means since she is not shaking the axle vigorously enough.

In this case, Emily’s incomplete understanding is a matter of degree rather than quality. Her conception of “play” in a hub, based on the relatively few hubs she has tested is that the axle visibly shakes and rattles inside the hub indicating that the scale of the gap between bearings and races is in millimeters, not tens of microns. As Josh insistently challenges her on her claim that there is play, the resolve in Emily’s voice diminishes. She finally asks for clarification of the term “play”. Josh explains verbally and demonstrates physically how he shakes the axle to test for play. When she finally feels the play that Josh alone has implied was there, she understands that even an almost undetectably small amount of play can be significant. As Josh explains at time 37:52, play in any degree is significant enough that when circumstances prevent an exact adjustment without tightness or play as happened in this case, it is better to err on the side of being a little too tight. At the very end of this work episode in the excerpt below, when Emily gets program director Tori to approve the repair, Tori confirms that notion.

What is notable in this episode is the balance between conceptual problem solving and embodied, perceptual, possibly even non-conceptual problem solving. There is a conceptual, mechanical explanation to the principle that cone adjustments should err on the side of tightness. The idea is that play in a bearing joint hastens wear of both the bearings and races because it increases the impact and stress of road shock. A tiny amount of overtightness is preferable because not only is road shock kept at bay but also, through normal forces of wear, the tightness will eventually dissipate. There are so many factors to weigh that this is one of the ongoing debates in the professional bicycle mechanics community of practice at large. Beginning students like Emily and even an advanced apprentice like Josh are spared the minutiae of this debate. At

the beginning levels of participation in a community of practice, “scientific” principles are often deferred until a later stage of participation.

The guiding principle behind this “limited knowledge” practice is *appropriate knowledge*. The principle of *appropriate knowledge* or *appropriate participation* suggests that the resource constraints of a work situation make it more efficient for workers to develop just enough necessary competence. This may conflict culturally with ideals of excellence, especially intellectual excellence. But such a constriction of the degree of conceptual knowledge to be mastered also operates under the principle of allowing competence to evolve, to unfold situationally rather than the little questioned more-is-better principle that guides the schooling model of learning.

One other aspect of Emily and Josh’s interaction deserves note. Josh has an especially dramatic style of mentoring, particularly in his instructions for physical actions: “kill it, kill it” and “don’t kill me.” His style makes for a dynamic and often entertaining for both Emily, the student, and myself in my role of general assistant.

Below, Josh wraps up the hub cone adjustment episode with Emily before he migrates to another work group and leaves Emily to work independently for a few minutes. The final step of having Emily final check the work with Tori underscores a key aspect of the representational infrastructure in place at Cascade. Work checking is a commonplace practice in production industries and service industries but goes through some odd transformations in learning enterprises.

00:38:35 -39:27	<p>Josh: OK. It doesn’t look like the axle’s bent... [still twirling the axle] But, because of the way it’s behaving, I’m gonna say it’s a teenie bit bent. It’s just a teenie bit tight, so I’m gonna see if I can get this to work this time without killing it.</p> <p>He readjusts the cones.</p>
00:39:28 -39:49	<p>Josh: Tell me what you think. Is there play? Emily: [Feels carefully.] No.</p>
00:39:50 -40:59	<p>Josh: It’s still a little bit grindy, but go tell Tori the axle’s a tiny bit bent and have her check it.</p> <p>Camera pans to E waiting to speak with Tori who is sitting at the front of the classroom. Emily hands Tori the wheel. Tori feels the axle.</p> <p>Tori: OK, so how does it feel? Pretty well? There’s a little bit of a catch. Does it feel like the kind of thing that’s going to destroy the inside of your hub? Emily: No. Tori: No. So what are we gonna do? Emily: Leave it alone. Tori: Yeah. [returns wheel to Emily].</p>

6.5 Discussion

The cases in this chapter have provided numerous perspectives on the experience of participating in an exploratory bicycle shop. The six students who repaired tires in a standard

task exercise showed that even in such a simple activity, different degrees of expertise are discernable according to degrees of difficulty experienced by the students. Two of the four older students, Carl (Cascade) and Colin (Heartland) encountered no difficulties and, moreover, demonstrated an understanding of tire repair beyond the basic procedural knowledge as indicated by two brief checks they added for valve straightness and tire seating. These two quality control checks are often not considered when an instructor assesses a beginning student's work, since the most important criteria for tire repair are that the tire does not lose air, and the wheel is properly aligned when reinstalled. But experienced mechanics understand how consequential mistakes in valve straightness or tire seating can be, even if those consequences occur rarely. These two extra quality assurance measures thus serve as reliable signs of advanced understanding and professionalism. They accurately indicate a more central degree of participation in the bike repair community of practice.

Of the other two older students in the tire repair activity, Debra (Cascade) illustrated how age and intellectual maturity do not necessarily compensate for practical experience. The simple appearance of a rubber rim strip tripped up Debra for a couple minutes because, in her limited experience, she had never noticed such a part of the wheel assembly. The other older student, Marcus (Sierra), however, seemed to contradict the "expertise follows experience" trend. Marcus is a senior apprentice at Sierra who had mastered one of the more conceptually complex procedures, wheel truing, in addition to other challenging procedures. Yet he encountered difficulty with simple tire repair, not just in the "test environment" of the standard task exercise but also in the course of naturalistic shop activities.

The case of Marcus brought to light the problem, shared with several other study participants, of test anxiety negatively skewing assessment results. But Marcus's problem with tire repair extended to non-test instances also. He paradoxically exhibited a mental block against remembering the cardinal "one-side-on" rule of tire installation when he seemed to have no trouble remembering a complex set of rules, procedures, and mechanical concepts related to wheel truing and many other tasks. Or, is the "Marcus paradox" attributable to something other than a mental block?

Regardless of the source, Marcus's occasional problems with tire repair did not stop the Sierra staff from hiring Marcus as a paid intern. In that respect, Marcus has advanced further toward the center of Sierra's bicycle repair community of practice. What does that advancement say, however, about what Marcus has learned or how the Sierra staff has assessed Marcus's learning about bicycle repair? Furthermore, why does Marcus still have trouble fixing tires? An explanation is needed for this logical discontinuity between Marcus's strong skills for some advanced procedures and lack of skills for certain basic procedures.

Solving the Hub Adjustment Problem

To further explore the "Marcus paradox" and other learning problems that surfaced in the "standard task" exercise, I took a detailed look at how various students solved hub adjustment problems, either individually or in work-group pairs. The large body of ethnographic videos collected from the three study sites made it possible both to study students' experiences in depth and to compare their experiences across individuals and across study sites.

In the first work-group examined, Cascade apprentice 15-year old Josh guided 10-year old Emily through the procedure. The crux of understanding hub adjustment lies in the ability to feel the fit of the ball bearings sandwiched between the two bearing races with the same perceptual acuity experienced by a professional mechanic. Emily understood the concept of

“play”, that is, a gap between bearings and races that allows the axle to wiggle. However, her understanding was limited by her small number of experiences with hub adjustment. She had deduced from her experience that axle play was not significant unless it visibly wiggled. Josh taught her that even the smallest amount of barely perceptible play was significant and undesirable.

Learning Paradoxes and Questions about Assessment

Getting a close look at the processes by which Emily advanced her conceptual understanding of hub adjustment raised several questions in the context of trying to resolve Marcus’s learning paradox.

1. Emily appeared to advance her understanding of hub function and adjustment technique through a shared perceptual experience with Josh of “feeling” the balance between too much play and too much roughness in axle motion. How stable is this understanding? How well would it stand the test of time?
2. What other learning processes could be observed if Emily were videotaped repeating the hub adjustment procedure?
3. What result would a formal assessment of Emily’s hub adjusting ability produce?

To answer these questions I met with Emily again for a follow-up interview and work session about three months after her initial hub adjustment work session was videotaped. Debra also participated in that work session on hub adjustment. Because Emily had more experience with hub adjustment, she served as the senior member of the work team even though Debra was five years older. During the work session both girls demonstrated a stable knowledge of the procedure of hub adjustment. Both girls repeated multiple times, both verbally and physically, the procedural rule “Tighten the cone by hand, then back it off a quarter turn before tightening the locknut.” However, neither one could solve the mechanical problem of fine tuning the adjustment to the point of no play and no roughness.

Their mechanical conundrum did not seem to result from insufficient conceptual understanding of the mechanical design and geometry of the hub assembly because in the follow-up interview both girls described in remarkable detail how one full turn of the hub cone moved it laterally the distance between two axle threads. What their working image of the hub system seemed to lack was an understanding of how the ideal system of a threaded cone moving along the axis of the threaded axle was subject to real world problems. In this case, the problem resulted from an imperfect motion of the cone along the axle due to an imperfection in the threads or simply dirty threads. Such a simple problem rendered their standard procedure ineffective and derailed their attempts to resolve the problem. Once I introduced to them a technique to work around the problem by incrementally adjusting the hub by as little as five degrees (resulting in about a 15 micron lateral shift) they quickly finished the procedure without further difficulty.

6.6 Problem Arc

One conclusion to draw from this episode is that ways of seeing (or haptic feeling) and procedural knowledge can both accurately index conceptual understanding, but they fall short in indexing certain aspects of competence including problem solving. It is important for a learner to be able to distinguish the appropriateness of abstract knowing versus concrete knowing. In a bike shop or other manual skills environment, abstract forms of knowing such as the kind illustrated

by the academically precocious student who was looking for a generalized understanding of brake cable function, can be inappropriate. The appropriate way to understand brake function in that case was to harness the intelligence embedded in the object itself that was within arm's reach. This example of *appropriate knowing* can be extrapolated to more general learning situations including conventional school learning. Learners should, as a rule, learn to take full advantage of available resources in their immediate environment, both social and physical. That kind of learning will occur as the prevailing lock on academic (i.e. textbook) learning gives way increasingly to the more phenomenological, broader scope of learning advocated by Lave (1988) and Roth (2003) among many others.

- **Problem Arc 7.** This final problem arc summarizes the last steps in the data analysis. The two study branches identified in the last chapter generated several analytic episodes in this chapter. However, only two issues were pursued to the ultimate level of analysis: a) Marcus's development of visual and haptic competence in the wheel truing task and b) Emily's development of a notable level of problem solving expertise and also some peer instruction skills.

A noteworthy relationship between formal and informal learning emerges in the Emily-Debra episode. The formal-informal dichotomy is closely related to the scientific-everyday knowledge dualism and also the abstract-practical dichotomy. One way to interpret this episode is that the two girls were conditioned by their school-based problem solving practices to follow heuristic rules in executing the standard hub adjustment procedure as they had learned it. This pattern of problem solving behavior is deeply woven into virtually all school-learning cultures.

After repeated tries, however, the girls discovered that the rule specifying the student to "tighten the cone by hand, then back it off a quarter turn" would not produce a satisfactory result. Even with a couple of insightful variations on technique suggested by Emily, the hub resisted adjustment within standard tolerances. Only when the girls made a slight variation in technique based on one of my comments did they finally achieve a properly adjusted hub.

Jordanova (1994) remarked about the proximity of scientific and everyday thinking. This dialectic arises too in the dialogue with the dairy loader in Scribner (1984) quoted in Chapter 1. That dairy loader, though, adds a strong visual cognition element that prompts me to compare his experience to that of Emily and Debra in their hub adjustment episode. The same formal-informal reasoning dialectic is at work in the Emily-Debra exchange because both girls try to return to the rule-based solution path and they only make progress when they revert, after many trials, to the informal strategy path.

Chapter 7: Conclusion and Implications for Teaching and Learning

This inquiry set out to accomplish some ambitious goals. VA is, in many respects, antithetical to the “scientific” standard for research. VA rejects most of the research assumptions made by the scientific positivist tradition—including knowledge production claims, objectivity claims, evidence standards, and other aspects of the “master narrative” of the dominant culture—that shaped anthropological scholarship for most of the 20th century. VA not only rejects certain logical fallacies in scientific standards but also repudiates the manner in which that tradition projects its own values, logics, and narratives onto other cultures as its method for “understanding” those cultures. VA was the response to that tradition and its prevailing scholarly practices. To effect a repudiation of canonical practices and the values they perpetuate, VA tries to disrupt the logical pathways that tend to always lead back to the habitual practices.

What began as an inquiry into the nature of learning and problem solving in the exploratory bicycle shop evolved into a methodological experiment that explored the boundaries of cognitive research and applied anthropology. The anthropological stance, as interpreted through VA, observes a culture to enhance rather than observing to explain to a faceless scholarly ideal. The psychological stance is perpetually explanatory in nature. It may use observational techniques to enhance the accuracy of the explanation, but the end goal is explanation in the service of scholarship. VA questions the consequences of “objective, valueless” explanation. It also questions the justification for “knowledge production.” VA responds to the otherizing practices of cultural anthropology, a distancing of other cultures to that of the investigator in the name of understanding of other cultures. VA’s response is to embrace the other culture rather than analyze it. To raise the voice of the other culture to make it heard more widely and strongly.

The study began with two main objectives. One was to examine the nature of learning in the exploratory bicycle shop, particularly the relationship between the shop setting and apprentices’ learning processes. The second was to test drive social practice theory as an explanatory framework for the workplace learning in the exploratory bike shop using primarily VA methods. In other words, does the social practice model for learning and thinking make sense under conditions of visual analysis. Does it appear to provide a valid model of thinking processes in the context used for this research? The two study objectives are closely interdependent. The answer to the nature of exploratory bike shop learning in the first objective provides the basis for answering the second objective about the social practice model.

Given the conflictual relationship between VA and the tradition of cognitivist and other science-based research, how does one even begin to approach the first research question about the nature of learning in the exploratory bike shop, from a VA stance? I began by selectively appropriating the most valuable aspects of VA’s critical stance against the positivistic scientific method and tempering some of the radical positions like the prohibition against explanation. My strategy was based on the assumption that an explanatory framework could be humanized and stripped of many of its most “otherizing” biases without a wholesale rejection of the explanatory purpose.

7.1 VA Methodology Alters the Framework for Findings

In the realm of VA methodology answers do not emerge on the basis of empirical or statistical probabilities. Instead, VA investigators draw inferences from qualitative data often collected from a small sample of cases rather than a pool of data points. Findings, therefore, take

the form of observations organized into a narrative ethnography or a collection of descriptive pictures. Pictures, both verbal and image-based, can function either as data to be analyzed or as representation of the culture being studied. In sharp contrast to most types of data analysis, VA analyzes data only after the data has been collected and organized in a whole picture of the focal phenomenon or a collection of related pictures.

A study conducted strictly according to VA methodology would not try to analyze the data beyond the level of cultural representation. Representation of a culture is the only outcome of research acceptable to visual anthropologists because it does not claim to have “found” knowledge produced by the focal culture or to “produce” knowledge about a culture’s true nature. Instead the VA practitioner is content to reflect on and represent an observed culture, a passive type of inquiry that leaves the job of interpreting a culture to the reader of the research.

This inquiry model relies as much on description and representation of cultural practices as evidentiary claims, if not moreso. The most adamant visual anthropologists forsake empirical evidence, relying entirely on description and/or representation. Because this study takes the more moderate course of bridging situated cognition research with findings from more traditional research, it attempts to redefine “scientific” standards of evidence rather than discard them. This study found that, like many visual anthropologists (e.g. MacDougall and Pasqualino) have found, concerted efforts to decrease researcher bias and increase naturalism in the informants’ practices produced a quality of researcher-informant interaction that differed noticeably from that of more traditional cognitive research methods. The contrast in interactions produced by the two types of methods emerged clearly in this study since both types were included in the protocol and were directly observable. For example, student responses during the formal interview phase were often accompanied by a guarded posture and other body language that suggested an oppositional stance toward the researcher. In contrast, during the more naturalistic bike repair activity phase in the shop environment, the same students were visibly more open in the body language, and the nature of their verbal responses likewise reflected a more trusting and cooperative attitude.

Further evidence of the salutary effect of naturalistic setting on informant attitude emerges over periods of months. Certainly some improvement in researcher-informant relations can be attributed to increased familiarity between the two parties. However, in the case of Mario at the Sierra shop, for example, I already had a year-long relationship with him, and when I started to collect video data, the quality of the relationship sank. Mario became evasive, more confrontational, and uncooperative. Mario’s keen perceptiveness rendered ineffective my efforts to approach him more obliquely by working first with other students and then reapproaching Mario in the hope that he would adopt the other students’ cooperative attitude. Only after I abandoned all efforts to videotape or do an audio interview with Mario for over three months did he finally soften his resistance to cooperating with the research.

Details about students’ attitudes, beliefs, and motives emerge readily in an ethnographic account. However, their “truth” value, or accuracy is not certified by scientific method. Rather, the validity of ethnographic claims lies more in the extent to which the researcher has accounted for his own unavoidable biases, both by identifying them as limitations to the study and by minimizing them through the careful design of research method.

Customarily in a mixed methods research design, the results of an ethnographic study phase are used to pinpoint research questions for further inquiry using quantitative methods. VA alters this scheme by dismissing the validity of quantitative verification. Instead, VA uses the ethnographic “findings” to guide further research or to otherwise aid the culture being studied as part of an applied anthropology or action research agenda. This study does include an action

research agenda, described below under “Implications of the Research.” But in keeping with a more traditional research design, the ethnography was also used to guide the controlled conditions quasi-experimental study phase.

The ethnography focused on case studies of three exploratory bicycle shops, but five years of field notes and participant observation in other shops including Boston, New York, Philadelphia, Eugene augmented the data and was used to corroborate findings in the three focal sites. Key findings from the participant observation sessions focused on issues of how student learning appeared to be enhanced in a study population that included a high percentage of students who were failing academically. Of the four specific focus issues that emerged, the most compelling was the issue of peer tutoring and cooperative problem solving. One advantage of using this issue to define subsequent research questions for the quasi-experimental phase is that it subsumed the other three issues to some degree. Within the context of cooperative learning, the next study phase could also examine questions related to a) master-apprentice interaction, b) visual grammar, and c) adult assessment of student learning.

Two “intervention” activities took place in Phase II based on a comparison across students of two standard tasks: a) tire repair and b) hub cone adjustment. The hub cone activity in particular highlighted several of the issues that emerged from Phase I. First, it consisted of a peer instruction situation between two girls, Emily and Debra. That situation evolved into a more equal power relationship of cooperative problem solving in which each girl contributed roughly equivalent degrees of competence and problem solving insight. Because the two girls had difficulty solving a technical problem, the adult instructor intervened after 30 minutes to help resolve the difficulty. Finally, the issue brought to light questions about assessment of competence. In effect, all four aspects brought forward from the Phase I ethnography could be examined in this one activity.

Because this study combined VA and grounded theory methodologies, I used both approaches to analyzing the Phase II data. The more traditional grounded theory analysis yielded the conclusion that a key indicator to competence in problem solving is the student’s ability to know when to invoke abstract knowing or concrete knowing. Each type of type has its place in practical problem solving. Abstract knowing consists of factual, generalizable information or concepts. Concrete knowing involves direct, perception-oriented, contextualized, local understanding of a situation. Competence in bicycle repair tended to correlate positively with the ability to judge which type of knowing is appropriate in each situation.

This finding resulted from the compilation of findings at each step in the Phase II chain of inquiry steps. Visual analysis of videotaped work session accounted for most of the interpretive work used to reach that conclusion. What part of the visual analysis can be labeled VA analysis is not easy determine. Rather than claiming that VA analysis is responsible for specific parts of an interpretation of data, it is more appropriate to claim that VA principles guided the overall interpretation.

7.2 Implications of the Research

The goal of the first chapter was to explain the need for the study and to establish a rationale for using the social practice theoretical framework and visual anthropology (VA) methodology. While apprentice learning in a manual trade had been studied from a social practice perspective before, most notably in Lave (1988) and Lave and Wenger (1991), those studies did not extensively examine the ways in which cognition and working intelligence are distributed beyond local situational factors into the physical material of the setting. Also, the

level of problem solving that Lave (1988) studied was at a simple, everyday household level. Studying the phenomenology of household arithmetic problem solving is an effective approach to establishing a social practice model of knowing and thinking, but it does not address issues of more complex conceptual learning. On the other hand, work studies by Hall (2001) and Hall et al (2007) examined occupational activities at intricate levels of problem solving. This study cut a middle path between these two extremes and it addressed equity problems directly by studying informants of school age.

Like much of the existing research on workplace learning this study collected extensive video footage of informants in problem solving situations. However, VA methods make fundamentally different assumptions about researcher bias, study validity, and accuracy of informant verbal responses. Because VA theory challenges the accuracy of data from traditional verbal protocols in general, it depends on visual methods to circumvent the traditional linguistic analytic methods.

One surprising methodological finding was that the process of writing the dissertation and organizing the format to accommodate the novel VA methodology itself constituted an important part of the research process. Each chapter played a distinctive role in building the overall VA analysis. Even the literature review in Chapter 2, for example, produced “findings” of a sort that were useful in building the continuum of linked problem arcs from chapter to chapter.

Before describing the visual analysis in Chapters 5 and 6, Chapter 3 provided an ethnography of the exploratory bicycle shop both to orient the reader to this unusual setting and to set the stage analytically with a more holistic rather than analytic approach to presenting the results of participant observation in the three focal study sites. The ethnography attempts to convey the range of variation in setting characteristics such as facility, budget, philosophy, community economics and politics, and participant demographics among others.

The ensuing two chapters explained the methodology in detail—actually a combination of VA and grounded theory—and laid out the findings, first in a presentation of the case for visual analysis, and then in a detailed analysis of a comparative task exercise and several selected student cases. As discussed in the previous chapter, the findings demonstrated that perfectly stable procedural knowledge can produce ineffective problem solving ability when idealized procedures are subjected to real world conditions. Also, expert ways of perceiving (i.e. seeing, hearing, or feeling) conditions in a bicycle repair situation can serve as good indicators of competence as Goodwin (1994) demonstrated, but they do not address all aspects of competence. Expert ways of perceiving can reflect effective conceptual understanding without any indication of an apprentice’s problem solving ability.

A common thread that runs through all the cases in this study concerns the problem of assessing an apprentice’s knowledge or competency in performing a task. These findings suggest that an apprentice’s understanding of bicycle mechanics cannot be accurately evaluated based on conventional assessments, even performance tests. In fact, to understand an apprentice’s competence and command of the practice of bicycle mechanics requires understanding the relation between the assessor and the student. Since that ideal situation is not feasible on a large scale, the technological design of education needs to be tweaked to approximate that ideal. The first step toward that objective is to demystify educational processes by framing education as a technology that can be studied through a reverse engineering process to understand how its designers originally created it. Then systematic solutions to problems need to follow based on

accurate assessment of the technological system, its breakdowns and failures being much more instructive for crafting future design improvements than its apparent successes.

Bourdieu (1977) modeled such a systematic approach to improving the scientific rigor of the social sciences in each of his meticulously designed sociological studies. He developed increasingly sophisticated methodologies to maximize internal validity and data reliability. That strategy worked to strengthen the social sciences from within as opposed to the external solution of trying to impose truth standards of the physical and biological sciences. In a like manner this study has sought to improve validity through the *methodological naturalism* of VA and other strategies for reducing the divide between researcher and the human activities being studied.

7.3 Future Research and Development of the Educational Model

The exploratory bicycle shop movement is undergoing a transformation led largely by the kind of political motives that were responsible for starting the movement but which became secondary during the middle years when the movement focused on the educational experiment. The new Richmond Spokes organization described in Chapter 3 seeks to lay a cooperative network infrastructure to help launch cooperative economic development in Richmond and in the many other cities in the U.S. where it is developing philosophical and operational linkages. Richmond Spokes will benefit particularly from the findings of this study that describes in detail how an economically viable learning setting, the commercial bicycle shop, affects apprentices' attitudes and shapes thinking practices. Among the more intriguing aspects that Richmond Spokes adds to the way exploratory bike shops will be managed in the future include a built-in student attitude sampling system that will provide immediate quantitative and qualitative survey data to funding partners. Another innovation will involve the way in which student work in the educational setting will be measured quantitatively as "units of service" which can be effectively marketed to meet the priorities of potential funders. In some respects this trend toward generation of "hard" quantitative data, and tweaking of the organization thrust to satisfy corporate funding objectives seems like a step away from the high idealism of the VA ethic. Future research can compare the two approaches to determine which has better short-term and long-term benefits for the youth that all stakeholders claim to serve.

References

- Anthony, S.B. (1896). *New York World* (Speech delivered on Feb. 2, 1896).
- Banks, M. (2001). *Visual methods in social research*. London: Sage.
- Barab, S. & Roth, W-M. (2006). Curriculum-based ecosystems: Supporting knowing from an ecological perspective. *Educational Researcher*, 35, 3-13.
- Bartlett, F (1958). *Thinking*. New York: Basic Books.
- Bateson, G. (1972). *Steps to an ecology of mind*. New York: Ballantine.
- Becker, HS (1998). Categories and comparisons: How we find meaning in photographs. *Visual Anthropology Review*, 14, 3-10.
- Bikes Not Bombs (1992). *Spoke 'N Word* (article in organizational newsletter).
- Bourdieu, P. (1977). *Outline of a theory of practice*. Cambridge, England: Cambridge University Press.
- Carraher, D.W. & Schliemann, A.D. (2002). Is everyday mathematics truly relevant to mathematics education? In M. E. Brenner and J. N. Moschkovich (Eds.). *Everyday and academic mathematics in the classroom*. Reston, VA, National Council of Teachers of Mathematics.
- Carraher, T.N., Carraher, D.W. & Schliemann, A.D. (1985). Mathematics in the streets and in schools. *British Journal of Developmental Psychology* 3(1): 21-29.
- Cobb, P. (1986). Contexts, goals, beliefs, and learning mathematics. *For the Learning of Mathematics*, 6, 2-9.
- Cobb, P. (2000). From representations to symbolizing: Introductory comments on semiotics and mathematical learning. In P. Cobb, E. Yackel, & K. McClain (Eds.) *Symbolizing and communicating in mathematics classrooms: Perspectives on discourse, tools, and instructional design*. Mahwah, NJ: Lawrence Erlbaum.
- Cobb, P. (2002). Reasoning with tools and inscriptions. *Journal of the Learning Sciences*, 11, 187-215.
- Cobb, P. and Hodge, L. (2002). A relational perspective on issues of cultural diversity and equity as they play out in the mathematics classroom. *Mathematical Thinking and Learning* 4(2&3): 249-284.
- Cobb, P., Stephan, M., et al. (2001). Participating in classroom mathematical practices. *Journal of the Learning Sciences* 10(1-2): 113-163.
- Cole, M. (1996). *Cultural psychology: A once and future discipline*. Belknap/Harvard University Press.
- Cole, M. (1997). *Culture and cognitive science*. Paper presented at the May 15, 1997 meeting of the Cognitive Science Program, University of California, Santa Barbara.
- Collins, A. (2004). Design research: Theoretical and methodological issues. *Journal of the Learning Sciences*, 13, 15-42.
- Dant, T (2004). Recording the "habitus". In C. Pole (Ed.) *Seeing is believing? Approaches to visual research studies in qualitative methodology*, (Volume 7, pp. 41-60). Amsterdam: Elsevier.
- Delpit, L. (1996). Skills and other dilemmas of a progressive black educator. *American Educator*, 20(Fall): 11-20.
- Dewey, J. (1916). *Democracy and education*. New York: Macmillan.

- Engestrom, Y (1999). Activity theory and individual and social transformation. In Y. Engestrom, R. Miettinen & R. Punamaki (Eds.) *Perspectives on activity theory*. Cambridge, UK: Cambridge University Press.
- Engle, R. (2006). Framing interactions to foster generative learning: A situative explanation of transfer in a community of learners classroom. *Journal of the Learning Sciences*, 15, 451-498.
- Erickson, F (2006). Definition and analysis of data from videotape: Some research procedures and their rationales. In JL Green, G Camilli & PB Elmore, *Handbook of complementary methods in educational research*. Washington DC: AERA and Mahwah, NJ: Lawrence Erlbaum and Associates.
- Ericsson, K.A. & Simon, H.A. (1993). *Protocol analysis: Verbal reports as data, Revised edition*. Cambridge, MA: MIT Press.
- Foucault, M (1976). *Society must be defended*. Lecture.
- Gagnon, G. & Collay, M. (2006). *Constructivist learning design: Key questions for teaching to standards*. Thousand Oaks, CA: Corwin.
- Gardner, H. (1985). *The mind's new science*. New York: Basic Books.
- Glaser, B.G. & Strauss, A.L. (1967). *The discovery of grounded theory: Strategies for qualitative research*. Chicago: Aldine.
- Goodwin, C (1994). Professional vision. *American Anthropologist*, 96(3); 606-633.
- Grasseni, C (2004). Video and ethnographic knowledge. In A. Afonso, S. Pink & L. Kurti (Eds.) *Working images*. London: Routledge.
- Grasseni, C (2007). Good looking: Learning to be a cattle breeder. In C. Grasseni (Ed.) *Skilled visions: Between apprenticeship and standards*. Learning Fields, Vol. 6. NY: Berghahn Books.
- Greeno, J.G. (1998). The situativity of knowing, learning, and research. *American Psychologist*, 53, 5-36.
- Hall, R. (1996). Representation as shared activity: Situated cognition and Dewey's cartography of experience. *Journal of the Learning Sciences*, 5(3), 209-238.
- Hall, R. (2001). Schedules of practical work for the analysis of case studies of learning and development. *Journal of the Learning Sciences*, 10(1), 203-222.
- Hall, R & Greeno, J (2008). Conceptual learning. In T.L. Good (Ed.) *21st century education: a reference handbook*. Los Angeles: Sage.
- Hall, R., Wright, K., & Wieckert, K. (2007). Interactive and historical processes of distributing statistical concepts through work organization. *Mind, Culture, and Activity*, 14, 103-127.
- Hanks, W. (1993). Foreword. In J. Lave & E. Wenger, *Situated learning: Legitimate peripheral participation*. New York: Cambridge University Press.
- Hutchins, E. (1993). Learning to navigate. In S. Chaiklin and J. Lave (Eds.) *Understanding practice: perspectives on activity and context*. Cambridge: Cambridge University Press.
- Hutchins, E (1995). *Cognition in the wild*. Cambridge, MA: MIT Press.
- Jordanova, L (1994). The hand. In L Taylor *Visualizing theory: Selected essays from V.A.R. 1990-1994*. NY: Routledge.
- Jurow, AS; Hall, R; & Ma, JY (2008). Expanding the disciplinary expertise of a middle school mathematics classroom: Recontextualizing student models in conversations with visiting specialists. *Journal of the Learning Sciences*, 17(3): 338-380.

- Kinnevy, SC; Healey, BP; et al (1999). Bicycle WORKS: Task-centered group work with high-risk youth. *Social Work with Groups: A Journal of Community and Clinical Practice*, 22(1), 33-48.
- Kliebard, H.M. (2004). *The struggle for the American curriculum 1893-1958*. New York: Routledge Falmer.
- Lave, J. (1977). Cognitive consequences of traditional apprenticeship training in West Africa. *Anthropology and Education Quarterly*, 8, 177-180.
- Lave, J (1988). *Cognition in practice: Mind, mathematics and culture in everyday life*. New York, NY: Cambridge University Press.
- Lave, J. (1993). The practice of learning. In S. Chaiklin and J. Lave (Eds.) *Understanding practice: perspectives on activity and context*. Cambridge: Cambridge U Press.
- Lave, J. & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. New York: Cambridge University Press.
- Lindwall, O & Lymer, G (2008). The dark matter of lab work: Illuminating the negotiation of disciplined perception in mechanics. *Journal of the Learning Sciences*, 17: 180-224.
- MacDougall, D (1998). Transcultural cinema. In L Taylor (Ed.) *Transcultural cinema*. Princeton: Princeton University Press.
- Martin, D.B. (2000). *Mathematics success and failure among African-American youth*. Mahwah, NJ: Lawrence Erlbaum.
- Merleau-Ponty, M. (1962). *Phenomenology of perception*. London: Routledge.
- Moses, R. & Cobb, C. (2001). *Radical equations: Math literacy and civil rights*. Boston: Beacon Press.
- National Council of Teachers of Mathematics (1989). *Curriculum and evaluation standards for school mathematics*. Reston, VA: National Council of Teachers of Mathematics.
- National Council of Teachers of Mathematics (2000). *Principles and standards for school mathematics*. Reston, VA: National Council of Teachers of Mathematics.
- Nichols, B (1991). The ethnographer's tale. *Visual Anthropology Review*, 7(2), 31-47.
- Ogbu, J. (1992). Understanding cultural diversity and learning. *Educational Researcher*, 21, 5-14.
- Orr, J. (1996). *Talking about machines: An ethnography of a modern job*. Ithaca, NY: Cornell University Press.
- Pasqualino, C (2007). The place of video in anthropology. *Visual Anthropology Review*, 23(1): 84-91.
- Pink, S (2004). Situating visual research. In A Afonso, S Pink, & L Kurti (Eds.) *Working images*. London: Routledge.
- Pink, S (2006). *The future of visual anthropology: Engaging the senses*. New York: Routledge.
- Resnick, L (1987). *Education and learning to think*. Washington, DC: National Academy Press.
- Roth, W-M (2003). *Toward an anthropology of graphing: Semiotic and activity-theoretic perspectives*. Dordrecht: Kluwer.
- Roth, W-M & Lee, Y-J (2007). "Vygotsky's neglected legacy": Cultural-historical activity theory. *Review of Educational Research*, 77(2): 186-232.
- Saxe, G. (1990). *Culture and cognitive development: Studies in mathematical understanding*. Hillsdale, NJ, Lawrence Erlbaum.
- Scribner, S (1984). Studying working intelligence. In B Rogoff & J Lave (Eds.) *Everyday cognition: Development in social context*. Cambridge, MA: Harvard University Press.

- Scribner, S. & Cole, M. (1973). Cognitive consequences of formal and informal education. *Science*, 182(4012), 553-559.
- Secretary's Commission on Achieving Necessary Skills (SCANS) (1991). *What work requires of schools: A SCANS report for America 2000*. Washington, DC: U.S. Department of Labor.
- Sfard, A. (2002). The interplay of intimations and implementations: Generating new discourse with new symbolic tools. *Journal of the Learning Sciences* 11(2-3): 319-357.
- Sfard, A. (2008). *Thinking as communicating*. New York, Cambridge University Press.
- Sfard, A & Lavie, I (2005). Why cannot children see as the same what grownups cannot see as different?—Early numerical thinking revisited. *Cognition and Instruction*, 23(2): 237-309.
- Stevens, R and Hall R (1998). Disciplined perception: Learning to see in technoscience. In M Lampert and M Blunk (Eds.) *Talking mathematics in school: Studies of teaching and learning*. (pp. 107-149). Cambridge, England: Cambridge University Press.
- Suchman, L.A. (1987). *Plans and situated actions*. Cambridge, UK: Cambridge University Press.
- vonGlaserfeld, E. (1995). A constructivist approach to teaching. In L.P. Steffe & J. Gale (Eds.) *Constructivism in education*. Hillsdale, NJ: Lawrence Erlbaum.
- Vygotsky, LS (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.
- Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. Cambridge, UK: Cambridge University Press.
- Willis, P. (1981). Cultural production is different from cultural reproduction is different from social reproduction is different from reproduction. *Interchange*, 12, 48-67.
- Wynn, JR (1996). *Bike shops, tumbling teams, and other primary supports: Opportunities for learning and civic life*. Chicago, IL: Chapin Hall Center for Children, University of Chicago. [also ERIC (microform). Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement]
- Youth Bicycle Education Network (1997). An interview with Milbrey McLaughlin. *Re:Cycle*, 2, 6-8.

Appendices

Appendix A: Instructional and Interview Protocols

Introduction

Novel study setting. Amid the large body of research on how middle-school-age students do problem solving, the current study stands apart in the way it examines early adolescent thinking in an actual work setting: a commercial bicycle shop. Work-based studies have for decades comprised one of the most active sectors of learning research due to widespread recognition among researchers of the situated and distributed nature of knowing, thinking, and learning. In the case of mathematics, for example, school teaches students abstract, generalized forms of knowing whereas work settings engage learners in localized, often more concrete, ways of knowing (see Table 1 below) that are embedded in a rich ecology of affective, social, cultural, historical, and physical relations and interactions. Yet, in the U.S., work studies have been limited by law to adult populations, leaving learning sciences and cognitive development studies of early adolescents at work in non-school settings virtually unexamined.

The recent phenomenon of the educational bike shop—a hybrid learning-working setting in which apprentices as young as age 14 earn wages and those even younger can exchange sweat equity for bikes or bike parts—enables the formal study of U.S. middle school students in a true work environment, not just a simulation. Until very recently, research on work-based learning in this age range had to be conducted either in a simulated work setting (e.g. Greeno & MMAP, 1998; Jurow et al, 2008) or in a developing country (Carraher & Schliemann, 1985; Saxe, 1991) where child labor laws are not so stringent as in the U.S. A growing number of work-based learning opportunities for young adolescents in the U.S., including gardening and culinary activities, career academies, and internship/apprenticeships, has improved the potential for research on middle-schoolers in this context. Nevertheless, this is still new territory for cognitive development and learning research.

Table 1. Epistemological variants in the discipline of mathematics

	Informal	\leftrightarrow	Formal
Local	folk math (Luria, 1976)	Intuitive tutee math, Stevens & Hall (1998)	engineering and other practical & applied math
\updownarrow	visual quantification—dairy loader (Scribner, 1985); tailor apprentice (Lave, 1991); micronesian navigator (Hutchins)	Coordinate geometry tutee (late), Stevens & Hall (1998); workplace math	School math—didactic
General	street vendor math (Carraher & Schliemann, 1985) grocery shopper, blacksmith, visual problem solving (Keller & Keller, 2002)	School math—reinvented (Kamii, 2000);	Professional mathematics

Comparative and visual anthropology methodologies. In addition to using a novel activity setting, the present study takes advantage of two powerful research methodologies. One is a comparative ethnographic methodology used by Saxe & Esmonde (2005) and Zambrano & Greenfield (2004) for studying how cultural practices develop in societies undergoing radical economic transition. While this method was originally devised for use in developing countries, I have appropriated it for studying analogous cultures-in-transition in urban U.S. communities. It seems to be a valid method for revealing the dynamics of cultural change both in real-time detail and on a broader historical time scale.

The crux of the method is to examine changes in the changing cultures' use of linguistic and mathematical tools in problem solving activities over time. While the time span of the present study is less than a year, I nevertheless will look for small changes in students' discursive practices over several months that would warrant more extended studies in the future.

Another ethnography-based methodology employed in this study is visual anthropology, which captures visual aspects of students' discursive practices and analyzes the relations between images of competency and the students' thinking and problem solving processes. Visual anthropology thus achieves a highly emic analytic perspective for examining learning and development, which is enhanced through the naturalistic probing implied in the protocols below.

Note on inquiry strategy and purpose. The overarching purpose of this study is to uncover and analyze data that will ultimately help redirect the design of middle school learning environments and pedagogies. Such improved learning design would ideally give students tools for learning and adapting to the rapidly changing demands of the technological work place. These tools are expected to take the shape of general competencies and functional concepts such as "systems" and "process" as well as conceptual tools such as understanding that effective problem solving requires creative problem framing, solution checking, and social implementation, not just production of a single "correct" answer. No matter how well a learning institution understands these goals, however, its effectiveness will depend on its ability to reach students in their cultural frames of mind, whether that means reaching across ethnic, age, or developmental boundaries. Examining how thinking and learning occur in a manual skills work environment is expected to reveal useful findings about how to bridge those cultural differences.

In the following sections I provide first a restatement of my research questions which have been revised to reflect developments in the study design since the dissertation proposal meeting. The section after that provides sample instructional activities that I will draw from in giving students standardized problem solving tasks to be videotaped. Finally, I provide an initial outline of the interview protocol.

Revised Research Questions

1. What is the relationship between thinking and acting in the context of problem solving?
 - a. Specifically, how do physical actions affect the choosing of problem solving tools and discursive practices?
 - b. [Meta-analytic] How should we interpret physical-mental actions in terms of discourse?

- c. In the iterative, recursive process of trying, observing, assessing, changing discourse, and trying again, how does the mediating quality of the physical tool affect the general process or any of the subcomponent processes?
2. What kind of discursive practices occur during standardized repair activities?
 - a. Identify, describe, and document the course of discursive change, i.e. what learning has occurred?
3. How is students' understanding of bicycle systems distributed across shop tool artifacts?
 - a. Can students' general tool proficiency, i.e. instrumentalism, be measured?
4. Does the kind of work-based activity in the educational bike shop enhance students' problem solving capacity? Does it develop their repertoire of discursive practices?
 - a. Do students who gravitate toward manual learning generally have trouble navigating abstract thinking?
 - b. How does manual proficiency with a physical tool relate to conceptual proficiency in troubleshooting a bike system breakdown?
 - c. How does the above relationship in turn relate to Pickering's (1995) notion of "conceptual agency" as revisited by Hall and Greeno (2009)?

Instructional Protocol

In the following activities, instruction and assessment are integrated to promote the learning process. Each of the tasks below is designed to help me observe, discuss, and ultimately understand the student's thinking and learning processes. Each task could be implemented in a pre-test/post-test fashion as in a typical learning study. However, because this study is not designed to determine whether or to what degree the student has learned in such a constructivist sense, the emphasis will instead be on shedding light on learning as a cultural discursive process. Evaluating the degree of learning will occur to some degree, but only as a peripheral part of the overall study process, not as the key focus.

For now, at this beginning stage of the study, the plan for implementing these tasks is flexibly defined. I will likely administer Task 1 near the beginning of the data collection process for each student. The other tasks will occur after I have had a chance to refine my research questions and study design at which point a more definite plan for sequencing and scheduling these tasks should emerge. Task 3, the formal mathematics task, will not be appropriate for students who have had severe difficulties with school mathematics even though the problem is presented in a contextualized form. In that case, alternative problems will be provided.

1. **Troubleshooting hidden faults.** Ask student to fix a sluggish cable-actuated brake that has been prepared with faults in two of the three subsystems—brake lever, cable, and brake arm. For example, the faults could be an overtightened caliper arm or weak cantilever spring and a poorly cut cable end. Ask student to explain thinking aloud. Prompt student as necessary to elicit explanations. Student's reasoning should include a) general assessment of all three subsystems and b) a progressive detailed assessment of the components in each subsystem until the fault is located. If student cannot completely fix the brake, remind student about these steps in the troubleshooting process.

2. **Locating the source fault in a compound problem.** Ask student to repair a front wheel that rubs against a front brake pad. Possible sources include misaligned brake, out of true wheel, misaligned wheel, and wheel misalignment due to structural problem in fork or front dropouts. As in all tasks performed for this study, the student should think aloud or else explain each action or decision. Question any actions that are not adequately explained, especially the student's process of locating the source problem. If student starts to fix a part that does not need repair, prompt the student to reassess the source problem.
3. **Reverse sales tax calculation.** Ask student to solve the following problem scenario.

The shop manager tells you that another shop apprentice sold a bike without collecting the local 9.75 percent sales tax. Because the shop must pay the appropriate tax to the state for every bike sale, even if tax was not collected from the customer, the shop will have to figure out what portion of the gross \$179.00 collected from the customer constitutes the tax and what portion will constitute the adjusted net sale price. The manager asks you to make the calculation since he can't figure it out.

Give the student ample opportunity to solve the problem on his or her own. If the student produces an incorrect answer, ask the student how he or she can check the validity of the answer (by applying the tax rate to the adjusted sale price to get the original gross sale price.) If the student has difficulty framing a solution strategy, scaffold the student as necessary to produce a strategy. Start with guess-and-check approach, if necessary, then see if the student is able to progress from there to framing an algebraic equation to define the unknown quantity in more precise terms.

4. **Black Box Imaging Skills Task.** Explain to student how the wedge holds a stem into a fork with a traditional threaded headset design. Then scaffold the student through the procedure of removing the stem. Dialogue with the student will reveal the extent to which the student accurately envisions the hidden wedge mechanism.
5. **Observation Skills Task.** Ask student to assess the condition of a bicycle prepared with several faults including slightly loose hub cones, loose crank arm, improperly replaced chain pin, etc. The objective of this task is to assess the student's observation skills.

Interview Protocol

I will interview students twice, once at the study midpoint and then a final interview at the end. The final interview will consist of many of the same questions in order to provide a comparative perspective over time. But it will also contain new questions that emerge over the course of the study and reflect the evolution of the research questions.

- I. **Questions about student's attitudes toward learning, thinking, and doing manual work.**
 - A. What made you interested in working in an educational bike shop like this?
 - B. What kind of student are you in school?

1. What are your strengths in school? What subjects or activities are your strongest?
 2. What subjects do you find difficult or challenging?
 3. Overall, do you consider yourself a strong student, an average student, or a below average student? What criteria do you base this judgment on?
 4. What are the most valuable subjects, ideas, or skills that you have learned in school?
 5. What should you be learning in school that school is not adequately helping you to learn?
 6. What should you be learning in life that life is not adequately helping you to learn?
- C. How is working on problems here different from working on problems in school?
- D. How important to you is being a critical, independent thinker, a person who makes most or all decisions based on his or her own thoughts and principles?
1. [Discuss the meanings of critical thinker, independent thinker.]
 2. How much has school helped you become a critical thinker? A lot, some, not very much or not at all?
 3. Which classes or school activities have aided your critical thinking the most?

II. Questions about student's manual skills work and learning experiences.

- A. What manual skills do you have?
1. What materials have you worked with? Wood, fabric, metal, other?
 2. What kinds of objects have you made and/or designed?
 3. What kinds of machines, other than bikes, have you operated?
 4. What kinds of machines, including bicycles, appliances, electronic gadgets have you repaired or tried to repair?
- B. Where have you previously learned or developed manual skills such as learning from a relative at home or other community member, shop class at school, workshop at another institution, etc.?
1. Where did you first learn to use any hand tools—hammer, screwdrivers, etc?
 2. What thinking tools have you learned, and where did you learn them?
 3. What tools—either physical or mental—are important to learn for what you want to do in your life?
- C. Name a repair procedure, in or outside of the bike shop that you have mastered.
1. What tools are involved in this procedure?
 2. How important to mastering the procedure is your mastery of tools specific to this procedure?
- D. Please name any thinking tools you have gained from school, home, or work in this shop that are important to you and to the achievement of your life goals.
1. Which of these thinking tools have you mastered to some degree?
 2. How did you develop that mastery?

III. Questions about the relationship between thinking and acting while engaged in problem solving in the educational bike shop.

- A. I asked you earlier to compare your approach to solving problems in the bike shop to the way you solve problems in school. Let's talk about that question again now that

we've touched on some broader aspects of thinking and learning. Think again about how working on problems in the bike shop differs from problem solving in school, say in math class, for example. How would you say problem solving in these two different settings are different? What kinds of mental, social, or physical thinking tools do you use in each situation?

1. How is problem solving in the shop *the same as* problem solving in school?
 2. Finally, please compare problem solving at school or at the bike shop with the way you approach problem solving in everyday life at home or in other neighborhood situations.
- B. Does mathematics help you solve problems in activities outside of school?
- C. Think of a common, everyday problem that you encounter outside of school (examples: What is the shortest route from a friend's house to school?)
- D. What problem solving strategies do you use to resolve the problem?
1. Trial and error solutions strategies—what are the pros and cons?
 2. What are other solution strategies you have used?
- E. What kinds of self-checking have you used to verify the accuracy of your solution results? How frequently do you check your results?

Appendix B: Content log sample

Content Log: SLC120209_CL.doc

Class: SLC, Charlie Patterson teaching Sonia and Marcus

Topic/Activity: Sonia, 3-speed hub overhaul; Marcus, frame alignment, replace chain

Date: 12.02.09; 17:10

Tape: SLC120209.mov

Camera operator: Charles Hammond

Content Log by: Charles Hammond

Summary: Continuation of work on Sonia's English 3-speed bike, including overhaul of 3-speed hub. Marcus received new bike assignment, a 20" derailleur shop bike, Specialized ATB, to prepare for the December Holiday Sale. He replaced the chain and straightened the derailleur hanger using the hanger alignment tool. Lead Instructor: Charlie Patterson (CP).

Episode Structure (Time stamps keyed to Quicktime Movie):

00:00:00 – 00:06:47: Marcus cuts new chain. Sonia starts 3-speed hub disassembly.

00:06:48 – 00:30:43: M experiments with der. hanger alignment tool. S continues disassembly.

00:30:44 – 00:53:02: Marcus installs chain. Sonia cleans and reassembles hub.

00:53:02: Tape ends

Log:

TIME:	CONTENT:	NOTE S:
00:00:00	[After having removed rusty chain and determined it to be unsalvageable, according to CP, Marcus lines up a new chain end-to-end with the old one and prepares to cut it to replacement length.] Marcus positions the chain end to be cut in the chain tool, unsure of what the two tracks in the tool are for. CP explains the tool design and cutting procedure, describing sequence of male-female (inside-outside) link segments. CP moves briefly to Sonia who is removing locknut from 3-speed hub then back to Marcus.	

00:02:03	<i>Marcus removes excess new chain, checking his new cut length against the old chain. CP points out bent derailleur hanger, checks bottom bracket bearings which are OK, tells Marcus to remove derailleur. CP moves to Sonia who is still removing locknut from axle, now with the aid of Channelock pliers to stabilize the axle.</i>	
00:05:40	CP describes function of derailleur hanger tab stop, retrieves hanger alignment tool from board and asks Marcus to thread tool into hanger.	
00:06:49	As Marcus contemplates the tool inserted into the hanger, CH prompts him to explain how he thinks the tool is designed to work. CH demonstrates lining up indicator rod at point of maximum rim deflection. Marcus experiments with levering the tool to bend the hanger but seems baffled by use of the indicator.	
00:08:14	Marcus continues to explore the function of the tool by levering the main body, sliding indicator chassis up and down the body, and sliding indicator rod in and out with no apparent systematicity. CH demonstrates differential in indicator gap between 7 o'clock and 1 o'clock positions.	
00:09:00	Marcus identifies gap at 9 o'clock, tests movement action of indicator rod and chassis, seems unsure of how to accommodate the eccentric movement of indicator due to the tool's pivot around a center offset from the center of the rear wheel. CH queries Marcus about the meaning of the variation in indicator gap size and tries to get him to correlate gap size with coplanarity of hanger and wheel.	
00:11:02	Marcus starts to unscrew tool from hanger and CH cautions him not to. After watching Marcus start to look helpless in exploring the tool function, CH gets more didactic in his approach, advising Marcus to compare readings at 6 and 12 o'clock. In doing so, Marcus tends to fumble with the indicator rod instead of leaving it at the original setting for comparison among different positions.	
00:12:51	CH: Where's the gap the biggest? M: Gap's getting biggest right here [9 o'clock]. Marcus continues to make motions that don't conform to the logic CH is advocating including spinning wheel and levering tool at 8 o'clock. CH remarks that gap is indeed starting to even out.	
00:14:30	Marcus finally demonstrates informed use, i.e. basic mastery, of the sliding chassis function of the tool as he expertly takes gap measurements through about 210 degrees of arc. Yet he also still demonstrates apparent misunderstanding of sliding chassis action. He makes repeated levering adjustments around 9 o'clock but hardly at all in other positions.	

00:18:20	CH watches as M explores tool function, alternately checking gap and levering the tool body against the hanger. He is definitely demonstrating understanding of the chassis sliding action, but his physical dexterity with the tool is still unsure and incipient.	
00:21:09	M frequently turns the knob on the chassis for reasons that are not clear. CH occasionally asks M to take a gap reading in different positions. CH asks M to check the 7 o'clock position where gap seems to close to zero. CH: Now, which way do you want to bend it? M: To close the gap... CH: Well, the gap is already... [M makes an off-camera gesture to which CH responds affirmatively and gestures an outward motion with hand.]	
00:23:13	M bends the hanger out, appropriately.	
00:24:15	M starts to look a bit exasperated with the varying gap. CH asks CP to check M's work, and he asks Marcus to be prepared to explain to CP what he has done and how he figured out how to do it. M practices his explanation with CH starting with a reading at 6 o'clock, then moving to 9 o'clock. CH notes that the gap difference is small and he asks M to approximate the size in millimeters.	
00:25:20	M takes another reading at 12 o'clock, but when CH asks him to estimate the gap size, he pushes the indicator rod to close gap. CP arrives and M mumbles an explanation, continually pushing in the indicator rod to close the gap.	
00:26:00	CH notices that the tool body wobbles in the hanger and checks the tightness of that joint. CP takes the tool to make his own readings, but Sonia calls him away. CH tells M that he is getting close to completion and that lack of trueness in the wheel prevents a perfect adjustment.	
00:27:06	CP explain canonical tool use. Due to play in tool body movement, CP always keeps an outward tension on tool in order to make consistent readings. He demonstrates taking readings at 4 main clock positions. CP returns to Sonia and M tries a few more fine adjustments. Sonia has completely removed gear assembly from hub shell, and she meticulously cleans each part.	
00:30:44	CP returns to M and says the adjustment is close enough. He instructs M to replace the derailleur. Sonia degreases the hub shell interior. M has slight difficulty rethreading hanger bolt into hanger but finally masters the procedure. He takes new chain and wraps it around the large f/w sprocket and chainwheel without threading it through the derailleur wheels.	
00:35:09	M continues to explore how to manipulate the floppy chain in a controlled way. He has some success in engaging in teeth of both the f/w and chainwheel, but still has neglected to	

	thread the derailleur.	
00:38:22	CH finally challenges M's installation and instructs him to thread the chain through the derailleur. CH advises M to use another derailleur bike to model the path of the chain. M carefully traces the path of the chain on an adjacent bike.	
00:40:45	<i>CH commends M for threading the non-pin end of the chain through the front derailleur, an indication that he has learned from the difficulty of threading the pin end on the previous try.</i>	
00:43:40	M experiments with different approaches to threading the chain. CP reviews M's progress and notices that the rear derailleur is not positioned behind the hanger tab. CP then demonstrates the most efficient way to thread the chain.	
00:47:03	<i>After chain is threaded, M struggles with joining the chain ends prior to pushing in final pin.</i>	
00:48:50	<i>Sonia has completely reassembly. CP is advising her on cone adjustment.</i>	
00:49:44	<i>CH demonstrates joining chain ends to M. M pushes in final pin, too far. CP inspects progress. M makes final correction to pin adjustment.</i>	
00:52:00	<i>CP advises M to use middle track on chain tool.</i>	
00:53:02	<i>End of class</i>	
	<i>Tape ends.</i>	

Appendix C: Student Interview – Marcus

INTERVIEW

Site: SLC
Date: May 2, 2010
Time: 1:45 pm
Location: meeting room
Interview with: Marcus
Role: researcher, co-instructor
Interviewer: Charles Hammond
Transcriber: Charles Hammond
File name: intvx-slc050210marcus.doc

	:40	Marcus		
	:30	CH	I know that in school you're in the Life Academy	
	:31	Marcus	Life Academy, department [inaudible]	
	:42	CH	OK, tell me what's different about the Life Academy.	
	:56	Marcus	Life Academy? It's like a smaller class size. There's about 30 kids in the whole school. And, it's a good school, you know, if you had a hard time with the other school, the Academy would be a great alternative.	
	:58	CH	Yeah.	
	:10	Marcus	It's nice.	
	:32	CH	It's nice because of...	
	:48	Marcus	Because of the small class sizes and you have more one-on-one with the teacher.	
	:37	CH	And so what does that improve for you.	
	:41	Marcus	It improves. Like when I was in eighth grade, I was failing, but now I'm starting to like raise up my grades. Like math is always going to be a struggle for me.	
	:47	CH	OK.	

	:58	Marcus	But I'm trying. I'm trying to get through it.	
	1:02	CH	And so that kind of learning environment, which is different, helps you to get through it?	
	1:03	Marcus	Yeah.	
	1:04	CH	What about it is more tolerable than just a conventional classroom?	
	1:09	Marcus	Well, like. Actually I'm a shadowing student at the main campus and like the classes are really big and it seems like. It seems like I can't really like, like really ask questions. Like, the teacher will go over it once and after that one time nobody asks questions or anything.	
	1:39	CH	And so now you have more of a chance to ask questions?	
	1:57	Marcus	Um hmm.	
	2:28	CH	And have conversations with...	
	2:29	Marcus	I've built really good relations with the teacher, with my teachers.	
	3:44	CH	What about talking with other students in that class? Is there more of that or less of that?	
	3:49	Marcus	There's, actually more of it [chuckles]. Than the big school.	
	3:51	CH	OK.	
	3:53	Marcus	Like,	
	4:01	CH	And I mean not, not just socially but academic.	
	4:02	Marcus	Academic.	
	6:02	CH	Is there that	
	6:25	Marcus	[coughs] Excuse me.	
	8:44	CH	Sure.	
	9:09	Marcus	Um. Yeah, there's a lot of academic talk. We ask questions about homework, and like, there's all this group discussion.	

	9:10	CH	OK, all right. What are the most valuable subjects or ideas or skills that you learn in school?	
	9:48	Marcus	Most valuable subjects. Uh. Hmm. I have to say English. Cause, yeah, English cause when I'm trying to apply for college I have to use like that English grammar to do my essay about myself. Yeah, English is really the most valuable subject.	
	0:18	CH	OK, and tell me a little bit more, what about English. Well, you told me, so it's, so you think the writing skills are gonna help you write those essays.	
	0:26	Marcus	Yeah.	
	2:45	CH	Do you think school is that much different than...do you think the communication and language skills that you're learning in school,	
	3:34	Marcus	Um hmm.	
	5:48	Marcus		
	5:49	CH	Are that much different from what you would by not going to school?	
	5:50	Marcus	If I didn't go to school I wouldn't have a very distinctive vocabulary.	
	6:24	CH	OK.	
	6:32	Marcus	It's so sad, like, I see people that attitude about school, they don't even go to school. It's sad. And I'm really grateful cause I have a distinctive vocabulary.	
	7:39	CH	Their vocabulary is limited.	
	8:03	Marcus	Yeah, very limited.	
	0:03	CH	Yeah, OK. What should you be learning in school that school is not helping you to learn, if there's anything?	
		Marcus	There's nothing.	
		CH	Nothing to mention?	
		Marcus	No.	
		CH	What should you be learning in life that life is not adequately helping you to learn?	

		Marcus	Uh. Like meanings of things. Like why is the sky blue. Those are things I've asked myself. I never really had an answer.	
	4:04	CH	The basic mysteries of life.	
		Marcus	Yeah.	
		CH	OK. You consider yourself a philosophical person?	
		Marcus	Um hmm.	
	4:32	CH	OK. How much has school helped you to become a critical thinker? You know what I mean by critical thinker?	
		Marcus	Uh. It's like, it's helped me a lot. Like. It's helped me a lot. I can't really go into detail.	
		CH	OK. Which classes have aided your critical thinking the most?	
		Marcus	I'd have to say P.E.	
		CH	That's interesting.	
		Marcus	I don't get why we have to do P.E.	
		Marcus		
	0:08	CH	Well, I'm asking which classes have aided your critical thinking the most.	
	0:28	Marcus	Oh. English class.	
	0:31	CH	English.	
	0:32	Marcus	I'm sorry, I'm sorry.	
	0:52	CH	That's OK. And back to issue of communication and vocabulary?	
	0:55	Marcus	Um hmm.	
	0:57	CH	Related to that?	
	0:59	Marcus	Yeah.	
		CH	Do you spend much time reasoning about and putting together arguments in English class?	
		Marcus	Well, I've thought of them but I'm kind of a shy guy. Like I'm not really a loud speaker.	
		CH	OK.	
		Marcus	But I've thought of those. I've had conversations [inaudible]	

		CH	OK. I'm not sure if we went over this in that group interview or not. What are some of your strongest skills in the bike shop?	
		Marcus	Strongest skills in the bike shop. I'd have to say is repacking the headsets. Repacking, no, no, no, no. Taking apart the frame cups, the best. That's the best part.	
	4:49	CH	Uh, what part of the frame cups are you talking about?	
	4:55	Marcus	Uh [moves over to bike off camera].	
	5:21	CH	OK, so the ball bearing cups in the headset. So, um, there's the crown race and then there's, I can't even remember the name either. OK, um, have you, let's see, so, overhauling the headset is similar to what other aspects of working on a bike?	
	5:22	Marcus	Overhauling a headset. Similar to the bottom bracket.	
	5:44	CH	Right.	
	6:00	Marcus	Cause you have to, you know, clean like, for that headset you have to take, take out things, take the fork out, take out the stem, handlebars and you have to check if the bearings are [inaudible] smoothly. And if they're not, then you have to take out the fork, well, take, unscrew the headset. And then like take it out, look at the bearings, if they have like cracks in them. And if they don't, then put em in a bowl, WD-40 spray. If they're like really rusty, put em in some cleaner, and then wipe em down really firmly and then grease up the place where the bearings run. Stick it back together. Well, do one side first, so you then flip it around and do the other side. Then dry it and put everything else back together. And that's also similar to that bottom bracket. The bottom bracket you have to, you know, make sure it's not loose. If it is,	
	6:02	CH	Well tell... if you find a headset or bottom bracket that's loose, what do you do? So let's stick with the headset.	
	6:48	Marcus	Find a headset that's loose.	

	1:23	CH	Or you've cleaned it. You overhauled it and you're putting it back together and tightened the locknut down. And you test it and you feel there's a little play in it.	
	1:25	Marcus	There's a little grind.	
	1:26	CH	So, well not grind, but there's actually play, which would indicate it's too loose.	
	1:27	Marcus	Um hmm. Then I would tighten the locknut, well, no, yeah, I would tighten the locknut, well.	
	3:17	CH	Well, here. We can bring this bike over. Do you know whose bike it is?	
	4:28	Marcus	No.	
	5:41	CH	[sets up the bike on kickstand] So why don't you tell me if the headset is loose on this. Go ahead and test it and tell me if it's loose.	
	5:42	Marcus	[turning handlebars left and right] It's not loose. But if it was loose, when you wiggle it, it would start to like, move, but not like with, as you're moving it in the other direction... Then you, then you have to... take out the stem, take out the handle— well, you don't have to take out the handlebars, you have to take out the stem, the like woo-ooo, you hold the fork... I don't know about this bike.	
		CH	You know what. This bike is different because, there's two kinds of headsets. There's threadless and normal headsets, and which one is this?	
		Marcus	This one's normal.	
		CH	Well this one is... pretty sure it's threadless, yeah, this one is a threadless headset. So it's not like, it's very different from a bottom bracket.	
		Marcus	Oh, yeah, yeah, yeah.	
	2:45	CH	So, let's skip the headset. Tell me if the bottom bracket is loose. Test it.	
		Marcus	It's not loose. But if it was loose, as you shake it, it would start to pick up [inaudible].	
		CH	Right.	
		Marcus	If it had play, you would take the pedals and cranks off.	

		CH	Uh huh.	
		Marcus	And then you'd get down to the actual bottom bracket. And you'd test it just to see if it's loose. Oh, you're laptop's about to fall.	
		CH	Thanks, gee.	
		Marcus	Um just to make sure if it's loose, and if it is, then you grab a cone wrench, no, you got one of those big wrenches, yeah, big wrench, the adjustable wrench.	
		CH	Adjustable wrench.	
		Marcus	...and you tight—no, no, no. You get a bottom bracket tool. Well, like there's this tool, and there's an adjustment, these two pieces. And you get the one that fits on this and tighten, yeah.	
		CH	You know, this bike is newer than most, so even the bottom bracket is a little different. It doesn't have the adjusting cup, so it's just a cassette that you pop in and pop out. I mean you pop it in and you just crank it down tight. So there's no adjusting to do on that. So, bad question for me to ask you on this bike. So what other part of the bike is actually like the bottom bracket and the headset in terms of how you tighten it or loosen it.	
		Marcus	The brakes.	
		CH	Well, do the brakes have ball bearings in them?	
		Marcus	Uh, no. No, no, no, no. The hub.	
		CH	The hubs, right. These are pretty conventional hubs. And so, tell me on this. First of all, test the hubs. See if they're too loose and then tell me what condition they're in.	
		Marcus	They're [inaudible].	
		CH	They're good?	
		Marcus	Yeah.	
		CH	OK.	
	5:31	Marcus	But if they weren't.	
		CH	Yeah, so if they're too loose, how do you fix that?	

		Marcus	Too loose, then you unscrew the axle nuts and you take the wheel and get a cone wrench and a little, 14 or 15, well, if it's too loose, right?	
		CH	Uh huh, too loose.	
		Marcus	If it's too loose, you grab it and pull it together to tighten it.	
		CH	Uh huh.	
	6:00	Marcus	Then you check, you like check it, make sure there's no play. And if there's, if there still is play then you loosen it and then go tighten it a little bit more. Well, no, no. They're always saying like you tighten it maybe a third more, then you test it.	
	6:11			
	6:15	CH	All right. Good enough, Marsalis. I think that's enough on that. What I'm gonna do is save some time to actually go back in the shop and find a wheel that needs to be adjusted. [CH gives Marsalis notebook computer for viewing a previous day's work.] So, just stop [the movie file.] Do you remember what the situation is?	
		Marcus	The situation.	
		CH	I mean, what's the problem you're working on?	
		Marcus	[inaudible, clasps palms onto face] I can't remember.	
		CH	OK, well, just...	
		Marcus	Oh yeah, when we tried to lace to put it like	
		CH	The cup//	
		Marcus	Yeah, the cup to turn it back and it wouldn't go back. I don't think it wouldn't go in or something. It wouldn't fit, so we found, we went to the drawer and found a couple...we started finding a bottom bracket...	
		CH	So when it didn't fit, tell me a little more about how you knew it wasn't fitting.	
		Marcus	Because when we...I don't...I don't [grimaces]	

		CH	So, I don't remember just now if Charlie said anything about it, but I'll fill you in a little bit, I'll refresh your memory a little bit. One of you had gone ahead and screwed it in almost all the way, but there was a gap at the top and a gap at the bottom still because it wouldn't screw in all the way.	
		Marcus	Yeah.	
		CH	And, let's go ahead forward a little bit and see. Well, let me close this [inaudible]. That should help. Remember what this tool's called.	
		Marcus	[hands to face] My god, we just worked on this last Friday.	
		CH	[laughs] It's a weird//	
		Marcus	Weird, it's like a [gestures with hands]	
		CH	Yeah, that's good, it's a micrometer.	
		Marcus	A micrometer. I'm sorry, I forgot [inaudible]	
		CH	That's OK. You're allowed to. So tell me and listen. He's telling you to get the jaws of the micrometer at a right angle so you get a straight measurement. And, can you tell me what you're doing, now?	
		Marcus	Measuring the gap [gestures with two index fingers pointing straight down, parallel, about six centimeters apart] Like, we're measuring how big the gap is.	
		CH	So why do you have your whole body at a strange angle there?	
		Marcus	Because it has to be at a [gestures with two parallel hands facing each other] when you place it in, you have to measure at a certain angle so it like, you...when you measure it and then like when you go to another side, you have to make sure it's still the right measurement so you move it. Well, you move it, but like...	
		CH	Cause, cause you're, you're, uh, well you're...I'm trying to think it out and describe it myself. Charlie asked you to make two measurements, one on top and one on the bottom. Does that ring a bell?	
		Marcus	[sighs, shakes his head in negative response]	

		CH	Or maybe not. OK. So, that's OK. I'm explaining now that that's what Charlie wanted you to do. And we're going to watch a little more video now so you can see yourself measuring the top and .	
		Marcus	The top and bottom//	
		CH	bottom gap.	
		Marcus	Ohhh.	
		CH	And so what I want you to explain to me, why Charlie asked you to measure the top and bottom gap. Can you explain that? What would that accomplish?	
		Marcus	That would accomplish [inaudible]	
		CH	OK, that's true but that doesn't tell me why, that doesn't tell me much about why it won't thread in. Here, let's go ahead and play a little and see what	
		Marcus	[snaps fingers, looks up and half-smiles] Cross thread. I think it might be cross-threaded.	
		CH	What does that mean?	
		Marcus	It means it might, it might like...we probably put it in the wrong way. We threaded it in the wrong way. That's what cross threaded... 's like...	
		CH	Are there different ways of threading the cup?	
		Marcus	Yeah, there are different ways. Yeah, I remember cause we were doing that on my bike. Cause it had a French bottom bracket.	
		CH	So//	
		Marcus	So it was cross threaded. It was cross threaded.	
		CH	That's the problem here, it's cross//	
		Marcus	Yeah//	
		CH	//threaded. And that's why it didn't go in?	
		Marcus	Yeah. That's why it had the gap.	
		CH	Had the gap. And uh. Do you know why they call the condition cross-threaded?	
		Marcus	Cause we, cause usually we go against the traditional way? So I guess they use, they say cross threaded because	
		CH	[CH explains the cross threading phenomenon. CH and Marcus discuss other bikes Marcus has worked on.] Remember you had that blue Gitane?	

		Marcus	Yeah.	
		CH	What was the problem with that?	
		Marcus	Uhhh.	
		CH	Problem with the Gitane was the stem thing in the fork, remember that?	
		Marcus	Oh yeah, cause it was like a 32 something point four.	
		CH	Yeah, was it like 22.2.	
		Marcus	It was exact measurement, both fork and stem.	
		CH	Exactly. And so, as Chris pointed out, you don't want//	
		Marcus	The exact measurement.	
		CH	//the exact one. It isn't gonna fit. One's gotta be smaller. It's kinda weird, this is something I haven't showed Charlie yet. Let me show you then we're gonna head back in. ... You guys were talking about 21.1 and 21.2.	
		Marcus	I think it was 22.2, but...	
		CH	It turned out to be 22.2. And Charlie was saying, when Chris said you can't have both of them 22.2, the stem has to be smaller than the opening in the fork, Charlie said "21.1 is too//	
		Marcus	//should fit//	
		CH	//is way too//	
		Marcus	//too small//	

		CH	<p>//too much of a gap. Now he's right that 21.1 would be way too much of a gap because the fork is 22.2...Charlie was remembering the wrong number, is what he was doing and I haven't told him yet. But I think that may have been the problem. I don't know whether it got fixed or not. But OK, so that's that. And we talked a little bit about threads. Anything else on here? [looks at interview protocol off-camera]. Let's head back over. I want you to find a wheel that has a loose hub. I want you to tighten it, and I want to get that on videotape.</p> <p>[inside shop. Marcus has a front wheel in his lap and a wrench in each hand.] I want you to explain to me what you're doing, what tools you're using, and if you can't remember the names, I'll help you remember the parts.</p>	
		Marcus	<p>This, uh, this is pretty loose [touches the axle]. So what I use is a 13 [holds up a cone wrench] cone wrench and an adjustable wrench. The goal I'm trying to complete is to, the hub to get tight.</p>	
		CH	<p>OK, cause it's too loose. [M presses the two wrenches together hard, then gets up out of his seat and stands at the bench to get even better leverage. He is tightening the locknut against the cone which may make the cone more secure in place or may back it off a few microns, making the adjustment looser. M clearly does not realize that these are the only two possible results of his action.]</p>	
		Marcus	<p>[After tightening as described above with all his strength. He lays both wrenches on the workbench.] Still pretty loose. [M picks up both wrenches again. He tries the same action.]</p>	
		CH	<p>OK, so, you're tightening the locknut onto the cone.</p>	
		Marcus	<p>But, I think that's just the problem, cause even after tighten it, still pretty loose.</p>	
		CH	<p>Um, is the cone moving at all? I mean, yeah.</p>	

		Marcus	This the cone? [M holds up the cone wrench in his L hand and wiggles it.] Oh, the cone. [M grabs the cone between two fingers of his R hand.]	
		CH	The cone, right.	
		Marcus	Uh.	
		CH	What would be a way to... you know the cone isn't moving much any more now that you've got it tight. Now you've got the locknut tight against it. [M removes the q/r skewer.] So how would you get the cone to move more?	
		Marcus	Loosen it?	
		CH	Sorry?	
		Marcus	By loosen it?	
		CH	OK.	
		Marcus	I'll just do the opposite. [M places both wrenches on hub again.] I'll just go like that to bring it together. That'll bring it out. [M screws up his face in determination and exertion as he pushes the wrenches against each other. They are so tight now that they don't budge. M shakes out his left hand to remedy the pain.]	
		CH	OK, yeah, so that's gonna loosen the locknut. Don't like, don't hurt your hands. [M removes both wrenches and examines his palms.]	
		Marcus	Sorry, I did something. I'm a daredevil.	
		CH	[Chuckles.] OK.	
		Marcus	[inaudible]	
		CH	Well, don't hold me responsible for any blood. That's what I'm trying to say. [M reapplies the two wrenches.] See, that's a good technique is to kinda pull...	
		Marcus	Yeah, Charlie showed me that.	

		CH	//with your fingers. But I mean also not only positioning the wheel in the corner there but also pulling with your fingers prevents it from slipping and then you rip the skin off your knuckles. But evidently it's not strong enough. But here's another technique, to um, position the two wrenches...put, go ahead and put the cone wrench in. Now position the adjustable wrench in a way that you can squeeze the two together with your hands and it will loosen, so, just like a little. Nah, you can't squeeze that. Put it a little closer to the cone wrench, yeah. That won't work, cause it's too close. So flip the wrench. Now it's still too close. So try it. Now squeeze them together. No that's a little too far still, so it's not going to work. Anyway, sometimes it helps. [M tries again using his previous method with both wrenches at about 160 degrees with respect to each other.]	
		Marcus	It's not going to work.	
		CH	Then let me see if I can muscle it for you. [CH puts the camera down. He places the two wrenches about 30 degrees apart but realizes that he needs to switch their positions to loosen the locknut. He switches their positions then demonstrates how he would squeeze the two together, then offers M a chance to try squeezing them. M does so, and the locknut backs off easily.]	
		Marcus	[Wiggles the axle.] Still loose, so.	
		CH	OK.	
		Marcus	So, I have to tighten it.	
		CH	Right. So you don't want to just retighten the locknut against the cone. You want to tighten the cone against the bearings. So how do you do that? [M carefully closes the jaws of the adjustable wrench for several seconds, but the positioning of the wrenches will still only tighten locknut against cone. He tries to position the wrenches 30 degrees apart like I showed him.]	
		Marcus	Too close. [He tries repositioning the wrenches.	

		CH	So right now how does it feel, too loose or too tight?	
		Marcus	It's still too loose.	
		CH	How about if you grab another 15 cone wrench.	
		Marcus	This is a 13.	
		CH	Oh, this is a front wheel, so grab two 13s.	
		Marcus	Oh yeah, and then put them together.	
		CH	Well, no, I wanna say put one 13 on the bottom. Bottom cone. And hold. And hold the axle so... this kinda requires three hands. But anyway hold like that. [off-camera] Reach leggo with your R hand. And come around the top from the top. And grab it, OK. That's actually pretty awkward too. Lemme hand...so. Now what you wanna do is I'm gonna hold this for you. And you tighten the cone above there [camera swings back to M's work.] Slightly. That's loosening, so go the other way. That's tightening. Tighten a little more. OK. Now hold it there and tighten. No, hold that cone wrench and grab the adjustable wrench and tighten the locknut on it. And then explain to me why we did this and did that help at all.	
		Marcus	Yeah.	
		CH	OK, now what did we just do?	
		Marcus	What we did is we got two 13s, put one on the bottom, one on top and while we held this one. While we held one so it wouldn't move, we got the other one, like this.	
		CH	Uh huh.	
		Marcus	And then we tightened it. This way.	
		CH	OK. So, why did the cone tighten?	
		Marcus	Why did the cone tighten? Cause the//	
		CH	//and it didn't tighten before.	
		Marcus	Before I was using this. Like I wasn't, applying any bottom [inaudible]	
		CH	Uh huh.	
		Marcus	But now, but then...	
		CH	OK, then, is it, is it, is it accurate to say that by holding the bottom cone that you're actually holding the axle steady. And then when you tighten, tighten//	
		Marcus	Yeah,	

		CH	//cone against the axle it's not moving, cause look. The axle moves.	
		Marcus	So we had to get one side of it stable so we could...	
		CH	Right.	
		Marcus	...tighten the other.	
		CH	And one thing we forgot to do. Can you add something that we didn't do that would have been a good first step before we tried to hold the cone on the bottom steady? Uh, because what if this locknut is not tight. It is tight. But what if it hadn't been tight? You would have grabbed this and the axle still would have moved. Could have moved. So, it's always good to check and make sure.	
		Marcus	That the axle.	
		CH	That the locknut is tight on this side, so you don't pull, before you try to pull your axle that way. And then do your work on the other side. So, what does it feel like now?	
		Marcus	It feels much better. But there's still a little tiny...	
		CH	A little tiny play. Well, we're out of time, so let's wrap it up here.	
		Marcus	Sign off?	
		CH	Yeah. Just, put it back together in a basic way.	
	9:57		Tape ends.	
		CH		
		Marcus		