Riding to Learn: Informal Science in Adult Cycling Communities

Joel R. Drake
Utah State University

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RIDING TO LEARN: INFORMAL SCIENCE IN ADULT CYCLING COMMUNITIES

by

Joel R. Drake

A dissertation submitted in partial fulfillment
of the requirements for the degree

of

DOCTOR OF PHILOSOPHY

in

Instructional Technology and Learning Sciences

Approved:

______________________  ____________________
Victor R. Lee, Ph.D.   Deborah Fields, Ph.D.
Major Professor              Committee Member

______________________  ____________________
Kristin Searle, Ph.D.   Eadric Bressel, Ph.D.
Committee Member              Committee Member

______________________  ____________________
Amy Wilson-Lopez, Ph.D.     Laurens H. Smith, Ph.D.
Committee Member               Interim Vice President for Research and
                               Dean of the School of Graduate Studies

UTAH STATE UNIVERSITY
Logan, Utah

2018
ABSTRACT

Riding to Learn: Informal Science in Adult Cycling Communities

by

Joel R. Drake

Utah State University, 2018

Major Professor: Dr. Victor R. Lee
Department: Instructional Technology and Learning Sciences

Extant research has demonstrated that practice can support multiple ways of knowing, each shaped by the structure, artifacts, and norms of the practice; social interactions; and the participant’s prior knowledge. Separately, researchers have shown that engaging the (whole) body provides a more immersive experience and can change learners’ perspective on the content. Taken together, one might infer that features of practice might shape knowing through physical engagement, and vice versa.

Recent years have seen increased academic in learning and knowing that are or can be supported in informal settings, particularly settings that support learning science, technology, engineering, and mathematics (STEM) content and practices. Informal environments are ideal for STEM learning because they allow for long-term participation in activities of interest to the participant while also providing means for directly experience experiencing and engaging with phenomena.

This dissertation reports the findings of a two-year study of an adult recreational cycling community. Using ethnographic methods of participant observation and interviewing, this study examines the characteristics of cycling practice and the
opportunities for learning that it supports. This study also analyzes the relationship between the practices of cycling and the cyclists’ knowledge about two phenomena they engage with regularly and intensely through that practice: mechanical advantage and air resistance.

Cycling practice centered around participation in a weekly group ride. Participation was predicated on having access to appropriate equipment, including a bike and cycling-specific clothing. Norms were enforced through interactions with the bike shop and intentional instruction. Instructional opportunities were triggered when a rider arrived improperly equipped.

The cyclists’ heuristic knowledge was shaped through “socially mediated embodiment”—the aggregation of physical experience filtered through the goals and expectations for participation. For both mechanical advantage and air resistance, the cyclists’ heuristics focused on minimizing the instantaneous perceived effort needed to maintain a desired performance level. Through a series of problem-solving tasks, the cyclists’ understandings paralleled the canonical explanations. These results further validate the notion that we should expand our definition of what it means to know. They also open the door to other studies of learning through long-term physicality in practice.
PUBLIC ABSTRACT

Riding to Learn: Informal Science in Adult Cycling Communities

Joel R. Drake

Our understanding of how the world works is shaped through countless interactions with things in it. These interactions are our first exposure to science. Through them, we learn that heavy things are hard to push and books do not fall through tables. Our interactions are also shaped by the rules of the groups to which we belong (e.g., families, religious organizations, athletic teams). These rules lead us to accept that some things cannot or should not be done, limiting our interactions with the world. At the same time, these rules change our appreciation for what we do experience.

Prior research has focused largely on the separate influences of either physical interactions or social interactions, leaving (relatively) unexplored their combined effects. In this dissertation, I describe how adults understand science related to their long-term participation in a recreational road bicycling group. The cyclists demonstrated a rich understanding of gearing and air resistance that paralleled, on a practical level, the explanations taught in school. This understanding was shaped by the cyclists’ years of physical experience interpreted in light of their individual goals for participating. For the cyclists in this study, knowing the science helped them be more efficient and faster riders.

In the end, this study supports the idea that productive and valuable learning takes place in many settings and that it is important to account for the relationship between the social and physical aspects of learning when designing instructional experiences.
ACKNOWLEDGMENTS

Victor Lee, my advisor, provided a space for me to pursue questions of interest to me. He supported and encouraged me as I gained the experiences and skills needed to complete this dissertation. Without his mentorship, this dissertation could not have achieved its current form. Thank you, Victor.

Ryan Cain was my research partner in crime. He was always willing to chat—providing feedback on anything, commiserating on the joys of grad school, and hitting the trails when we just needed to get out. His friendship made many days under the fluorescent lights of the office bearable. Thank you, Ryan.

My wife, Amber, has been my primary, most ardent, and most important supporter. She believed in me first and gave me reasons to keep going. She encouraged me through the endless hours in front of the computer and urged me to ride even when it did not result in dissertation data. For the last few years, she raised our kids as a grad school widow, and they are phenomenal kids. Every success I have had is because of and belongs to her. I love you, Amber.

I am grateful to cyclists of the “Downtown Cycles” Wednesday Night Ride group for allowing me to ride with them and be a part of them during this study and beyond.

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Joel R. Drake
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CHAPTER ONE
INTRODUCTION

Developmental scholars have argued that it is through countless interactions with and observations of the physical world that we develop our intuitive understanding of how the world works (Piaget, 1963)—balls bounce, heavy things are harder to move, unsupported things fall, things that are the same size balance (diSessa, 1993). At the same time, we socialize and are socialized through participating in practices (Rogoff, 2003). These social practices give structure to our interactions with the world, influencing how, when and even if we will interact with certain objects (Holland, Skinner, Lachicotte, & Cain, 1998). If practices do shape the way we act and interact, we may infer that there is a relationship between the practices in which we participate and the way we know things, even through physical interaction.

Said another way, particular ways of engaging (be it with objects or in practices) might support different ways of knowing. For instance, while the Physics underlying collisions are assumed to be the same (Drake & Lee, 2016), the practices through which Physics students and American football players engage with collisions are substantially different. In Physics class, students learn about elastic and inelastic collisions, the conservation of momentum, and how to calculate the effects of two objects interacting; this learning may also include laboratory experiences where they smack objects together. An American football player, on the other hand, learns about collisions by physically colliding with other players. This learning includes ways of colliding that are best for knocking down other players, and which types of collisions are illegal or likely to cause harm to the players themselves or to others. This understanding is honed through
thousands of collisions over a career. It would not be a stretch to assume that the Physics student and the football player would have qualitatively different understandings of collisions. In most (if not all) instances, the Physics student experiences collisions as an analytical third party—checking the velocities and masses of the interacting objects and, perhaps, classifying the collision as elastic or inelastic. They are rewarded when they correctly manipulate symbols to calculate the results of collisions under a variety of conditions. Football players participate in collisions. Defensive players initiate collisions, while offensive players seek (in general) to avoid them. As participants, they feel the effects of these collisions, whether the short-term sensations of impact or the longer-term effects of injury. "Lighting up" an opposing player (Figure 1) is rewarded with cheers from the crowd and a psychological advantage over the opposing player, who may be reticent to be hit like that again. I do not expect that a Physics student would have any qualms about repeatedly slamming billiard balls together, unless they got their hands stuck between them on one trial.

The National Research Council (2009) has called for additional research into informal learning spaces, specifically because of their ability to "grab learners' attention, provoke emotional responses, and support direct experience with phenomena" (p. 42, emphasis added). Many informal spaces (e.g., museums, after-school clubs, family time and hobbies) can be structured such that phenomena are experienced intentionally and scientifically. However, the richness of both informal learning spaces and phenomena necessitates the sensible extension of research into spaces where science learning may be incidental, as in the football example above.
Figure 1. Nebraska receiver Kenny Bell blocks Wisconsin defensive back Devin Smith during the 2012 Big 10 Conference Championship game (Reed, 2012).

Particularly for adults, hobbies of various sorts can take up a considerable amount of a person's leisure time, yet they receive comparatively little attention from researchers (for some notable exceptions, see Azevedo, 2013; Nasir, 2000). What work has been done in hobby spaces has shown them to be promising spaces for studying informal learning, including in STEM areas. This dissertation is motivated by an interest in how STEM content is encountered in a somewhat atypical, informal learning context—particularly how routinized physical experience and long-term participation in practice jointly shape the understanding of scientific concepts.
Theoretical Perspectives and Literature Review

STEM Learning in Hobbies

Researchers in various fields have recognized the relationship between STEM content and participation in hobbies and other leisure-time activities. In some hobbies, the acquisition of scientific knowledge is the goal of participation. Bird watchers (Law & Lynch, 1988) and astronomers (Azevedo & Mann, 2018) learn to classify and identify the objects of their observations. Personal (Flynn, Smith, & Freese, 2006) or local health crises (Alsop & Watts, 1997) can drive people to seek out medical and scientific information. In other activities, meeting the goals of the activity are supported by STEM learning. Successful gardeners learn which plants grow best in their local climate, when to plant them, what fertilizers are required, and how best to control pests (Rahm, 2002).

Even informal activities that are not typically thought of as STEM-related can be rich spaces for engaging with STEM content and in STEM practices. Elite World of Warcraft players engaged in scientific argumentation and mathematical analysis when determining the best course of action for their future gameplay (Steinkuehler & Duncan, 2008). Fantasy sports players can engage in various statistical analyses when determining the athletes to include in their weekly lineups (Halverson & Halverson, 2008).

Although these studies may not involve the introduction of a new learning intervention, the findings reported are still of great importance to those interested in the design of instruction and learning environments. At a minimum, they identify resources that could be used by others. Those resources could include prior knowledge, types of activities that could be introduced in a design, or a model outcome for what competence understanding or performance would look like. Beyond that, studies of knowing as
situated in practice provide a glimpse into the nature of knowing and understanding as it takes place naturally—as part and parcel with context rather than divorced from it. The accumulation of work in this area serves to raise the related questions: 1) what counts as knowing? and 2) where and how can we see learning taking place naturally?

**STEM Learning and the Body**

Within established practices, hobbies can also support STEM learning through bodily engagement. Arguably, all knowing and learning of science takes place with some involvement of the body. For instance, Farrington (1953) argued that "Science arises in contact with things, it is dependent on the evidence of the senses, and however far it seems to move from them, must always come back to them." In one extreme example, Sir Isaac Newton, wanting to experience the effects of prismatic refraction directly, inserted a bodkin in the space between his eyeball and eye socket to temporarily deform his eye (Hall, 1955). More recently, the desire to "feel" electromagnetic fields inspired people to insert magnets under their skin near nerves (Heffernan, Vetere, & Chang, 2016).

The role of the body in learning STEM concepts extends well beyond potential self-mutilation. Cuisenaire rods and other "manipulatives" have been used successfully in math education for many years in teaching content such as addition and fractions (e.g., Martin, Lukong, & Reaves, 2007), with virtual manipulatives being included in the award-winning DragonBox series of mathematics games (Marchal & Huynh, 2012). Math education researchers have also leveraged innate kinesthetic and proprioceptive capacities to help students gain a sense of proportionality (Abrahamson, 2009). While many of these studies focus on limb-scale motions, other researchers have designed encounters that engaged learners' whole bodies. Students have used their recollection of
certain bodily motions to understand both velocity and graphical representations of those motions (Nemirovsky, 2011). Students "playing at" being a ball (Enyedy, Danish, Delacruz, & Kumar, 2012) or a meteor (Lindgren, Tscholl, Wang, & Johnson, 2016) enact the motion of the object to learn about the effects of applied forces on that motion.

These full-body experiences are of particular interest to me. Full-body engagement activates a wider range of kinesthetic sensations, which serve to more fully immerse the participant in the learning experience. When participants can change position or location, they access new vantage points from which to observe and experience the phenomena with which they are engaged. Returning to the football example, tackles near the line of scrimmage (e.g., surrounded by other players, lower speed, stronger opposition) are qualitatively different than open-field tackles (e.g., alone, higher speed). Each of these situations engages the body uniquely and, thus, elicits different kinesthetic responses, which can highlight distinctive aspects of collisions.

**STEM Learning and the Social**

In the sociocultural view, learning is framed as shifting participation in the practices of a community (Lave & Wenger, 1991). Communities of practice develop over time as people come together in mutual pursuit of a shared enterprise (Wenger, 2000). As they form, these communities develop shared resources that aid in the performance of the enterprise and encourage continued engagement. These resources include specific objects, artifacts, and processes (e.g., job aids, specialized tools, skills); interpersonal relationships (e.g., with members, nonmembers, and specific kinds of members); and ideas about one's place in the community and what is valued (Nasir & Cooks, 2009). Taken together, these resources help define the extent of the practice, what is and what is
not included (Lave & Wenger, 1991). Additionally, practices involve sets of norms, expectations, and values that inform the way in which individuals may participate (Holland et al., 1998).

In defining how individuals may participate, a community's practice establishes trajectories of participation, which enable varying degrees of participation suited to the goals and abilities of individual members (Wenger, 2000). Some of these trajectories lead to greater participation in the community, while others may marginalize participants and limit their ability to participate. Legitimate peripheral participation is the process through which newcomers are allowed to join the community. Access to community resources is essential for legitimate peripheral participation and centripetal trajectories toward full participation (Lave & Wenger, 1991; Nasir & Cooks, 2009). As peripheral participants, newcomers participate in the community in a limited but valued way.

For example, the Vai tailors in Angola introduced their apprentices to the practice of tailoring by having them learn the process of finishing a garment (e.g., attaching buttons, hemming) before allowing them to assemble the garment or cut them out. Beginning at the end of the production practice focused the novices on the breadth of the practice and the desired outcomes while preparing them to understand the details (Lave & Wenger, 1991). The model rocket enthusiasts observed by Azevedo (2013) developed many ways of knowing that a rocket was stable (e.g., using commercially designed rockets, checking with an expert, swinging the rocket on the end of a string). Commercially designed rockets and expert checks allowed newcomers to safely participate in the breadth of the community's activities while they developed the more
sophisticated ways of knowing. Child candy sellers in Brazil were initially assisted in price setting and inventory purchases by more capable sellers (Saxe, 1988a).

In each of these examples, newcomers were provided with access to resources they needed to participate in their respective practices through interaction with community “oldtimers”. The novices were allowed to participate through "similar, simpler" versions of their respective community's full practices. As their mastery of skills and artifacts increased, novices were allowed opportunities for learning through greater participation.

This research project is informed strongly by sociocultural theories of learning with cognitivist influences. While sociocultural and cognitive approaches have often been treated as completely alternative perspectives on knowing and learning, there have been some deliberate efforts to understand how cognition is affected by participation in cultural practices (e.g., diSessa, Levin, & Brown, 2016). In this vein, Saxe observed that "as an inherent part of their daily activities, children construct and address problem-solving goals; in their efforts to accomplish these goals, children generate new understandings" (Saxe, 1992, p. 218). Based on this observation of culture and cognitive development, Saxe developed the emergent goals framework, which targets for analysis 1) the structure of the practice, 2) social interactions, 3) norms and artifacts, and 4) prior understandings (Saxe, 1991). The combination and interaction of these components form the basis for individual emergent goals and, thus, for individual learning (Figure 2).
This framework was informed by his work on the development of mathematical knowledge among the Oksapmin (Saxe & Moylan, 1982) and informed his research into the mathematical practices of child candy sellers in Brazil (Saxe, 1988b). Extensions of this framework have also been used to investigate mathematics understanding developed through, for example, basketball (Nasir, 2000) and the religious practice of tithing (E. V. Taylor, 2013). To be clear, this is where I situate myself theoretically.

In addition, I draw on the construct of community resources for learning and identity (Nasir & Cooks, 2009). As mentioned above, access to community resources is key to the legitimate peripheral participation of novices and the continuing participation of oldtimers. Nasir and Cooks identify three categories of resources—relational, material, and ideational (Nasir & Cooks, 2009). Relational resources are interpersonal relationships fostered through participation. Material resources are the tools, artifacts, and objects employed in the execution of community activities. Ideational resources include a participant's understanding of their place within the practice and what the community values. Understanding these resources, and the social interactions and structures by which
they are made available, is essential to understanding how cognitive activity is shaped and encouraged through participation in the community.

As mentioned previously, the culture of a practice can influence whether and how a person might engage with phenomena. Through participation, newcomers learn culturally valued ways of appreciating experiences (Becker, 1963). Returning again to the football metaphor, defenders learn the value of "lighting up" a receiver or returner in the flow of a game. Good defenders also learn when a standard tackle is more appropriate. Understanding the processes through which people solve practice-linked problems can help us understand and value atypical or unexpected ways of knowing.

**Cycling**

The research cited above shows, separately, the importance of both the body and social context in learning and understanding. Much of the work relating to bodily engagement seems to focus on short-term or single events. And, while the sociocultural studies engage with long-term processes, the role of the body in this work is somewhat diminished. What is needed is more work looking at learning and understanding developed through long-term, direct experience with phenomena as part of a social practice. Through studying such practices, differences in physicality and engagement with goals for practice may become open to inspection. To this end, I chose to focus on STEM learning through participation in the practices of an adult recreational cycling group.

**Research in cycling.** Even though riding a bike is simple enough that three-year-old children routinely master it, bicycles and bicycling have attracted and continue to attract the attention of researchers from a variety of disciplines. Engineers have examined
the mechanics of the bicycle (e.g., Han, Thomlinson, & Tu, 1991; R. S. Sharp, 2008; Yavin, 2006). Physiologists and biomechanists study the effects of cycling on the body (Bini, Hume, & Croft, 2011; Bressel & Larson, 2003; Hull & Gonzalez, 1990). Due to the familiarity of bicycling as an activity, children's understandings of bicycle mechanisms have been used by researchers as a gauge for both cognitive development (Piaget, 1963) and conceptual change (Smith III, DiSessa, & Roschelle, 1993). Sociologists study and debate the role of the bicycle in the history and future of transportation (Horton, Rosen, & Cox, 2007). In the learning sciences, bicycling as a practice has only recently begun to be explored as a potentially rich area of interest, noting that it encourages unique ways of thinking about movement and motion in the world (Hirsh & Levy, 2013; K. H. Taylor, 2017; K. H. Taylor & Hall, 2013).

**Introduction to cycling practice.** Group cycling has been an important part of bicycle culture since the invention of the bicycle and was instrumental in maintaining the bike's popularity through its initial development (Herlihy, 2004). Over the years, specialized equipment has given rise to multiple sub-disciplines (e.g., road biking, mountain biking, and commuting), each with its own distinct norms and practices. *Cycling*, particularly as it relates to the present study, is understood as the practices of communities of adult road bicycle riders (aka "cyclists").

Becoming a cyclist involves acquiring specialized knowledge and mastering complex physical and social interactions (V. R. Lee, 2013). Moving in tight packs, cyclists cover long distances at high speeds under their own power. In doing so, they routinely engage with several phenomena, including mechanical advantage and air resistance. One way cyclists encounter mechanical advantage is through gearing. Cyclists
manipulate the mechanical advantage of their bicycles (i.e., shift their gears) to respond to changes in terrain—to help them climb hills or go fast on flat ground. As cyclists move faster, they experience increased air resistance. Even at the speed of a typical recreational group ride, air resistance can account for more than 70% of the cyclists' power consumption (Gross, Kyle, & Malewicki, 1983). To reduce air resistance and save energy, cyclists use specialized equipment, adopt aerodynamic body positions, and engage in the practice of drafting—following closely behind another cyclist.

Given that cyclists regularly engage with mechanical advantage and air resistance through their participation in cycling practice, I will show through this dissertation that cyclists develop distinct ways of understanding and engaging with these Physics concepts.

The next two sections will outline the current state of research into knowledge relating to mechanical advantage (particularly as concerns gearing) and air resistance.

**Literature on knowledge of gears**

Gears have been used in educational research for many years. Gear systems provide two chief benefits to researchers: 1) they are open to inspection and 2) they can pose problems in spatial, kinematic, dynamic, and mathematical domains. Gears can also bridge abstract mathematical and sensorimotor knowledge (Papert, 1980). Researchers have employed gears in open-ended, hands-on interview tasks to examine students' problem-solving strategies (Metz, 1985) and as interview props to see how students' explanations develop through interaction (Metz, 1991) and with age (Lehrer & Schauble, 1998). Other researchers have used the mathematical properties of gears to teach fractions (Andrade, 2011) and proportionality (Bamberger, 1999).
While the kids in these studies seemed, for the most part, qualitatively aware of the effect of gear size on the rotational speed of different sized gears, they were less able to provide a mechanism to explain the difference (Lehrer & Schauble, 1998). Mechanical advantage is not a concept that students "get" intuitively, and much of the research cited above introduces gears mounted to a gear board, a wall, or the like, rather than in an actual use context that would require the participants to explicitly attend to gears' dynamic features. One exception is in the Lehrer and Schauble study, which included a section where the children were also asked to explain how gears worked on a bicycle and why a rider would want to shift gears (Lehrer & Schauble, 1998). To aid in the explanation, the children hand-pedaled a bicycle while the gears shifted. Many of the older children recognized that gears had something to do with pedaling difficulty. However, only about 20% of the older kids even hinted that there might be a trade-off between pedaling effort and speed (Lehrer & Schauble, 1998). Several recent studies have begun using gears as a vehicle for teaching mechanical advantage (Chambers, Carbonaro, & Murray, 2008; Lindgren & Johnson-Glenberg, 2013; J. A. Taylor, 2001).

These studies suggest that mechanical advantage is a difficult topic for children to grasp, even given a familiar context and immediate haptic and visual feedback. However, children do not often subject themselves to situations where the full range of gears available to them is needed like adult cyclists do. Additionally, during my own interviews with fifth-grade students (Drake & Lee, 2013) several of the students had no experience riding a bike "with speeds." Adults who participate in cycling groups, on the other hand, subject themselves to a range of road grades at speeds that seem to require them to be more cognizant of the effects of gearing on their performance. Plus, while children may
ride their bikes for a few minutes to school or a friend's house or tooling around the neighborhood, participants in adult cycling groups have years of experience riding several times a week for several hours at a time. This prolonged, purposeful exposure may provide the adults with distinct understandings of mechanical advantage.

**Literature on knowledge of air resistance**

To find literature relating to the teaching and understanding of air resistance, I searched the ERIC, Education Source, and Google Scholar databases. The queries I used included "air resistance," "aerodynamic," "aerodynamic drag," "air drag," and "pressure drag" as well as combinations of these queries and "education," "knowledge," and "concept." The results of these searches fell into three categories: 1) performance studies, 2) lesson plans, and 3) education studies. "Performance studies" were professional studies on the influence of air resistance on technological or athletic performance. Some of these were included in the canonical description of air resistance (see Chapter 5) below. "Lesson plans" presented instructional procedures for teaching about air resistance. "Education studies" reported on the effectiveness of an instructional approach to teaching air resistance. Included in these educational studies are studies focused on participants' conceptual understanding of Physics, including air resistance. Both lesson plans and education studies are included in this review.

The results in these included categories predominantly focused on air resistance on falling or ballistic bodies (e.g., Y. C. Lee & Kwok, 2009; Oberle, McBeath, Madigan, & Sugar, 2005; Whitaker, 1983). Oberle and colleagues (2005) identified what they called the "Galileo Bias," where the effects of air resistance on falling bodies are ignored and it is assumed that the bodies released simultaneously will hit the ground at the same
time. For the students who exhibited it, this bias was persistent even after repeated experimentation. On the other hand, diSessa (1996) reported that Physics students routinely adopt a narrative related to terminal velocity in which air resistance increases to the point it balances the gravitational force and velocity becomes constant. This “balancing forces” idea was supported by the solution strategies adopted by undergraduate Physics students working through a series of problems related to terminal velocity (Sherin, 2001).

When their attention is focused on horizontal motion, students recognize the ability of air to resist motion (McCloskey, 1983; Smith III et al., 1993). Elite triathletes take this further and center their knowledge on concepts that give them a competitive advantage, such as drafting and drafting techniques (Hirsh & Levy, 2013). Still, Hirsh and Levy noted that further research was needed to characterize people's initial understandings of air resistance, including using interviewing techniques rather than questionnaires for data collection.

**Research Questions**

In this dissertation, I will address the following three research questions:

1. What are the characteristics of participation in a cycling community of practice? What opportunities exist or are created for learning through participation?

2. How do cyclists describe and explain mechanical advantage? How is it related to their participation in cycling practice?

3. How do cyclists describe and explain air resistance? How is it related to their participation in cycling practice?
Dissertation Organization

For rhetorical purposes, I included a good deal of the fundamental literature in this introductory chapter. As a result, the next chapter will present the methods I used in this study. The three subsequent chapters will then present the findings relating to cycling practice as a social environment for learning (RQ1) followed by cyclists' practice-linked understandings of mechanical advantage (RQ2) and air resistance (RQ3).
CHAPTER TWO

METHODS

Focal Community

This dissertation examines learning and understanding in the context of adult recreational cycling. While bike riding is familiar to many, the practice of cycling in groups is not as widely understood. Therefore, below I am presenting a description of the history of the group as well as its current makeup.

The cycling community I selected for this study is the Downtown Cycles\(^1\) Wednesday Night Ride group. They are associated with Downtown Cycles (DTC), a small, independent bicycle shop in a mid-size city in the Rocky Mountain Region of the United States. The history of the group presented below shows how the evolving relationship between the shop and the ride group influenced the group's current culture.

Community Background

**In the Beginning: The Wednesday Night Recovery Ride.** The Wednesday Night Ride (WNR) was instituted in 2005 by the original owners of DTC as a "recovery ride" for members of the Wheelmen, the local competitive cycling club. As a recovery ride, the WNR developed a reputation of being both slower and more collegial than other Wheelmen rides.

\(^1\) All proper names used in this dissertation are pseudonyms.
Changing Owners: WNR for Beginners. In late 2007, the shop was sold. The new owner enlisted Kali\(^2\), an advocate for women's cycling, trainer, and former professional cyclist, to harness the ride as a means for introducing women to the sport and supporting their continued participation. In 2008, the local newspaper published an article announcing the WNR as a ride friendly to beginners and women, which attracted Celeste and Dana to their rides. Both Kali and the owner were powerful and well-respected cyclists, and they enforced beginner-friendliness by controlling the speed of the group and disinviting riders who did not buy into the new rules. To further their aims of supporting women and beginners, they incorporated more structured, team-building events and instruction into the weekly ride. While there is no indication that these were frequent occurrences, their inclusion at all was a marked departure from the typical "weekly ride."

Today's WNR. After a few years, Kali moved out of state, and the shop was sold to Wally. Wally took a more laissez-faire approach to the WNR, coming out occasionally to chat with the group and to hand out "nutrition" samples but returning to the store before the ride began.

This approach allowed the riders to decide what they wanted out of the ride. Though the ride became decidedly less beginner-friendly, it still maintained that reputation through the beginning of the study and in the minds of several of the participants. My observations began in the second year of Wally's ownership.

\(^2\) The names of certain individuals are introduced here because they will reappear throughout the dissertation.
Participants

Throughout my observations, the group was led primarily by four cyclists—Dana, Celeste, Dean, and Kurt. Dana and Celeste were both women in their early-40s, and Dean and Kurt were men in their mid-60s. Celeste's and Dana's roles as ride leaders reflected greater participation by women in the WNR than is typical in other riding groups (e.g., T. D. Brown, O’Connor, & Barkatsas, 2009). This was a legacy of Kali's activism with which she was doubtless pleased.

The WNR attracted approximately 10 cyclists per week, with as many as 30 riders and as few as three riders attending on a given week. The core of the group included approximately 10 cyclists who attended regularly, though by no means every week.

Setting

DTC is located in a mountain valley that is home to many outdoor recreation opportunities. Relative to the valley, the city is nearly centered north-south and against the mountains on the east. While the east side of the valley is being developed rather rapidly, the west side is still comprised mainly of agricultural land, with a few small communities scattered throughout. The relative flatness and lack of traffic on the roads and highways through this area make them popular among local cyclists looking to "get in a few miles." For those cyclists looking for more challenge, the mountains ringing the valley provide multiple opportunities to "get vertical."

Each week on Wednesday, the group meets at 5:30 pm in the parking lot of DTC. Lasting between 2 and 3 hours, the ride covers between 30 and 50 miles. During the two years of observation, the group routes amounted essentially to variations of four different routes.
Data Collection

Understanding the components of the emergent goals framework (discussed in the previous chapter) together requires systematic, in situ observation as well as in-depth, formal interviewing. The sections below detail the methods I used for data collection.

Participant Observation

Participant observation has a long history and is frequently used for documenting practices in the wild. The very terms "participant observation" hint at two different roles for the researcher. First is the role of participant. Participant observation has been defined as the "context in which [fieldworkers] assume membership roles in communities they want to study" (Angrosino & Rosenberg, 2011, p. 470). As a participant, the researcher's role is to behave as a member of the community, essentially trying not to rock the boat with their presence. In assuming a membership role in the community, fieldworkers get close to the other community members. In their other role as observers, however, they must find a way to maintain or at least achieve some analytical distance to allow them to systematically analyze the group and the context(s) in which they operate.

Participating and observing cycling adds its own set of challenges that are not typically encountered in other situations for observation. Some researchers have even argued that activities like cycling may be too strenuous for ethnographic research (Lorimer & Lund, 2003). Where other observations can take place in a single or a small number of relatively stationary settings, the setting for a cycling ride is constantly shifting as a direct result of the cyclists' own physical efforts. As noted previously, cycling groups can cover between 30 and 50 miles in a single ride without giving it much thought. Over
this distance, the physical relationship between the cyclists is constantly changing due to
shifts in formation, automobile traffic, and terrain, to name a few.

My observations of the WNR took place during the 2013 and 2014 cycling
seasons, which begin and end with Daylight Saving Time (March – October). I employed
methods typically used for observations—field notes and video records—modified for the
unique constraints of cycling observations.

**Field notes.** Emerson, Fretz, and Shaw (2011) recommend that fieldworkers use a
two-step process to record field notes. The first step is to record "jottings" or quick
reminders to assist in the recall of important events from the observation. These jottings
are intended to be relatively unobtrusive and not take much time to record. In some
settings, they can even be recorded during the observation. Recording full field notes is
the second step. This is a time-consuming step and can take as long to record field notes
of an observation as it did to make the initial observations. Because the act of
remembering is inherently an act of reconstruction, the use of jottings as a memory aid
can be extremely beneficial.

Group cycling is not an activity that lends itself to in-observation note taking.
Throughout each ride, I tried to take "mental notes" and maintain a running narrative in
my head of observations I wanted to remember. Because high levels of exertion are
contraindicated for good performance on memory tasks (Mueller, Gibbs, & Vetere,
2008), this was likely a hit-and-miss proposition.

I audio-recorded my "jottings" during my drive home following each ride using
an audio recording app on my phone. These recordings begin with the date, the route of
the day, and a list of all of the participants I could identify. If I did not remember or catch
the name of a participant, I described their appearance (chiefly apparel and bike) as well as possible in case they became regulars at some future point. After that, I followed with a roughly chronological account of what I observed, including interactions with other cyclists, the group's interactions with new cyclists (if any), and formations used at various points in the ride. I tried to be as complete as possible in these descriptions as it was sometimes several days later that I was able to record full field notes from these recordings. Though it did not happen every time, I tried to finish the recordings with an observational or analytic aside for things to look for in the current ride or on future rides.

After I started video recording rides during the second season of observation, these jottings came to focus more on my reactions to the events of rides, emotions I felt during the ride, and any potentially salient physical sensations during and following the ride.

In most cases, I was able to produce full, written field notes from jottings for each ride within a couple of days of the ride. However, for some of the video-recorded rides, I overlooked the recordings and did not produce extended field notes. This did not happen often and the combination of the jottings and video record for these rides seems to be sufficient for this study. Examples of jottings and field notes are included in Appendix B and Appendix C, respectively.

**Ride videos.** Beginning in June 2014, the second year of observation, I wore a point-of-view camera mounted to my helmet to record the events of each ride. I chose the GoPro Hero3+ Silver Edition because, at the time, it was the only camera capable of recording a 2-3 hour ride and had the best video and audio quality. Point-of-view (POV) cameras are popular in many outdoor sports, including mountain biking. However, it is
rare to see a road cyclist with any sort of camera during a ride. This is mostly due to the perception that watching POV video for road rides is boring. More recently, cameras have gained in popularity with the road crowd as a means of recording inappropriate, unsafe, or illegal behavior by the motorists they encounter. Several times throughout the study I was asked "Did you get that?" by other cyclists, referring to a motorist's behavior. While the recordings were good enough for analytical purposes, I was not able to capture license plate numbers as some of the cyclists wished.

POV cameras have been used successfully in previous studies for data collection (e.g., Spinney, 2011; K. H. Taylor & Hall, 2013; Umphress & Sherin, 2014). In these previous cases, the cameras were worn by participants. In this respect, my approach is more "traditional" with the researcher capturing the data. I chose the helmet mount because 1) it isolated the camera and its microphone better from the road vibrations than direct mounts to the bicycle (this effect was noted while researching available POV cameras and viewing YouTube videos), and 2) it mapped better to my point of view as a cyclist, showing more of what I was looking at (and moved away from the "butt shot" that would have resulted from a handlebar mount).

My intention was to only record segments of the ride I deemed salient to the coming analysis, but after losing the first ride's video to a stray button press, I chose to run the camera continuously and scrub the data after the fact.

**Interviews**

Participant observation is necessarily limited to those aspects of the practice that occur during observation. To get beyond this limitation and explore other aspects of the practice and an individual's participation therein, researchers have used both formal and
informal interviews. The goal of ethnographic interviewing is to unpack and gain insights into the meanings of particular aspects of the practice (Spradley, 1979).

**Informal interviews.** Informal ethnographic interviews seem conversational to the interviewee, though the researcher maintains a focus on gathering specific information related to the study's research questions (Spradley, 1979). Among the segments typical of the group's rides, which are described in greater detail in the next chapter, are several segments that are amenable to informal interviews—the pre-ride meet up, segments where the group rides in two-abreast and unstructured formations, and in-ride regrouping points. I used these times to learn about the other riders—their cycling history (e.g., how long they have been riding, how long they have ridden with the group, how they maintain their bikes,), goals for the year (e.g., races they will participate in, fitness plans they are using, how they feel they are doing with respect to their goals), what they did outside cycling, what they thought about the group, etc. Because all of the "regulars" knew that I was also studying the group, these conversations also included direct discussion of my study (often including questions about when I would be done and whether they could read the final product). These discussions served to increase my integration into the group and provided information useful for creating profiles of each of the riders. These informal interviews and conversations helped me identify riders who seemed most likely to contribute to my study and would be open to more formal interviews.

**Formal interviews.** For this study, I developed three semi-structured interview protocols—Relationship to Cycling, Mechanical Advantage, and Air Resistance. The Relationship to Cycling interview explored the cyclists' histories, including how they
were introduced to the sport, their history riding with groups, and the current state of their participation. While the other two interviews focused on the cyclists' understandings of their titular phenomena, the cyclists' responses to some of the questions revealed information about the norms and values of the group. During the formal interviews, I conducted three separate interviews with each of seven cyclists.

The interviews were designed to take approximately 60 minutes each. I conducted three separate, one-on-one interviews with each of seven cyclists in an office in the Education Building following the second year of observation. Each interview was recorded using a digital video recorder.

**Relationship to Cycling Interview.** The primary goal of the Relationship to Cycling interview was to gain a clearer sense of each cyclist's trajectory of participation in cycling and in the DTC group. The questions in this interview were intended to encourage the cyclists to tell stories about events and people throughout their participation in cycling that helped them learn what it is to be a cyclist. The questions begin by asking how the interviewee first began cycling. The phrasing was intended to be vague enough to allow the interviewee to respond as far back as when they learned to ride a bike or to confine it to their more recent return to biking as a sport rather than a mode of transportation. None of the interviewees began their cycling history prior to picking up a bike as an adult, though several mentioned their childhood biking experiences in passing. Because the shift from riding alone to riding in a group seemed to be a momentous occasion in the development of a cyclist (and marks the point at which they began an inbound trajectory), the next questions focused on their early experiences with group riding and the DTC group in particular.
After the history section, the next questions dealt with how they positioned themselves within the group—what they felt their strengths are, which other cyclists they compared themselves to, and which cyclists they thought were best. Additionally, the interview included questions intended to gauge how the cyclists identified and engaged with new riders. These questions were intended to provide some insight into what the cyclists thought were important characteristics for being a cyclist and for their own identities as cyclists in the DTC group. The protocol for the Relationship to Cycling interview is in Appendix D.

**Physics content interviews.** The emergent goals framework requires interviews to characterize participants' knowledge beyond how that knowledge is manifest in practice (Saxe, 1991). The extent to which knowledge can be manifest through practice is inherently limited by the circumstances of the observation. For expert or long-time participants, much of the knowledge employed may be internalized to a great degree. Additionally, the routine nature of many practices reduces the need to make explicit any of this knowledge for problem solving. To examine the cyclists' knowledge about the phenomena they encounter through their cycling practices, I used interview protocols that can charitably be described as "semi-clinical." Clinical interviews are intended to uncover the nature of the interviewee's thinking (Piaget, 1963). The interviewer engages the interviewee by posing problems. As the interviewee responds, the interviewer poses additional questions to encourage the interviewee to elaborate on their responses. The real challenge of this method is making sure that the line of questioning does not suggest desired responses for the interviewee. That said, clinical interviews have been well and successfully used in physics education research (e.g., diSessa, 1993).
While my interview protocols did include several questions that followed the clinical tradition, I intended for other questions to engage the cyclists in telling stories about their deployment of phenomenon-related knowledge throughout their participation. These questions were worded to elicit stories relating to generalized thinking as well as thinking during specific events.

Because the physics content interviews covered two relatively unrelated topics, I divided the Physics topics into separate interviews that took approximately an hour each. The specifics covered by each of these interviews are as follows.

**Mechanical advantage.** The mechanical advantage interview had four sections: 1) general bike knowledge, 2) ride-specific gearing, 3) gear ratio questions, and 4) atypical drivetrains. The General Bike Knowledge section asked the cyclists to draw a bike, describe generally how to “make it go”, and their strategies for selecting gears in a ride. The first part of this section followed the format used by Piaget (1963) and other bike drawing studies (e.g., Greenberg, Rodriguez, & Sesta, 1994). The intent of this was to assess what aspects of the bike and its use were important to the cyclists. This discussion segued into discussing gears and gearing strategies.

After discussing gearing generally, the Ride-Specific Gearing section focused the discussion on four ride segments that the cyclists had ridden—three that were routinely included in Wednesday Night Rides, one that the cyclists had ridden as part of a special event the previous season—and one that none of the cyclists had ridden previously. The intent of this section was both to elicit stories about how the cyclists approached gear selection across each of these segments. The third section of the interview asked the
cyclists to reason through selecting gearing with similar gear ratios for two different sizes of driver gear (chainring).

In the final section, Atypical Drivetrains, I showed the cyclists various historical bicycle drivetrains that applied different machines for mechanical advantage. This section sought to probe what features cyclists attended to when assessing bikes and how they would reason through adjusting the mechanical advantage of each of these bikes. The protocol for this interview is in Appendix E.

The findings in the Mechanical Advantage chapter (Chapter 4) report primarily on the cyclists' responses to the Ride-Specific Gearing and Gear Ratio segments of the interview.

Air resistance. The Air Resistance interview assessed the cyclists' understanding of the causes and role of air resistance in cycling practice. This interview was based in part on the survey developed by Hirsh & Levy (2013). While their focus was on assessing triathlete's understanding of air resistance and drafting as complex systems, my task was more generally about how recreational road cyclists thought about and dealt with air resistance in and through their own practices. The questions can be broken down into three sections: 1) the effects of wind and air resistance on a single cyclist; 2) practices and knowledge related to drafting; and 3) the effect of equipment changes on air resistance. The first section dealt primarily with how the cyclists experienced air resistance and how it affected their performance. The second section, on drafting, included three lines of questioning: 1) how the cyclist defined drafting and acted on that definition in the course of a ride, 2) what drafting formations they were familiar with, and 3) comparing the level of effort of various cyclists in a range of formations. The final
section dealt with the cyclists' assessment of the aerodynamic effects of certain equipment choices, which were intended to tease out how much thought they gave to the two components of air resistance—form drag and skin friction. The protocol for this interview is included in Appendix F. Chapter 5 reports on findings based primarily on the drafting questions.

Data Summary

Over two years of observation, I received signed consent forms for 30 cyclists—15 men and 15 women. Seven of these cyclists, four women and three men, agreed to be interviewed.

The data collected for this dissertation covers 48 rides, with 18 rides being video recorded for a total of 37 hours of ride video and 128 pages of field notes. I conducted 19 interviews (two cyclists chose to combine their science-related interviews into one session each) for a total of 26 hours of video. A detailed list of the data corpus is provided in Appendix A.

Data Preparation

Though not officially part of the analysis process, data preparation includes all the processing tasks needed to ensure that the data are ready for analysis. Because each type of data collected required different techniques for preparation, they are presented separately here.

Interview Data

The primary means of preparation for the interview data was to transcribe each interview video. I transcribed approximately 75% of the interviews and an undergraduate assistant transcribed the remainder. Given that the focus of interviews is on getting the
cyclists to talk about their history in cycling and their understandings of phenomena they experience, the content of their utterances is more important than the manner in which they deliver the utterance or the interaction that led to it. These transcriptions captured statements made by both the interviewer and the interviewee, but omitted pauses, stutters, minor interjections from the interviewer, etc. Where gestures were important to understanding what was being said, the gesture was recorded in brackets at the point in the conversation it was made. The transcripts were timestamped at each principal interviewer question.

Transcribing the interviews provided an opportunity to reflect on and review the content of the interviews. During this period, I started putting together many of the ideas that I used in coding the interviews later.

**Ride Videos**

To prepare the ride videos for analysis, I created a time-referenced content log of the events of the video (Derry et al., 2010). I used an event-based scheme for producing my content logs—creating entries when the ride formation changed, when riders swapped turns at the front of the pack, and when the group stopped at regrouping points. I flagged entries that corresponded to segments of video where conversations were recorded clearly enough to transcribe. Additionally, conversations and events that were of particular interest for this study were marked as "interesting." These included conversations relating to cycling practice ("how we do things"), air resistance, and gearing.

**Data Analysis**

In addition to theoretical direction, Saxe's (1992) Emergent Goals Framework also provides analytical guidance. Such being the case, this section is organized around
the components of the framework: 1) the structure of the practice, 2) social interactions, 3) norms and artifacts, and 4) prior understandings (Saxe, 1991).

**Characterizing the Ride Structure**

The first parameter of the emergent goals framework that needs to be understood is the structure of the practice (Saxe, 1991). The structure of the activity includes the "prescribed objectives and rules that have implications for the [participants'] emergent goals" (Saxe, 1992, p. 222). In other studies using this framework, this has been interpreted to mean the typical "order of events" for the practice. For example, Taylor (2009) identified three phases in low-income students' purchasing practices—1) selection of items, 2) payment, 3) change given. Nasir and Hand (2008) described the differences in approach to basketball practice between middle and high school teams in the same district. In each study, the goal of this breakdown was to help understand the opportunities and limitations imposed on mathematics problem solving afforded by the practice.

To analyze the structure of cycling practice and its role in science-related goal formation, I primarily used the field notes and ride videos. My first task was to establish the "phases" of a "typical" ride. The first part of this analysis began during the production of field notes. To help make the field notes easier to follow, I sectioned the field notes using headings. These headings marked major events or the beginnings of segments for a particular ride. I compared these headings against events in the ride video content logs looking for recurring patterns of events across the various routes that the group followed. I noted that events were marked by changes in average speed, riding formation, and the presence or absence of conversation. The changes in speed were verified by cross-
checking identified segments with my personal GPS data collected during each ride and stored on strava.com.

**Analyzing Social Interactions**

The second parameter in the Emergent Goals Framework is social interactions. For my analysis, I looked at social interactions that directly addressed either gearing or air resistance. I began by checking the ride content logs to identify segments flagged as "conversations." Next, I reviewed the transcripts of those segments for conversations where members of the group engaged in discussions relating to scientific topics of interest. Because the turns in each of these conversations were short (you only have so much air for talking in the middle of a ride), I coded each conversation at the turn level, focusing on the purpose of the utterance within the conversation—what it referenced, how it positioned the speaker, and how the speaker used their knowledge of the phenomenon.

These interactions typically took a few different forms: instruction, shared ride recollection, and storytelling. Instructional interactions are when a cyclist or cyclists help other cyclist(s) with a skill or other aspect of participation. Some of these were extended interactions with multiple turns, gestures, etc. Others consisted of single or a few turns. In any case, these interactions had a "source" and a "recipient". Shared ride recollections were instances where the main participants in a conversation engage in a conversation about a ride that they all experienced, typically in the recent past. Finally, storytelling conversations were characterized by one or a small number of cyclists recounting a ride to another cyclist or cyclists who had not participated in the ride being recounted.
In addition, many questions throughout the formal interviews were intended to elicit stories of past interactions with cyclists. I looked through these responses for recollections of specific interactions with other cyclists. To be considered for analysis in this instance, the recollection needed to be of a specific interaction and provide details as to the way that the interaction played out. I analyzed these recalled interactions in much the same way as I did the observed interactions.

**Analyzing Practice-Linked Norms and Artifacts**

The third of Saxe's four parameters covers practice-linked norms and artifacts. Of particular interest are those norms and artifacts that support the emergence of disciplinary content-related goals. Nasir & Cooks (2009) called practice-linked artifacts and the norms surrounding their sanctioned use "material resources." They argued that access to these resources was key to both learning within a community and to developing a practice-linked identity.

With this in mind, I used the next pass through the data to identify material resources available in the group and how they came to be used by the members of the group. Some important equipment was previously documented by Albert (1984) and O'Connor and Brown (2007) in their sociological studies of professional and competitive amateur cyclists, respectively. For this study, the identification of this equipment and other materials used by the cyclists is not simply to account for them but to use that accounting to understand the role that the use of this equipment plays in cyclists' understanding of cycling-related phenomena.

In determining the relationship between material resources and physical phenomena, I began with my own experience in cycling as a baseline for setting my
expectations. At every group ride, I noted the equipment used by the various cyclists in the group and what deviations from implicit norms warranted comment from others in the group. These deviations and comments were recorded in the field notes. This helped me to identify the peculiarities of equipment that the cyclists in this group attended to and valued. For many new cyclists, their equipment, clothing, etc. made them stand out from the group. Because of this, I used equipment to identify newcomers when their names were not known.

Several questions across the three formal interviews were intended to elicit the cyclists' understanding of various pieces of equipment, the uses of the equipment, and its role in the cyclists' knowledge about mechanical advantage and air resistance. For example, the last question of the air resistance interview asks the cyclists to reason through various equipment substitutions and order them based on their relative contribution to reducing air resistance (e.g., changing out baggy clothes for tight-fitting clothes). Analyzing this segment of the interview focused on identifying the features of the various pieces of equipment that the cyclists point out and their reasoning for arranging the equipment in the order they did.

Analyses of ride videos looked at how the cyclists used the arena and setting in which they rode. My use of "arena" and "setting" come from Lave (1988), for whom they meant the physical arrangement of objects within a space and the social construction of that space. In the content logs, I recorded the formations the cyclists adopted at various points in the ride, including the arrangements of the cyclists, the group's location, and their use of the road. Examining these gave an idea of how the cyclists socially produced
the space in which they rode and the role that production played in their understanding of the focal science content.

**Analyzing Cyclists' Prior Knowledge**

One of the goals of the Relationship to Cycling interview was to establish each cyclists' history with the sport—why they started cycling initially, how they came to ride with the DTC group, and why they keep riding. My intention with this was to establish, in part, the practice-linked identities they sought to develop. Additionally, I hoped that by exploring their cycling histories, I could understand the goals, events, skills, and knowledge each cyclist felt was important to their becoming the cyclist they were at the time of the interview. I used these as an analog for the cyclists' prior knowledge entering the interviews. To analyze their cycling narratives, I set about creating technobiographies for each of the interviewees.

The term "technobiography" was coined by Henwood, Kennedy, and Miller (2001) as they explored the effects of technology in women's lives through the stories they told about interactions with technology. The idea was later used to inform the uptake of motion capture animation and video production technologies by a youth engaged in a computer clubhouse (Barron, Wise, & Martin, 2013). While a bicycle is not necessarily the high-technology of the previous stories, the importance of bicycle technology to cyclists is inarguable. The cyborg/centaur nature of their practice has been explored to some degree previously (e.g., Spinney, 2006).

To develop technobiographies for each of the interviewed cyclists, I identified stories they told that included enough information to locate them in time. I ordered these stories chronologically to construct a timeline of their participation, from their earliest
cycling recollection to their current participation. I never anticipated these to be veridical accounts of their participation, but rather viewed them as a product of 1) their current relationship to cycling and the WNR group, 2) their relationship to me and their assumptions about what I "wanted to hear," and 3) what "actually" happened.

The results of the preceding analyses are presented in the Cycling Practice chapter (Chapter 3).

**Analyzing Mechanical Advantage Thinking**

The data I collected in this study provided two windows into how cyclists think about mechanical advantage and gearing. First were the conversations the cyclists had during the rides. These conversations were analyzed as part of understanding the social interactions relating to gearing within the cycling group and were covered in a previous section. The second window was through the formal interview, particularly the mechanical advantage interview.

To analyze the cyclists' gearing thinking in the mechanical advantage interview, I started by using an open coding scheme (Saldaña, 2012). After open-coding four interviews, I noticed that codes relating to effort and efficiency occurred frequently. The potential importance of effort and efficiency was in line with my expectations based on my own cycling experiences and the focus of much of the biomechanical and physiological research into cycling. I chose to focus my next pass on understanding how effort and efficiency played into cyclists' talk about gearing and mechanical advantage. Chapter 4 explains in greater detail the importance of these constructs for cyclists.
Analyzing Air Resistance Thinking

In reviewing the Air Resistance interview videos and transcripts, I noticed that the cyclists seemed to be operating in a space where they understood two forms of drafting—one as practiced and one as ideal. While the cyclists repeatedly stated that they "didn't know the science" behind their gearing choices, they seemed comfortable with their gearing selection within the parameters of their practice. Drafting and air resistance mitigation had a different valence—they understood their practice as inherently constrained by the skills and individual goals of the other cyclists and other realities of the road; while the ideal was a potentially achievable improvement upon that practice.

So, my coding focused on identifying characteristics of the cyclists' ideal versions of different air resistance mitigation techniques and the types of constraints that shape these techniques in practice. For an example of these constraints, the cyclists always rode on roads and streets built and regulated for cars. As secondary users of these facilities, the cyclists were legally obligated to travel as far to the right as "practicable." The goal of this coding was to understand the role of constrained and permitted performance on their understanding of air resistance, which is discussed further in Chapter 5.

Reliability

Ensuring the reliability of their analyses and conclusions is a key responsibility for all researchers. For this study, I used three strategies for assessing the reliability of these results. Firstly, and most basically, I relied on my own experience as a cyclist. At the beginning of the study, I had 8 years of experience as a cyclist and participant in two ride groups. Riding and talking with other cyclists gave me several insights into how they thought and what aspects of practice were important to them individually and as a group.
As I formulated the findings for this study, I continually asked: “How does this fit with what I already know about cycling?”

The second strategy I used was triangulation between the events I observed in the rides and the cyclists’ responses to the questions. With the large corpus of ride field notes and video data collected (Appendix A), I was able to stitch together an acceptable picture of what was typical of cycling practice for the DTC group and what was atypical but potentially noteworthy. Because the formal interviews took place after the observations, I used several of the interview questions to test the cyclists’ support for my observations (e.g., cyclists’ thoughts on the importance of tight clothing primarily for performance versus social reasons). I took alignment between the cyclists’ interview responses and conclusions based on my observations as an indication of reliability.

Finally, I looked for commonalities across cyclists’ responses to interview questions. While differences in their responses can be useful in understanding how the cyclists engage individually in the practice, similarities in their responses can illuminate the common spaces of the practice.

**Ethics**

Data collection for this study began in March 2013 with the beginning of the cycling season. As noted previously, data collection activities at this point were limited to writing post-ride field notes of a public activity. Initially, I identified myself to the group as only a new cyclist. Over the following months, I made my intention to study the group known to the cyclists.

Initial IRB approval for this study was obtained on July 26, 2013, and first consents were obtained at the beginning of the ride on August 7. During the pre-ride
discussion, I announced the purpose of the study (to study individual and group goals) and made clear that at some point I might video record rides (prompting several of the cyclists to ask, "Why would you want to do that?"). I also informed them that I might ask them to be interviewed separately from a ride at some point and that they were free to say no. Recruitment continued throughout the observation period, with riders typically signing the informed consent document (included in Appendix G) during the pre-ride period.

Throughout the early weeks of the study, I identified potential confederates within the community who could provide additional information about the group and cycling practice. Of these, four consented to be interviewed formally—Kurt, Dean, Dana, and Celeste. Others either left the ride group or declined to be formally interviewed. Three others were identified from slightly more peripheral positions in the community who consented to be interviewed. Phoebe joined the group during the 2014 season and participated actively throughout the season. Sam had been an active participant, but his impending retirement and changes in group membership led him to reduce his participation. Reba attended intermittently throughout both the 2013 and 2014 seasons and regularly rode with Dana and Celeste in women-only groups.

Initially, the interviewees were to have been paid $10 per interview, for a total of $30. Because of difficulties filling the interview pool, I submitted and was granted IRB approval to increase this to $20 per interview and had each of the interviewees sign the updated consent form.
In keeping with Saxe's (1991) Emergent Goals Framework, this chapter presents a description of cycling as practiced by the Downtown Cycles Wednesday Night Ride group. The contents of this chapter are divided into two major sections. The first section, "Looking like a Cyclist" describes the practice-linked artifacts and associated conventions. The second section, "Rides as a Central Social Learning Activity" outlines the structure of the weekly ride. Aside from this structural overview, the goal of this section is to highlight the naturally occurring learning opportunities available to participants.

**Looking Like a Cyclist**

For anyone looking to be identified as a member of a particular group, dressing appropriately is important (Gee, 1990). Wearing an oxford button down and khakis would be entirely appropriate for a presenter at an academic conference but would be completely out of place at a rock concert. Similarly, bike riders seeking recognition as cyclists must adapt to the norms of dress within the community they wish to join. In this section, I describe the clothing worn by and equipment used by cyclists and the purpose they serve.

**Clothing**

Cyclists have a distinctive style of clothing (Figure 3) that all participants are expected to adopt if they are to fit in.
Figure 3. Celeste (front) and Phoebe climbing through a canyon during a local charity ride.

**Kit.** The most conspicuous element of a cyclist's clothing is the form-fitting, often boldly colored, jersey and shorts. The form-fitting nature of these clothes serves two purposes. Firstly, it makes riding more comfortable. Because cyclists maintain the same, seated position throughout a ride, pedaling causes loose shorts to bunch in the groin area leading to discomfort, chafing, and sores. Wearing tight clothing reduces the likelihood of this bunching.

Secondly, specialized, form-fitting clothing reduces the skin drag component of a cyclists' air resistance (Gross et al., 1983). Although skin drag is a smaller component of air resistance than form drag, any reduction in air resistance allows the cyclists to go
faster or reduce the power needed to maintain a given speed. Compared to baggier clothes, road cycling clothing can reduce air resistance by as much as 30% (Lukes, Chin, & Haake, 2005).

The bold, bright colors often associated with cycling kit are due to the NASCAR-style inclusion of logos of sponsors and other affiliated businesses or groups. The combination of logos and colors on the kit signify a cyclist's affiliation with a particular group. In the figure above, Celeste is wearing the DTC club kit for 2014, which was a relatively understated gray with white and orange highlights. Previous DTC club kits were largely red, white, and blue. Cycling groups change the design of their kits at least every couple of years (often yearly), which also places a temporal component to the communication of affiliation. Wearing an old kit can have positive or negative valences. Interpreted positively, the old kit can signal veteran status, especially when accompanied by veteran levels of in-ride skill. Conversely, old kit on a pudgier rider may indicate a lapsed affiliation and time away not well spent. Because of their ability to communicate affiliation, in some cycling circles, it is bad form to wear the kit of a professional team or kit indicating an achievement one has not earned (e.g., national champion colors or the world champion’s rainbow; Velominati, 2014). Among the members of the DTC, this prohibition is largely ignored as Kurt often wore a BMC Racing Team kit given to him as a volunteer at the Tour of California.

**Helmets.** Bicycle helmets have only been mandatory in the professional ranks since 2003 (Union Cycliste Internationale, 2003). At the time of this study, helmet use

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3 BMC Racing is a top-level professional team (UCI WorldTeam) that is sponsored by Swiss bike manufacturer BMC and previously employed George Hincapie, one of Lance Armstrong’s former teammates. Kurt had a special affinity for Hincapie and frequently referred to him simply as “George.”
was taken as given by the members of the DTC group and was mandatory for all local races and charity rides.

Bicycle helmets are designed to 1) protect the cyclist's head, 2) be lightweight, and 3) promote air flow. In the US, all bike helmets are tested to standards provided by the Consumer Product Safety Commission (1998). Because these standards are considerably less stringent than those for motorcycle helmets, the practical protection afforded by these helmets is still an active debate in public policy and academic circles (e.g., Pucher & Buehler, 2008; Robinson, 2007). Some researchers argue that helmets provide a false sense of security that encourages increased risk-taking behavior among both cyclists and motorists (Walker, 2007).

Maintaining the lightness of the helmet is accomplished using expanded polystyrene foam covered with a thin plastic shell. Large vents further reduce the weight and direct air across the scalp of the rider to keep their head cool. Newer, high-performance helmets began trickling into the local cycling communities during the study. These helmets featured much smaller vents and were marketed as being both lighter and significantly more aerodynamic than a standard, vented helmet. Aspiring racers and accomplished riders alike began adopting these helmets in an effort to further reduce their air resistance.

**Shoes.** Road cycling shoes are designed with on-bike efficiency in mind. Where typical athletic shoes are designed to cushion the foot and bend with the toes, road shoes are intended to be lightweight and rigid. The soles are made of hard plastic or carbon fiber. The rigidity ensures a more efficient transfer of energy from the legs into the
pedals. The outsole of cycling shoes is slick, with rubber pads only at the toes and the heel of the shoes to facilitate minimal walking.

Further power-transfer efficiency is achieved through the use of a cleat mounted to the outsole at the ball of the foot. This cleat clicks into the pedals, holding the foot position steady (allowing only small changes in angle) throughout the pedal stroke and, thus, over the course of a ride. When properly positioned, cleats can hold the foot in the most efficient position. Additionally, by being fixed to the pedals, cleats allow cyclists to apply power to the pedals throughout the pedal stroke, rather than just on the downstroke.

The Bicycle

The centaurs of Greek mythology were defined as hybrid creatures with the upper body of a human and the lower body of a horse. Sociologists have turned the idea of centaur back on equestrians to explore the oneness of horse and rider (Game, 2001). Similarly, a cyclist may be envisioned as a hybrid creature with a human upper body and a two-wheeled lower body. In fact, Spinney (2006) argues that interviewing cyclists off the bike results in an interview with an entirely different entity (a person rather than a rider). Such is the importance of the bicycle for the cyclist.

For a typical "bike rider," little consideration is given to the bicycle beyond its having two wheels and some gears. For the cyclist, it is a different story. Maximizing efficiency within one's budget is a primary concern—even for those cyclists, like Celeste, who self-deprecatingly declared, "I'm not techno at all. My bike is pretty." She immediately followed that statement up with "And it can climb... that's all I cared about." An efficiency-based interpretation leads to the conclusion that Celeste's bike has been optimized to enable her to efficiently climb the hills and mountains in the area. This
optimization includes a lightweight frame and gearing that allows for greater mechanical advantage.

Leisure-time cyclists must balance various options available on bikes when making a purchase to get the most efficiency they can for their intended use within their personal budget constraints. Frame materials and component specifications must be considered carefully—aluminum frames are cheaper but "harsher" and heavier than modern carbon-fiber frames; carbon fiber can be manipulated in many ways to yield different ride characteristics and weights; different drivetrain "group sets" can be lighter but costs increase quickly for gram-level weight savings. With few notable exceptions, the DTC cyclists rode late-model, mid- to high-grade carbon-fiber frames with upper-tier components. For context, the $2500 I spent on my bike meant that I had one of the less expensive bikes in the group.

The search for increased efficiency continues after the initial purchase. The most often cited first purchase is a new wheelset, which reduces rotational weight and increases aerodynamic efficiency.

The idea that more recent, lighter, and carbon-fiber bikes are superior (or at least preferable) to their older counterparts was demonstrated when Sam arrived for a ride on an 80's vintage Colnago bicycle (ride log, 8/6/2014). It had a steel frame, but most visibly, the brakes were Campagnolo "Delta" brakes. The bike was a work of art, and in Sam's hands, it was plenty fast. Another cyclist gave Sam a hard time for coming on such an old, heavy (seemingly inefficient) bike.
Putting It All Together

An episode included in Dana's technobiography (Henwood et al., 2001) emphasizes the importance of equipment and "getting the look" down. Approximately two years prior to the interview, Dana's neighbor was looking to get into the sport. Her neighbor was just looking to buy a road bike, but Dana recognized that being a cyclist required much more.

[My neighbor] said "Dana, I want to buy a road bike. What would you suggest?" I said, "Go to Downtown Cycles because they're really big on customer service and they can help you out."...When she came in, I said, "What are your goals?" And she said, "Well, I just want to ride." And I'm like, "Do you want to do like an all-women's race like Artemis, or are you interested in T3?" and she said, "No, I don't want to do anything like T3 but maybe Artemis." ...She's tall and thin and seems to be athletic... I said, "I would recommend a Felt bike [with Shimano] 105." I asked Wally, "What do you have? We don't want to go lower than 105 components for her." ...He had a bike. She tried it out and said, "Okay, what else do I need?" And I said, "Do you have cycling shorts?" "No." So, we pulled several cycling shorts off... also the jerseys... She's like, "I think I'll have it." ...I said "Okay, Wally, she needs to have everything she needs on there. We need to get water bottles... a bike bag... I want a spare tire in there, I want the levers... I want the things for the water bottles on there." ...She bought shoes to clip in and we got her socks. I mean we got her the whole nine yards so that she would be able to come out and cycle... She was in there for 45 minutes at the most and she walked out as a new cyclist.
Dana helped her neighbor purchase a road bike and all of the equipment needed for her to be "a new cyclist" when she was done. Dana made a few important distinctions relating to the woman's ability to be a cyclist. First, she referred the woman to DTC (as opposed to the internet or any of the other local shops), which had provided Dana a ready source of expertise in all things cycling. Beyond being a place of commerce, bike shops like DTC are also places for learning—giving advice on equipment or making mechanics available for one-on-one time.

Second, she establishes how deep into cycling the woman is willing to go initially by asking what her goals are—Artemis or T3. There are several all-women's rides, like Artemis, in the area. They allow riders of all skill levels to participate at their comfort level—from racing to simply getting out. Most of these rides are also tied to a charitable cause, like the regional cancer foundation. Participating in T3 (a one-day, 200-mile race) indicates a degree of competitiveness and seriousness that not all riders (new or otherwise) are willing to cop to. Dana ties the goal of participating in these to component levels. Ultegra and 105 are, respectively, the second- and third-tier component sets manufactured by Shimano. Even though both component sets would work perfectly well in either case, 105 is considerably cheaper and is associated with a lower level of competitiveness.

Third, she appraised the woman's fitness level based on physique ("tall...thin...athletic"). Although looks were generally regarded as deceiving when attempting to size up a new cyclist, the practice was still very much in use. Leaner is better. Smaller is better. Thicker riders were expected to be fast on the flats. "Tall, thin,
and athletic" places this woman right in the sweet spot for local women's cycling—light enough to climb quickly, athletic enough to keep up on the flats.

Finally, Dana piled on the clothing and accessories. Rather than asking "Do you need?" questions, Dana went with "Do you have?" if she even bothered asking. Equipped as she was, Dana's neighbor could join a WNR and escape much of the pre-ride scrutiny she may have otherwise faced.

Dana's shopping list for her neighbor is an excellent example of the equipment needed for an "entry-level cyclist." It also shows how far Dana has come since her first forays into cycling and interactions with the shop. Over years of participation, Dana developed a relationship with the shop that allowed her to act authoritatively in guiding the first steps of participation for her neighbor. When she started riding, Dana bought a bike hoping it would obligate the shop to give her advice, and now she successfully directed her friend's shopping experience, calling her attention to many overlooked pieces of equipment and sending her home well-prepared for her first ride. Table 1, below, lists the equipment Dana said was needed to walk out the door a "new" cyclist, along with a few items she overlooked. Examples and prices from the DTC inventory are also included.

Table 1.

*List of basic equipment that a new cyclist would need to purchase to successfully and safely participate in a group ride.*

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bike (Felt FR30, aluminum frame, 105 component spec)</td>
<td>$1500</td>
</tr>
<tr>
<td>Jersey (Pearl Izumi Select)</td>
<td>$55</td>
</tr>
<tr>
<td>Shorts (Pearl Izumi Quest)</td>
<td>$50</td>
</tr>
<tr>
<td>Pedals (Shimano PD-R540 SPD-SL)</td>
<td>$60</td>
</tr>
<tr>
<td>Item</td>
<td>Price</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>--------</td>
</tr>
<tr>
<td>Shoes (Shimano RP2)</td>
<td>$100</td>
</tr>
<tr>
<td>Seat Bag (Blackburn Local Medium)</td>
<td>$20</td>
</tr>
<tr>
<td>Tube (Continental 700c Presta)</td>
<td>$7</td>
</tr>
<tr>
<td>Tire Levers (Pedro's)</td>
<td>$5</td>
</tr>
<tr>
<td>Bottle Cages (x2) (Topeka Shuttle Water Bottle Cage)</td>
<td>$20</td>
</tr>
<tr>
<td>Water Bottles (x2) (Shop Water Bottle)</td>
<td>$14</td>
</tr>
<tr>
<td>Socks (Pearl Izumi Elite)</td>
<td>$14</td>
</tr>
<tr>
<td>Bike Computer* (Sigma Base 400)</td>
<td>$20</td>
</tr>
<tr>
<td>Frame Pump* (Topeka Master Blaster DX II)</td>
<td>$25</td>
</tr>
<tr>
<td>Helmet* (Giro Foray)</td>
<td>$65</td>
</tr>
<tr>
<td>Sunglasses* (Tifosi Jet)</td>
<td>$40</td>
</tr>
<tr>
<td>Gloves* (Giro Jag)</td>
<td>$20</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>$2015</strong></td>
</tr>
<tr>
<td><strong>Sales Tax (7%)</strong></td>
<td><strong>$141</strong></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$2156</strong></td>
</tr>
</tbody>
</table>

* Not included in Dana's narrative.

For many people new to the sport, this expense can take them by surprise. After all, a number of apparently acceptable (and similar looking) bikes can be purchased at the local Walmart for a third the cost and a helmet for a quarter of that. Alternatively, many of the one-and-done newcomers to the WNR participated on what might charitably be called "vintage" bicycles. While these alternate modes of entry are certainly available, the willingness of a newcomer to lay out the money for proper equipment signals a desire to be seen as a real cyclist.

Of the items that are frequently overlooked by newcomers but that can signal commitment, the helmet, frame pump, and computer are emblematic. The importance of the helmet to cycling practice was discussed at length earlier in this section. By purchasing a frame pump, one is acknowledging the likelihood of an in-ride flat tire and that one is willing to, if not able to, repair the flat and continue on the ride. A newcomer
attentive enough to buy a pump is also likely to purchase at least a spare tube, if not the
tire levers, needed to actually perform the repair.

Of different import is the bike computer, which signals an interest in
understanding one's performance quantitatively. With a computer, a cyclist can monitor
their instantaneous speed (along with other performance metrics), which enables the
cyclist to effectively ride at the front of the group and contribute to the function of the
ride. Tracking this ride data reveals verifiable improvements over time and forms the
basis for comparisons with other cyclists and training regimens for further improvements
(V. R. Lee & Drake, 2013). Only one of the regular DTC cyclists did not have a cycling
computer, a distinction of which she was very proud.

An initial purchase similar to that of Dana's neighbor is certainly enough to get
one started with the group, but the desire to replace and upgrade that equipment seems to
afflict many cyclists. Some upgrades (Table 2), such as the move from standard water
bottles to insulated bottles, will likely happen rather quickly and reflect an understanding
of some of the tricks of the trade for making rides more comfortable (e.g., insulated
bottles keep water cooler over the course of a 2+ hour ride). Other upgrades (e.g.,
purchasing a custom kit, helmet or bike) take more time to occur but signal a deepening
commitment to improvement within the sport. The team kit makes it easier for members
of the community to identify other cyclists as "one of us" and members of other cycling
groups to identify them as "one of them." Locally, wearing a Wheelmen kit identifies one
not just as a member of the Wheelmen, but also indicates an ability and proclivity for
riding fast. Among the DTC riders, those who were also members of the Wheelmen were
regarded as more skillful and, thus, worthy of emulation.
Table 2.

*Upgraded list of basic equipment that a cyclist may purchase as they progress to higher levels of participation*

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bike (Felt FR1, carbon frame, SRAM eTap component spec)</td>
<td>$9000</td>
</tr>
<tr>
<td>Jersey (Custom Team Jersey)</td>
<td>$125</td>
</tr>
<tr>
<td>Shorts (Custom Team Bib Shorts)</td>
<td>$125</td>
</tr>
<tr>
<td>Pedals (Look Keo 2 Max Carbon Pedals)</td>
<td>$160</td>
</tr>
<tr>
<td>Shoes (Sidi Genius Carbon)</td>
<td>$260</td>
</tr>
<tr>
<td>*Seat Bag (Blackburn Local Medium)</td>
<td>$20</td>
</tr>
<tr>
<td>*Tube (Continental 700c Presta)</td>
<td>$7</td>
</tr>
<tr>
<td>*Tire Levers (Pedro's)</td>
<td>$6</td>
</tr>
<tr>
<td>Bottle Cages (Elite)</td>
<td>$40</td>
</tr>
<tr>
<td>Water Bottles (Polar Bottle)</td>
<td>$35</td>
</tr>
<tr>
<td>Socks (Pearl Izumi Elite)</td>
<td>$14</td>
</tr>
<tr>
<td>Bike Computer (Garmin Edge 1000)</td>
<td>$500</td>
</tr>
<tr>
<td>Frame Pump (CO2 Inflator &amp; Cartridges)</td>
<td>$30</td>
</tr>
<tr>
<td>Helmet (Kask Infinity)</td>
<td>$370</td>
</tr>
<tr>
<td>Sunglasses (Oakley Radar Path)</td>
<td>$220</td>
</tr>
<tr>
<td>Gloves (Craft Glow)</td>
<td>$40</td>
</tr>
<tr>
<td>Subtotal</td>
<td>$10692</td>
</tr>
<tr>
<td>Sales Tax (7%)</td>
<td>$749</td>
</tr>
<tr>
<td>Total</td>
<td>$11441</td>
</tr>
</tbody>
</table>

* Unchanged.

Although procuring the items in either of the above tables is expensive, being able to dress right and having the right equipment is an important part of being a cyclist. But it is only a part. Gee (1990) notes that one must also engage with particular language, values, actions, and relationships "so as to get recognized as a distinctive sort of who doing a distinctive sort of what" (p. 155, emphasis original). Proving oneself a cyclist happens in-ride, where skillful control of one’s bike and maintenance of group norms
take the fore. The ability to recognize and perform what is "skillful" and valued is
developed and manifest through participation (Lave & Wenger, 1991). To demonstrate
what it means to participate in a cycling group, the next sections outline the structure of a
typical DTC group ride, highlighting the opportunities for learning and enculturation that
occur within that structure.

**Rides as Central Social Learning Activity**

A key recurrent activity for adult recreational cycling groups is the scheduled
group ride (Albert, 1999; O’Connor & Brown, 2007), which occurs at least weekly
throughout the cycling season. Where most of a cyclist’s riding is done either solo or with
a small group of riders of similar ability, the weekly group ride provides an opportunity
to interact with riders of different abilities. As with other interest-based activities, cyclists
self-select into their riding groups based on a variety of factors including ability and
social connections. While this serves to narrow the ability range for a given group, the
open nature of cycling groups all but ensures that there will be a mix of abilities on the
rides. A cyclist’s ability to maintain an appropriate speed determines whether they can
continue riding with a group. Beyond this, as I will show below, the support newcomers
receive in their early rides determines to a large degree whether they will continue to
participate and can also shape the trajectory of their continued participation.

**Overview**

Though the particulars of group rides vary from group to group, the structure of
the group ride is predictable enough that visiting cyclists can join and know generally
what to expect. This structure includes five main segments: preparing, gathering,
warming up, riding, and finishing.
1. **Preparing** (hours to days prior to the ride): Cyclists ensure the fitness of their bicycle for the ride and perform maintenance tasks. Cyclists select and gather equipment for the upcoming ride.

2. **Gathering** (0-20 minutes prior to the ride): Cyclists arrive at the appointed location for the ride to start. The group engages in conversations, plans or announces the day's ride, and makes arrangements for ad hoc rides for the rest of the week. This segment ends when the group begins to ride away from the gathering spot.

3. **Warming up** (0-15 minutes after departure): The group rides at a slower average speed than they will for the remainder of the ride. The formations are looser and allow for the cyclists to continue conversing.

4. **Riding** (up to 3 hours after departure): Following the warmup, the group's speed increases to their cruising speed. The formation tightens, and the riders ride in a line close behind each other. Little if any conversation occurs during most of the ride. The group can cover 25-50 miles over the course of a ride.

5. **Finishing** (0-10 minutes prior to ride end): The group slows again to warm up speed. The formation loosens and conversations resume. Individual cyclists may break off to return to their homes or continue with the group back to the starting location. The group may reconvene at a restaurant or coffee shop for post-ride conversations.

The sections that follow describe each of these segments in greater detail, with special consideration given to their particular instantiation in the DTC group and the implications for learning as changes in participation.
Preparing. Preparation begins in earnest the morning of the ride. As "serious leisure" cyclists (Stebbins, 1982), many of the cyclists in the DTC group worked typical 9-to-5 jobs. Rides began at 5:30 pm, so much (if not all) of a cyclist's preparation needed to be completed prior to work so they could arrive on time. For each ride, a cyclist must prepare the following equipment and materials: their bike, their clothing, water bottles, and "nutrition" (in-ride edibles, such as energy gels or protein bars). Other equipment, such as spare tubes and CO₂ inflators or frame pumps, are typically stored on the bike and are only changed out when necessary. Preparing one's bike for a ride includes cleaning the frame, cleaning and lubing the chain, and adjusting the air pressure in the tires. Depending on the cyclist, these tasks can be completed on a basis ranging between weekly and seasonally.

During their preparations, the riders also check the weather, particularly expected temperature and chance of precipitation. Based on this information, they decide what equipment to pack. For most of the summer, this is the standard kit—a jersey, shorts, shoes, and a helmet. In the early and late season (March, April, September, and October), rain and cold become more of an issue. The standard kit is supplemented with jackets, full-length tights, and weather-proof shoe covers. Cyclists who came inappropriately dressed (e.g., wearing warm weather clothing when the rest of the group has jackets) were teased to remind them to pay closer attention to the weather.

Gathering. The Wednesday Night Rides began in the small parking lot behind DTC, which was located right on Main Street near the center of town. The entrance to the parking lot was on a side street just behind the building. Beginning about 20 minutes before the ride, cyclists began arriving and positioning themselves near the rear entrance
to the shop. This pre-ride gathering period was a soft introduction to the practices of cycling for newcomers and introduced other avenues for learning through observing the process of ride planning and through interactions with the shop.

**Orienting New Cyclists.** For cyclists in the DTC group, proper attire is key not only to continued participation but the respect of the group. New cyclists often arrived at the shop dressed in exercise or mountain bike clothes (i.e., “baggies”, Figure 4). During the Air Resistance interview, I showed Figure 4 to Celeste saying it was how a newcomer showed up to a ride; she made it clear that such clothing was unacceptable while also noting that it signaled a need for special attention and instruction from the old-timers.

Oh, my gosh! Does he even have clipless pedals? He can't if he's wearing that. That's horrible... I'd at least pull them aside and let them know that the next time they come back, they'd better dress like a roadie, not like a mountain biker. We're talking about road, right? This isn't an all-inclusive cyclist. I'd tell them that the Thursday night mountain bike ride is what they're looking for.

Celeste's reaction shows just how out of place a rider would be showing up wearing baggy mountain biking clothes—it would be "horrible." At the same time, new riders commonly show up at the DTC rides dressed essentially the same way, with some even wearing regular exercise clothes (e.g., basketball shorts, t-shirt, tennis shoes). Roadies and mountain bikers generally make different sartorial decisions, which reflect their respective projected personae. Mountain bikers generally project a laid-back attitude, willing to sacrifice a bit of aerodynamics to keep their baggy shorts. Roadies' form-fitting clothing reflects the importance of efficiency to their practice. Celeste's mock statement
"You're at the wrong place" reflects the (sometimes) good-natured tension between the two groups.

Figure 4. A man dressed in mountain biking clothes (Benedict, 2012).

Wearing form-fitting clothing may be one way of identifying and identifying with road cyclists, but this clothing can also be a barrier to participation, as Celeste noted.

I dressed [in baggy clothes] like that because you're not comfortable in Spandex at that point... I didn't jump into spandex, but I also didn't try to ride with DTC in that. I did know my limits of coolness... [If a new rider showed up dressed like that,] we would be kind. Probably not necessarily behind your back. I would
never say it, I would hear it, though. "Give the new guy a break, he obviously doesn't know. As soon as he takes off his reflector, we'll tell him about the dress code."

Adopting the "proper" road cycling attire can be more difficult than simply paying the cost of the new clothes. With the exception of the preternaturally self-confident or the well-built, the decision to wear Spandex (or Lycra) in public can be a difficult one. For Celeste, it was beyond her "limits of coolness." For all riders, lycra cycling clothing is a form of "conspicuous consumption" (Mackintosh & Norcliffe, 2007) that visibly aligns a rider with "those" people—as a cyclist. Being a cyclist can be aspirational, a desired identity that some newcomers feel they have not achieved and may not deserve, yet. For others, being a cyclist is associating oneself with the "lycra louts," defined as the stereotypically obnoxious riders who embody all that is wrong with the sport (Horton, 2007). New riders, including Celeste, have to come to terms with cycling style before they feel comfortable joining a group.

On those occasions that cyclists come inappropriately attired, they can be viewed with suspicion. When asked how he sizes up newcomers to the group, Dean noted "I want to make sure when they come, they look like they have all the proper equipment... We've had guys show up and they have two [flat] pedals and a pair of shorts and a t-shirt. My first thinking of that is, 'Uh-oh.'" Before taking notice of their bike (or even attending to their bike at all), Dean viewed proper clothing and shoes as essential equipment indicating fitness and preparedness to ride. Wearing the wrong clothes was taken by many cyclists, including Dean, as a sign that the newcomer was likely to also behave dangerously.
Attire can certainly indicate that a rider is not "one of us." However, as Celeste noted, clothes can indicate an opportunity for learning. Showing up in cycling clothes can be a sign that one is in-the-know and can be expected to behave appropriately. Baggy clothes indicate a knowledge gap to be filled before the rider can be expected to participate meaningfully.

On a ride during the first year of observation, a rider's attire provided just such a prompt for instruction. Dylan, a runner who was attending for the first time, arrived at the shop. He was wearing a running shirt and shorts and had clipless pedals on his older-model bike. He was investigating cycling as rehab for a running injury.

[After discussing the day's route] Dean asked if everyone had ridden in a paceline before. Dylan said that he had never ridden in one, as the largest group he'd ever ridden in was one other person. So, Dean began explaining the basics of pacelining and how to draft. Basically, stay right behind the person in front of you, don't overlap wheels. He then qualified this saying that if you're really experienced you can overlap, but that you shouldn't until then. If you do overlap, give them lots of space because if you bump your front wheel into their rear wheel, you're going to go down hard. There were a couple of assenting "Yeah"s (field notes, 08/28/2013).

Dean's question, while verbally directed to the whole group, was intended specifically for Dylan. Dean (and other members of the group) only ever asked this question when new arrivals appeared to need instruction, spurred primarily by the newcomers' clothing choices. In this brief example, Dean provided a brief rundown of acceptable behavior for riding in a paceline. This instruction was perfunctory by design. The other riders were all
assumed to be familiar with paceline behavior, so Dean's primer was all review for them (as evidenced by the chorus of "yeahs" as he finishes). As an introduction to drafting, this lecture was actually quite terrible. However, the focus of this instruction was not on drafting. Rather, this lesson was intended to help the newcomers ride safely, specifically to warn them against getting too close to the riders in front of them. Other pre-ride safety lectures included descriptions of hand signals the group used to point out obstacles in the road and changes in direction or speed.

One important aspect of this event that the field notes do not capture is the gestures that Dean may have used during this instruction. In other such introductions, the lecturer used their hands as stand-ins for either the cyclists or their wheels in modeling correct behavior, often interchangeably. In other instances, the lecturer will maneuver their bike to model appropriate positioning at full-scale. This approach gives the rider a sense of just how close to ride and not ride.

**Planning the Ride.** For the cyclists of the DTC, the main function of the gathering was to provide a space to quickly come to a consensus on the route of the day. By the time of this study, the group had settled on four standard routes—Little Tourmalet, Neuberg, Elk Hollow, and Badger Creek—ranging from 30 to 50 miles long. There were subtle variations to these rides (riding them in reverse, adding detours, etc.), but the rides were well known enough that these variations could be added without much trouble.

Most weeks, weather was the key factor in determining the route to take, especially the wind direction. Invariably, the riders would dictate a ride that headed into the wind on the way out, so as to (ideally) maximize the possibility of a tailwind on the
way back in. Other factors that played into the route decisions were road closures, traffic concerns, and roads that were recently chip sealed. Where wind often determined the general route, the other factors led to modest changes to the route, such as using side streets.

For newcomers, these planning conversations can be rather opaque. The route names pack with them a full script (Schank & Abelson, 1977) of locations and behaviors for a given route—the roads, the hills, regrouping points, and acceptable behaviors. Learning the scripts to be activated with each route is an important part of enculturation.

**Interactions with the shop.** It was not uncommon for cyclists in the WNR group to turn to the shop for their mechanical expertise. For several years, the shop was represented on rides either by a shop mechanic or by the owners, who provided roadside assistance to anyone who had a mechanical problem or a flat tire. Although this practice was discontinued before this study began, this level of involvement helped to cement the shop in the good graces of the veteran cyclists and emphasized the shop as an important site of expertise. Many of the WNR cyclists maintain a good relationship with Wally, the current shop owner.

While the group was gathering, some cyclists ran into the shop to grab last minute supplies—nutrition or an extra tube—or just to chat up whoever was behind the counter. Similarly, Wally occasionally came out to talk with the group or to share nutrition samples. Conversations with the owner inevitably included an invitation for him to ride with the group, which he would decline.

Wally also offered riders access to his mechanics to fix any minor issues before the ride. Most of the time, this help was limited to topping off the air in their tires or
replacing a tube, sometimes even going so far as making a quick adjustment to their
derailleurs to smooth out the shifting. As long as these adjustments were completed
before the scheduled time for the ride, no one minded. However, if the shop work lasted
too long, the riders began to complain. For example, Celeste was trying to sell her year-
old bike to finance a needed new car. Michelle was somewhat interested, and one day
Celeste used the pre-ride to convince her that she should try out the bike that day. Even
though swapping pedals and adjusting the seat height are relatively simple tasks, when
Celeste began the process, she was already cutting it close. This irritated some of the
other riders.

**Selling Bikes and Enforcing Norms.** The group's relationship with the shop
extended beyond the few minutes immediately prior to the ride. The shop also served as a
source of knowledge. Many of the riders had purchased at least one of their bikes from
DTC and relied on suggestions and recommendations from Wally in setting up their bikes
to help them meet their goals. When purchasing her last bike, Dana deferred to Wally
even though it went counter to her own wishes.

I've talked to Wally... and told him I wanted a triple crank... On my last bike he
said, "No, you're having a standard." And I said, "No, I want a triple." And so we
compromised once again on a compact... All three of my bikes have been a
compact, and I'm always wishing I had not just one more gear but two or three...
He thinks I need to be a tough rider and by making me not have a triple crank will
force me to be a little bit tougher... I think also because he knows that I'll probably
be made fun of from others in the cycling environment. It's not a cool thing
around here to have a triple crank.
Cranks (or cranksets) are the front set of gears on a bike, where the pedals are attached. For cyclists, they are referred to by the number of chainrings attached—single, double, and triple. Bikes with more chainrings have wider gear ranges, which allows the cyclist to adjust to a wider variety of ride conditions.

Dana defined her participation in cycling through her association with the WNR group and her goal of officially finishing T3. Dana knew that both of these pursuits would be considerably aided by the use of a triple crank. However, as Dana also notes, having a triple is "not a cool thing." Despite its advantages (or precisely because of its advantages), triples are eschewed by "serious" cyclists. Dean, who still identified as a racer even though he was many years removed from competition, summed up the company line when he stated that "we [racers] consider a triple a bailout, meaning you're weak." By denying her request for a triple, Wally was both enforcing this view that cyclists need to be tough as well as, potentially, protecting Dana from the increased scrutiny that both he and Dana expected to accompany her use of a triple crank. Had Dana been a rider with different goals or group affiliations, Wally likely would have been happy to supply her with a triple.

**Knowing all things mechanical.** Selling merchandise and providing advice for customers are well within the expected behaviors of any small business. The shop's role as a source of knowledge extends well beyond selling. The cyclists often approached Wally and his employees for advice and other bike-related know-how. Celeste remarked several times that one of the shop mechanics had been trying to teach her the ins and outs of bike components and how they work. Prior to participating in T3 as a relay for the first time, Dana decided that she needed to learn how to change a tire for herself, so she could
be more self-sufficient during the race. Feeling she had no one more knowledgeable to turn to, Dana turned to DTC.

I remember taking my bike into the shop and they were like "What are you going to do?" and I'm like "I'm going to let the air out of my tire. I'm going to completely take it off and then I'm going to put air back in my tire, and I just want someone to make sure I do it right." ...I did that because my husband doesn't know how to change a tire... so it's not like I can get help from him at home. I just wanted to be in a place that if I couldn't get the tire back on that someone could help me. So, I successfully changed it all by myself in there. So, I've actually done that twice. I think a year or two later I decided to do the rear tire to make sure I could do that.

Because of her history with DTC—buying a bike from them and joining the ride to learn to ride—Dana's decision to bring her wheel to the shop for practice is not surprising. As Dana hinted, there was an expectation that women in the group would turn to their husbands or significant others (many of whom rode with other groups) for basic cycling knowledge. Dana's husband was not a cyclist, and so did not know how to change a tire, removing this as an option.

Rather than try to learn to change her tire at home by herself or on a ride, Dana decided to use the captive expertise in the shop as support for achieving her goal of increased cycling self-sufficiency. So, with the mechanics looking on, she broke down her wheel and replaced the tube, ensuring that she knew how to fix a flat before she got a flat tire on a ride. That she felt comfortable enough with the shop and its mechanics to do
so in their limited space is evidence of the importance of the shop and the relationship of trust they had developed with their riders, particularly with Dana.

**Riding.** As the scheduled ride time approached, the cyclists not actively engaged in conversations began checking the time. For the last few minutes before ride time, members of the group ran through the names of any regulars who had not yet arrived and discussed whether or not to expect them. When this review was completed, someone said something to the effect of "Let's roll out," and the ride began. The rides progressed more or less predictably, with route-specific changes dictated by the environment. Each ride can be broken into four major segments: 1) Warming up, 2) Cruising, 3) Climbing, 4) Regrouping. The first four sections below briefly describe these segments. Following that, I will examine the learning opportunities available during the ride.

**Warming Up.** Warming up was characterized by slower speeds and loose formation. Riding at about 15 mph, the group split into pockets of two to four cyclists riding side by side. Cyclists used this time to finish conversations started during the gathering phase. This phase served as a transition between the relatively stationary work day and the exertion of the ride.

Physiologically, warming up is an important part of any physical endeavor. Warming up prepares the muscles and connective tissues for exertion (Behm & Chaouachi, 2011). For more competitive rides and races, riders will try to break a sweat and get their heart rates near their race rate for a few minutes as part of their warmup (Tomaras & MacIntosh, 2011). In the WNR, warm up seemed to be an afterthought. I heard several times that the first 15 minutes of a ride were dedicated to warming up. However, the reality was that the length of the warmup was determined by the route
through town. The Little Tourmalet and Neuberg routes passed through several controlled intersections, which kept the group's speed down. Routes with fewer traffic features resulted in shorter warmup times. The group tended to get a bit anxious (what they called “itchy”) to get on to the cruising segment of the ride.

_Cruising_. The greatest portion of each ride can be considered cruising. The cruising segment(s) of any ride featured tighter formations, typically single or double pacelines, with riders spaced at about a foot apart to draft off each other. When compared to the warmup, the speed was considerably faster—around 3-6 mph faster on average, though it may be as much as 15 mph faster in bursts across flat terrain or when descending.

While cruising, the group operated with the contradictory goals of going fast and keeping the group together. Their success in meeting these goals varied from week to week, dependent largely on who came to ride, which was reflective of the history of the ride. As noted previously, the ride had been a recovery ride for competitive cyclists before becoming an instructional group ride. With Wally letting the ride manage itself, the group became a mix of cyclists who each understood the goals of the ride somewhat differently. A passage from my field notes of the first ride of 2013 expresses the frustration and bemusement this misunderstanding caused:

As we rode back to the group, Easton said that the Wednesday Night Rides were more unpredictable than most other rides in the valley. He said that even though every ride featured riders who would shatter the group, they [the stronger cyclists] would sometimes spend much of their ride time waiting for the other riders, as it was a "no drop" ride. Other times, like tonight, the ride would be shattered, and
people would be dropped... [Two other cyclists] both remarked that tonight was a
good night because the ride broke into groups and everyone seemed able to find a
group that would ride at their pace. (field notes, 3/13/2013)

The nature of the ride seemed to change week to week, depending on who was in
attendance. On the above ride, 30 cyclists attended, so there were enough participants that
the ride could split into smaller groups. However, this was rarely the case. Sometimes the
week's participants were all of the same skill level and the group stayed together well.
Other times, some strong cyclists would join the group to "recover" at 25 mph. Not
wanting to be left behind, many in the group tried to match these riders' speed. This
inevitably resulted in the group being spread out and, as Easton pointed out, spending a
lot of time at regrouping points (described below) waiting for slower cyclists.

The breaking of the group and time spent waiting were a source of frustration and
the subject of much conversation throughout the first year of observation as the group
struggled to find an agreeable equilibrium and settle on an acceptable group identity.
Some argued that the ride should remain true to its "recovery ride" roots—that the speed
should be slow relative to the Wheelmen's rides but not actually slow. Another
suggestion was that the WNR should emphasize the "group" nature of the ride and focus
on keeping everyone together. To avoid long waits at regrouping points, as noted by
Easton, the "group ride" proponents suggested keeping the group together by varying the
speed to suit the slowest acceptable rider. In the end, even though the core cyclists
(Celeste, Dana, Kurt, and Dean) decided that the WNR was a group ride, the ride was still
regularly dominated by the strongest cyclists in attendance.
Climbing. Because the group was located in a mountain valley, climbing was an unavoidable part of the WNR. In calling it "unavoidable" I do not mean that climbing was something that the group disliked or sought to avoid. In fact, on several occasions, riders complained that there was not enough climbing in the typical routes favored by the group. Reba, for one, took vacations that provided opportunities for her to climb "real" climbs. Celeste's personal workouts often included repeated climbs up the hardest local climbs.

Where the goal of the "cruising" segment was for the group to stay more or less together, during climbing, all participants understood that they were on their own on climbs. Drafting and proper group behavior can mask differences in ability across flat sections. Because climbing is done at much slower speeds, the benefits of drafting are not as pronounced. As a result, weaker cyclists can quickly be left behind. Rather than force everyone to climb at the pace of the slowest rider, the DTC cyclists chose to let everyone climb at their own pace.

Over longer climbs, this practice resulted in separations of several minutes. To keep the group together, the WNR included regrouping points to allow the slower riders to rejoin the faster ones. On out-and-back climbs, like Elk Hollow and Badger Reservoir, cyclists regularly requested that the group not wait for them at the top of the climb, opting instead to turn around when the group passed them on their way down.

Regrouping. In a group with such variation in physical ability, it is (almost) inevitable that the group would break apart over the course of a 2-3-hour ride. A potential solution to this problem is for the whole group to ride more slowly. For this approach to be successful (or meet the preferences of all parties as much as possible), the fast riders
need to maintain a steady but reasonable pace and the slow riders need to ride at the upper end of their comfort zone. In theory, this works if everyone buys into the group goals. In practice, keeping the group together requires a great deal of in-ride coordination and communication, which can be facilitated by a charismatic leader who can keep everyone in line (both literally and metaphorically). In discussions with other cyclists, the consensus seemed to be that reining in the faster riders required a person with both the social capital and the physical ability to command the other cyclists' respect.

Lacking both such a leader and universal buy-in, the WNR featured scheduled regroup points along each route, unless the cyclists gave up on the idea of a no-drop/group ride and simply kept riding. Each of their typical routes had at least two customary regroup points. These points often followed climbs or marked a rough halfway point in the ride. Where possible, regrouping occurred at parks where riders would not block traffic and could refill their water bottles.

Sometimes regroups were required where there was no convenient spot to stop. In these instances, the group used a rolling regroup. These regroups were often ad hoc and were preceded by a call to "soft pedal," which meant to slow down by not pushing hard on the pedals. Cruising resumed when the last cyclists yelled, "We're on," meaning they were in position to draft again.

Because regrouping required faster riders to either slow down or completely stop, while waiting for the slower riders, regrouping provided another opportunity for conversation. These conversations typically dealt with events of the current ride. Topics included any especially good or bad behavior that needed to be called out, or petitions to change the route to extend or shorten it based on how everyone felt or how much time...
they had. During longer breaks, especially immediately before and after T3, the conversation turned to preparations for and experiences on T3. These conversations have included difficulties with particular sections, specialized equipment recommendations, and nutritional strategies.

**Finishing.** In other groups, rides often end with the cyclists visiting a local restaurant, pub, or coffee shop to unwind from the ride and to continue socializing (O’Connor & Brown, 2007). This is seen as an important part of the ride and of leisure cycling practice. For the WNR, the post-ride events were reserved for special occasions. The only one I observed was when one of the old-timers was leaving for the Pacific Northwest and a small group of us convened at the pizzeria across the street from DTC to wish him well.

More typically, the DTC had no "closing ceremonies" for their rides. Over the last few miles of the ride, cyclists would peel away from the group, shout their goodbyes and "thanks for the ride" and head home on their own.

A number of factors help shape this behavior. First, the shop's parking lot is extremely small, allowing for only two or three cars to park there at a time. As a result, any cyclists who drive vied for limited curbside parking spots scattered up and down the block. This arrangement leaves the group with no common area for post-ride discussions. Thus, arriving at the shop essentially marks an end to the group's association for the week. Anecdotally, when the shop moved several blocks north after this study, it moved to a location with more dedicated, co-located parking spots for cyclists to use. Rides at the new location often ended with the cyclists talking for several minutes as they stretched and stowed their gear.
The second factor limiting post-ride gatherings was that nearly all of the DTC cyclists lived on the south end of the valley, which was also the primary direction of travel for the group. These cyclists often arrived at the shop already having ridden several miles. Cutting off early saves them having to retrace the distance to the shop at the end of the ride and then double back to get home. With so many riders cutting out early, any post-ride socialization really would only include a few riders.

Finally, the WNR was scheduled to occur right after work and last until dusk and approached dark at the beginning and end of the season. Most of the cyclists have family responsibilities, that they need to attend to, and some struggled to schedule time to participate in the WNR regularly. So, making additional time for post-ride socialization was essentially out of the question.

**Learning In-Ride**

Because cycling is practiced in motion, learning to cycle must also take place while in motion. Thus, cyclists must take advantage of opportunities for learning and teaching that occur in the ride. Many of these opportunities come through proximity to more veteran cyclists and observing their situational behaviors. Explicit attempts at enculturating newcomers begin with two main subjects: safety and drafting. The sections below will describe how these topics and their related behaviors are taught.

**Safety Training.** In the interests of keeping everyone alive and in one piece, perhaps the most important bit of instruction a new rider can get in-ride regards safely operating the bike in the group. As I noted earlier, safety instruction occurs in a rudimentary fashion prior to the ride when new riders are identified. In-ride, veteran cyclists adopt a just-in-time instructional strategy.
For example, one of the most common causes of crashes is "touching wheels"—when a drafting cyclist hits the rear wheel of the rider in front of them. Touching wheels almost always results in the drafting cyclist going down. During the first ride of the 2013 season, I watched a veteran cyclist giving safety tips to the rider beside him.

The "instructor" positioned his front wheel in between the two riders in front of him and told the "learner" that this was the best place to position himself. He then moved his wheel to the left of the rider directly in front of him and said, "You don't want to put your wheel here because if he decides to move, you're going to lose." (field notes, 3/13/13)

With the rapidly shifting positioning within and throughout rides, I am not entirely sure what precipitated this incident—whether the new rider initiated the conversation, or the instructor led off. Based on other instances I saw or that were reported to me, the instructor probably initiated this exchange after noticing the newbie riding unsafely. With the group riding in a double paceline (two abreast) on a side road, it was safe for him to make this demonstration.

The instructor focused the newcomer's attention on his positioning relative to the cyclists in front of him. While the "big picture" of how the whole group moves is important to continued success, the narrow focus of this exchange served to further call attention to the appropriate behavior.

By providing the instruction during the ride, the instructor situated the behavior within the context of a ride much more clearly than would be possible during a gathering-time lecture. The in-ride instruction also allowed the newcomer to gain a sense of exactly what it took to be positioned properly. As improper positioning can result in serious
injury to both the improperly positioned rider and to the riders behind them, the instructor includes the personal consequences of not following the instruction.

**Learning to Draft.** Several of the cyclists I interviewed explicitly differentiated between riding a bike and cycling (or "really riding"). This difference was highlighted in the way that the cyclists mentioned having and riding a bike as a child. While the importance of these early experiences in forming the preferences (Azevedo, 2011) that led each cyclist back to the sport should not be understated, the cyclists separated these experiences from when they began "really riding." Really riding is characterized by more than simply being able to ride fast, having access to an expensive bike, or even wearing lycra. Rather, really riding is comprised of a set of behaviors that can be used to identify one as a skillful cyclist.

Drafting properly entails exhibiting many of these behaviors. The energy savings due to reduced air resistance while drafting keeps new cyclists in contact with veterans while they continue to learn. Thus, mastering drafting is essential to continued participation in groups. When Dana decided that riding in a group was the best way to "learn to ride" (her words), Kali started her enculturation by teaching her to draft. Like many new cyclists, Dana was reticent to learn how to draft, apparently viewing it as a skill for advanced riders. After Dana struggled through her first ride, Kali made it very clear that her continued participation was contingent on learning to draft. The paragraph below is Dana's recollection of Kali's instructional methods.

Kali informed me... that I would learn to draft if I was going to ride with the group because that was the only way I had a chance of even sticking with the group. So, as we were going up Elk Hollow Canyon, she had Bryce... ride right in
front of me, and she rode right beside me, and so I was learning how to draft because it was, "Bottom line, if you're going to ride, you're going to learn to draft, right now." ...She took the time and she was just a sweetheart but very blunt and said, "This is what's going to happen." So, we would try, and I'd be unstable, and so she would put her hand on my back and stabilize me and kind of push me back up on Bryce's wheel. So, I became kind of comfortable with her riding right next to me and riding in a group because that was the only choice I had... Over time she worked with me, particularly that summer, and she said, "Look at that person, they're kind of all over the road; you never want to be on that person's wheel." And as we were in different pacelines, she's like, "Okay, you want to get up on this person's wheel right now." And she kind of parted the way... and put me right where she wanted to do.

Kali's approach to teaching drafting was "blunt" but effective. The pattern can be broken into four phases: 1) establishing an immediate need for learning, 2) communicating an expectation that the learner will be successful, 3) providing ad hoc scaffolding, 4) establishing boundaries of acceptable performance. The sections below describe these phases in more detail.

**Immediacy of demand for learning.** Dana had struggled through her early experiences riding in the WNR. On the previous ride, she had been dropped by the group. On her second ride, she was again being left behind. Kali recognized that Dana needed to learn to draft to have any chance of keeping up with the group, but Dana had rebuffed an earlier attempt to teach her to draft. In light of this, Kali began the instruction by clearly establishing that Dana needed to learn to draft immediately. In her statement "If you're
going to ride, you're going to learn to draft, right now," Kali established the consequences of not learning—that Dana would not be able to "ride." Certainly, Dana would still own her bike and be able to take it for a spin as she chose, but she would not be able to "really ride" in a group. This indicated that if Dana continued to resist learning, no one in the group would hold up for her, and she would be left on her own.

**Expectation of success.** In addition to establishing the necessity of learning to draft, Kali communicated that she expected Dana to be successful in learning. In saying "If you're going to ride, you're going to learn to draft, right now," Kali established a learning objective and the behaviors that were going to lead Dana to those objectives. Instead of leaving it at "you need to learn to draft," Kali separated herself from the rest of the group and gave Dana her full attention. Kali was not the sort of person to spend much time on "lost causes," so her attention itself was a powerful indicator of Dana's ability to succeed. Beyond mere attention, Kali prefaced her instruction with verbal descriptions of her expectations for each instructional event—"Here's what's going to happen," and "You want to get up on this person's wheel right now." With each move, Kali made sure Dana had a clear path to continued success.

Other DTC cyclists also played a role in helping Dana develop an expectation of success. On her first ride with the group, Dana met Celeste, a woman in her 30s (at the time) who had joined the group only the year before. As the group rode back to the shop to end their ride, Celeste related the story of her first year with the group, essentially saying, "If I can do this, you can, too." This was the start of a cycling relationship that saw the pair leading the WNR through the two years I observed them.
**Ad hoc scaffolding.** The primary goal in drafting is to reduce air resistance as much as possible by getting really close to the rider in front of you. Practically speaking, drafting requires being able to recognize sensations related to optimal drafting positions and being able to adjust one's positioning to gain the maximum benefit from drafting. Drafting also entails assessing how much to trust the cyclists in front of you. A cyclist's trustworthiness is determined by their predictability, characterized by their smoothness, or ability to maintain both their lateral position (“hold their line”) and speed. New cyclists need to recognize and seek out these qualities in other cyclists and emulate them to be successful.

Kali, a former professional cyclist and racing coach, used materials and persons at hand to create scaffolds to help Dana experience drafting. Enlisting Bryce's help and separating from the main group, Kali reduced drafting to its essential elements so Dana could experience success. The skills required for drafting cannot be productively broken down into component skills that can be learned separately. Rather, the conditions under which these skills are enacted can be reduced in complexity to give the learner fewer things to have to pay attention to (Burton, Brown, & Fischer, 1984). With Bryce, an experienced and known-good cyclist, acting as the sole lead cyclist, Kali eliminated some of the dynamics of larger groups that make drafting more difficult. Dana could focus on Bryce as a model of appropriate behavior to emulate and a trustworthy rider to draft. As Dana attempted to draft, Kali rode beside her and corrected her position—stabilizing her with a hand on the back or closing the distance between her and Bryce with a gentle push. All of this allowed Dana to experience drafting bodily within the constraints of a real ride on an open road while controlling the situation.
In subsequent rides, Kali had Dana ride with the main group. However, rather than allowing the initial instruction to suffice, Kali continued to provide physical and social scaffolding for Dana that served to slowly increase the complexity of the drafting situation. This scaffolding included identifying the best cyclists for her to draft behind and then leading her to their back wheel. Riding with the whole group exposed Dana to the sensations and dynamics of drafting in a pack. By moving Dana up in the group, Kali kept her in the more stable, predictable parts of the group and out of the more variable and challenging dynamics at the back of the group.

Establishing boundaries. A key aspect of Kali’s instruction was to provide Dana with examples and counterexamples to bound acceptable behavior within the group, particularly within the tight quarters of ride formations. On the first ride, Bryce filled the role of model cyclist for Dana to follow, both literally and figuratively. At one point, Dana described Bryce as being "smooth" and "a good rider," hints that she had internalized Kali’s message. Kali also played a model cyclist throughout this initial interaction by riding close to Dana, helping her "get comfortable" with the close-proximity riding that would be required of her to be successful. To ensure that Dana also embodied these ideals, Kali moved closer to reposition Dana appropriately.

In subsequent rides, Kali kept Dana out of the rear of the group where frequent accordion-like bunching and spreading (colloquially known as “yo-yoing”) can tax the abilities of even professional cyclists. While important, this may have been a side effect of keeping Dana off the wheels of riders who were "all over the road" and to get her onto the wheels of smoother riders further up the formation. Kali consistently pulling Dana toward the front (but not to the front) taught her to be aggressive in finding smooth riders
who would allow her to go fast, a lesson she learned well. On several rides throughout my observations, Dana would tuck in behind some of the strongest riders and be able to outpace many of the stronger riders in the group.

**Chapter Summary**

This chapter described the characteristics of participation in a cycling community of practice and identified opportunities for learning through participation. Research into previously documented communities has shown the importance of access to and specialized use of equipment to continued participation in and identity with the community. For example, athletes on a track team only became “hurdlers” when taught valued ways of using starting blocks and strategies for approaching hurdles (Nasir & Cooks, 2009). Similarly, participation in cycling was governed by and signaled through riders’ use of particular equipment. Form-fitting, lycra clothing reduced air resistance and indicated one’s affiliation with specific cycling groups through a NASCAR-style display of logos. Investment in equipment signaled a cyclist’s commitment the sport and the degree to which they adhered to the norms of the group.

The local bike shop played an important role in enforcing these norms, guiding cyclists’ equipment purchases to align with the norms. This guidance was one part of the shop’s larger service as a space for learning. Beyond commercial concerns, shop employees helped cyclists learn to perform basic maintenance tasks and made cyclists aware of events to further their participation.

Being and learning to be a cyclist required more than regular visits to the shop; participation in the weekly group ride was key. Through participating in the rides, newcomers interacted with veteran cyclists, positioning themselves to observe a broad
range of valued behaviors (Hutchins, 1993). Oldtimers also employed several different instructional strategies when introducing newcomers to the practice of cycling. These strategies were shaped by the cyclists’ mobility (Cresswell, 2006) throughout the various segments of a ride. During stationary portions of the ride (e.g., gathering, regrouping), instruction predominantly focused on verbal reminders of general behavior for the safety of the group (e.g., not following too closely, pointing out obstacles in the road). More specific instruction was reserved for and enabled by moving down the road. In motion, newcomers’ behavior exposed their newness and need for correction. This in-ride correction was delivered just-in-time and focused on helping the newcomers to replicate and appreciate sensations related to valued behaviors (Becker, 1963), including the reduction in air resistance due to drafting. This personalized instruction provided newcomers access to a range of cultural resources (Nasir & Cooks, 2009), including relationships with the instructing oldtimers, practice enacting valued behaviors, and community-sanctioned interpretations of physical sensations over a range of terrains and ride conditions.

Given this structure to cycling practice and the central role of physical sensation in in-ride instruction, the question then becomes: How do cyclists think about physical phenomena they encounter as part of their participation once they are enculturated into the practice? The next two chapters address this question, focusing on mechanical advantage and air resistance.
CHAPTER FOUR
MECHANICAL ADVANTAGE

In the previous chapter, I described how the practice of cycling is structured and where this structure enables opportunities for teaching and learning. As new cyclists join the community, they are taught and can observe the practices of veteran cyclists in the community. These practices are performed with the use of sanctioned artifacts; have a particular, recurring structure that helps to inform the actions of the participating cyclists; and enable each cyclist to experience physical phenomena. In his research on the mathematical practices and knowledge of candy sellers and indigenous peoples, Saxe (1991) identified ways that knowledge is specialized for achieving practice-linked goals. Nasir & Cooks (2009) posited that cultural resources for learning and identity made available through participation in a community of practice can be one way of explaining the shape that this knowledge takes. Repeatedly enacting practices can result in accumulated understanding—practices inform how cyclists use their bicycles, and using their bicycles in valued ways generates experience that I argue also contributes to the cyclists' understandings of STEM content. As noted in the introduction, gearing has garnered a good deal of interest from the education research community. Given the cyclists' frequent experiences manipulating the gearing of their bicycles as a routine part of their practice, this chapter looks into the nature of cyclists' ways of knowing about mechanical advantage. The findings presented in this chapter address research question 2.

Because the discussion to come is fairly technical, a common frame of reference can facilitate understanding. With this in mind, the chapter begins with an overview of mechanical advantage, including the canonical description of mechanical advantage, its
treatments in textbooks, and its uses in cycling. After looking at how mechanical advantage is "supposed" to be known, I look at the ways cyclists actually know mechanical advantage.

In short, the canonical version treats mechanical advantage as a mathematical quantity to be calculated. This approach favors a detached, analytical view of mechanical advantage. Cyclists, on the other hand, have a very personal view of gears with themselves as the power source. Using a combination of quantified and embodied resources (Ma, 2014), cyclists use gears to manage their effort and achieve practice-linked goals.

**Introduction to Mechanical Advantage**

The first thing one needs to understand is that mechanical advantage is a characteristic of all machines, whether they are simple machines (e.g., levers, wheels and axles, inclined planes) or compound machines (e.g., can openers, bicycles, trebuchets). Mechanical advantage is, essentially, a measure of how much easier work is with the machine. More specifically, this is the ratio of the output force (load) to the input force (effort). For example, a lever multiplies the effort force by changing the distance between the input force and the fulcrum point (Figure 5). In this way, a smaller input force may be used to move a larger load provided that the input force is applied at a sufficient distance from the fulcrum.
Mechanical Advantage in Bikes

Bicycles typically have two sets of sprockets—the chainrings and the cassette—which are connected by a roller chain (Figure 6).

The mechanical advantage of a chain and sprocket system is the ratio of the number of teeth on the output gear (i.e., the cassette) and the number of teeth on the input gear (i.e., the chainring).

\[
\text{Gear Ratio} = \frac{\text{Teeth on the Cassette}}{\text{Teeth on the Chainring}}
\]

However, this only accounts for part of the machine that propels a bike. Force is applied to the pedals at the end of the crankarms and is output when the rear wheel pushes on the road. So, the crankarm and rear wheel must also be accounted for in determining the mechanical advantage of the bike's drive system. Calculating the mechanical advantage of the whole drivetrain requires multiplying the gear ratio by the ratio of the crankarm length and the radius of the rear wheel.
Shifting gears changes the size of the sprocket on either the chainrings or the cassette that the chain interfaces with, which changes the mechanical advantage. In low gears (high mechanical advantage; Figure 7, left), the drivetrain transmits more force from the pedals to the back wheel, but the wheel will not turn as far with each pedal stroke. The higher force transmission makes these gears well-suited for accelerating from a stop and for climbing hills. In high gears (low mechanical advantage; Figure 7, right), the wheels turn farther with each pedal stroke at the expense of lower force transmission to the back wheel. Because of the increased distance the wheels turn, high gears are ideal for riding at high speeds.

\[
MA = \frac{\text{Teeth on the Cassette}}{\text{Teeth on the Chainring}} \times \frac{\text{Crankarm Length}}{\text{Wheel Radius}}
\]
Figure 7. Mechanical advantage for a bicycle (Carlson, 2011).

Treatments of Mechanical Advantage in K-12 Textbooks

Further evidence for the preceding being the canonical description of mechanical advantage can be found in the way it is taught and assessed in formal instructional materials. For example, textbooks present mechanical advantage in units related to machines, work and power. In describing the concepts behind machines—force, distance, and work—textbooks show how machines trade force for distance and introduce mathematical formulae for calculating mechanical advantage.

In assessing students' mechanical advantage knowledge, textbook problems are structured to assess, after a fashion, both quantitative and conceptual understanding. Examples of each are shown in Figure 8. These questions are typical of mechanical advantage questions in the textbooks.
Figure 8. Examples of textbook problems to assess students' quantitative (Zitzewitz, Haase, & Harper, 2013) and conceptual understanding (Wysession, Frank, & Yancopoulos, 2012).

This approach to mechanical advantage asks students to develop specific conceptions of mechanical advantage. The conceptual questions ask the students to reason about the use of machines in the accomplishment of hypothetical tasks. The desired responses refer to the relative magnitude of the outputs of the machine (e.g., speed, force). The unspoken assumption of these is a fixed input (e.g., force, speed) to the system, which provides for an acceptable comparison between conditions.

The concepts making up the desired explanation then become terms in the equations the students are expected to use in responding to the quantitative problems. As shown in Figure 8, above, students are expected to identify the salient equation(s) from the chapter, replace variables with appropriate values from the problem statement, then turn the proverbial crank to arrive at a single number that is meant to represent the function of the machine. In the remainder of this chapter, I will demonstrate that cyclists
are able to meet, on a practical level at least, both the conceptual and quantitative criteria for understanding mechanical advantage while espousing a qualitatively different approach to the solutions.

**How Cyclists Think About Gearing**

The primary goal of the mechanical advantage interview (see Chapter 2, Methods) was to characterize how the cyclists understood mechanical advantage relating to gearing. In keeping with Saxe's methodology (1991), I framed the questions to emphasize the links to cycling practice. The analyses presented in this section come from six questions in the mechanical advantage interview. The first question asked the cyclists to describe their general approach to selecting gears during a ride. The five remaining questions asked the cyclists to describe the gearing they would use in several ride segments of varying familiarity (Table 3).

Table 3.

*Ride segments from the interview.*

<table>
<thead>
<tr>
<th>Situation</th>
<th>Distance</th>
<th>Average Grade</th>
<th>Times Ridden on WNR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Little Tourmalet</td>
<td>1.0 mi</td>
<td>5%</td>
<td>15</td>
</tr>
<tr>
<td>Little Mountain</td>
<td>1.1 mi</td>
<td>5%</td>
<td>3 (5x down)</td>
</tr>
<tr>
<td>Military Ridge</td>
<td>8.2 mi</td>
<td>6%</td>
<td>1</td>
</tr>
<tr>
<td>Neuberg TT</td>
<td>4.9 mi</td>
<td>0%</td>
<td>20</td>
</tr>
<tr>
<td>Bear Mountain</td>
<td>4.7 mi</td>
<td>5%</td>
<td>0</td>
</tr>
</tbody>
</table>

When introducing each segment to the cyclists, I presented a one-sheet with data about the segment from the activity tracking service strava.com (Figure 9). I identified the segment by name and identified the start and end points on the map. Once I was certain that we were both thinking of the same segment, I asked the cyclist a variation on
the question "How would you approach this segment, focusing on the gears you would use?"

**Figure 9.** Ride segment one-sheet presented to cyclists during the mechanical advantage interview showing a map of the segment and an elevation profile. It also includes the segment name and location, length, average grade, elevation range, and ride category.

**Cyclists' Qualitative Criteria**

When cyclists solved gearing-related problems, their qualitative criteria for identifying the right gears centered around two constructs—cadence (i.e., the rotational velocity of the pedals in revolutions per minute) and pedal resistance.
**Cadence.** When I asked the cyclists about their general approach to gear selection (asked as some variation on "How do you usually pick what gear you're in?"), each of the cyclists included cadence in their reasoning. For five of the seven interviewees, cadence was a primary concern in selecting gears, regardless of the situation. Cadence is the rate at which the cyclist turns the pedals. Cadence was also identified as important by cyclists in a previous study on the data practices of endurance athletes (V. R. Lee & Drake, 2013).

Six of the cyclists used sensors to quantify cadence as revolutions per minute. With cadence quantified, the cyclists then used gearing as a means of managing their cadence for the speed at which they were traveling. This approach was described by Reba when she said:

> I like to have my cadence high. So, if it means that I need to go into... a lower gear, then I change it to the lower gear so I can keep my cadence at the not too high and not too low... If I want to go fast, then I want to be at least 95 or above, 90, yeah 95 or above

Reba's preference for a high cadence was common across all of the cyclists. Those cyclists who cited a quantified cadence described a range that fell between 80 and 100 rpm, with the women targeting 90-95 rpm. Dean and Kurt, who both embraced the strength ("power") of their legs, claimed to ride at 80-90 rpm. Dan, a cyclist in his mid-40s who provided consent but did not wish to be formally interviewed, said that he typically raced at 115 rpm and maintained a cadence of 105 rpm during recovery rides, which is what he saw the WNR as. Most of the cyclists noted that their cadence target came through the recommendation of a coach or from popular training literature.
The cadence range cited by these cyclists has a basis in the physiology literature, which identifies a range of optimal cadences, based on the goals of a particular ride (Abbiss, Peiffer, & Laursen, 2009). For example, a long, endurance ride would want to maximize energy efficiency, which occurs at 70-90 rpm; short, high-speed events (e.g., the world hour record) require greater power, which is maximized at 100-120 rpm.

**Pedal Resistance.** Cadence provides a quantified, idealized metric by which cyclists can assess their gearing. Three of the cyclists noted that good cyclists had very high cadences—over 100 rpm—and noted that they could not match that rotational speed. The practical limits on cadence, both upper and lower, are set by the cyclists' perception of pedal resistance. Reba noted, "You can only go [pedal] so fast before you start spinning out. You don't have resistance so you're... not going anywhere with it. You need to be... pushing something." Spinning out occurs when the cyclist pedals very rapidly against a sensation of greatly reduced pedal resistance. This reduced resistance coupled with the leg muscles' diminished ability to produce force while contracting quickly (McCartney, Obminski, & Heigenhauser, 1985) contributes to a general sensation of ineffectual pedaling.

**Uses in Problem Solving.** Even though speed is an emergent property of a ride, stronger cyclists often position themselves at the front of the pack and have an outsized influence on the speed. So, for most cyclists, group speed feels externally imposed. As a result, cyclists must decide how to ride at the imposed speed within their abilities, and gearing can play an important role in achieving this goal. Phoebe described how she balanced cadence and pedal resistance in selecting gears for riding with different groups. To keep up with a faster group, Phoebe said, "If they're going super-fast... I sometimes
pick a slower gear, so I'm pushing the pedals harder to go faster. So, I feel like my legs
are working hard, and I'm working harder to keep up." By "slower" gear, Phoebe means
a higher gear, or one that requires a lower cadence to generate speed. This corresponds to
a higher pedal resistance, which makes her work harder to turn the pedals but allows her
to generate more speed.

More interesting, from a gearing perspective, is her approach to keeping up with a
group that is slower than she is. "I would pick maybe a less hard gear... so that I'm just
kind of pedaling, keeping my heart rate down, not working that hard, but just kind of
going with the flow." In this case, she picked a gear with lower resistance. This increases
the cadence at which she needs to ride and effectively caps her speed, making it easier to
maintain the slower pace of the ride. Alternatively, she could keep her usual gearing and
simply slow her cadence, but that would not provide the same speed ceiling that the lower
gear does. Looking at her strategies for both the fast and slow groups, Phoebe uses two
attributes for selecting her gearing: the "hardness" of the gear and the amount she has to
work her legs.

**Summary.** Taken as a whole, the cyclists generally understand and use gearing in
similar ways. Cadence and pedal resistance have a roughly inverse relationship—as
cadence increases, pedal resistance decreases (see Figure 10). When the cadence required
to maintain a given speed too high, the pedal resistance decreases to the point that some
cyclists reported that they were pedaling hard but felt they were not going anywhere, as
Reba did in the above quote. Conversely, when the pedal resistance is too high, cadence
falls too low, and the relative effort again feels too great for the speed being produced.
In both cases, cyclists reported that the level of effort in these outside cases was unsustainable, regardless of the speed at which they were trying to travel. With rides topping two hours, long-term sustainability becomes an important consideration in immediate gear selection. When cadence is in the ideal zone, 80 to 100 rpm, the cyclists report lower overall levels of effort. They feel more efficient and that their endurance has increased. In this ideal zone, the cyclists say they can ride "forever", which while not literally true seems accurate in the moment.

Figure 10. The Effort Curve.

Cyclists' Quantitative Criteria

The mechanical advantage interview included one question designed to assess the cyclists' quantitative reasoning. This question gave the cyclists a starting gear that would likely be available on their bike that used their large chainring and the 18-tooth cog on
their cassette. I asked the cyclists whether they could move to their small chainring and find a gear on their cassette that had similar ride characteristics (e.g., cadence, pedal resistance), and if so, what that gear would be.

One clear difference between the textbook quantitative questions (even ones that asked for comparisons) and the one I asked is that my question explicitly assumes that the cyclists would need to move between the two setups, which is practice-linked but must be accounted for in assessing the cyclists' responses. Sam and Dean, both veteran cyclists with racing experience, took similar approaches to the problem, so I present them both together. Refer to Figure 11, below, for the discussion that follows.

SAM: So, you're approaching and what I'll usually do is drop the cassette down one or two, usually two gears. So, this is an 18, so I'm down to a 16 or a 14 and then drop the front second. So, momentarily it's gotten a little more difficult. You're just soft-pedaling, freewheeling it, and then you just go bang bang and drop those [cassette gears] and follow that immediately with the front... and you know if you still find yourself pedaling too fast, drop it another one.

DEAN: So, if you went to your little, your 39, you'd probably want to go to a, to make it even, let me think here for a minute, 53/18, so you're going on the flat, 53/18, you'd probably want to go down a couple so probably a 39/14, something like that.

The "right" answer. The goal of a textbook version of this problem would be to find gearing with the closest gear ratio (or speed ratio for the cyclists) to the original gearing. The problem was formatted so that the chainrings matched the cyclist's individual setup. Sam had compact chainrings, so his initial gearing (50/18) had a speed
ratio of 2.79. The closest small ring (34-tooth) gearing would be 34/12 for a speed ratio of 2.83, an increase of 0.04. For Dean, who had standard chainrings, his initial gearing (53/18) yielded a speed ratio of 2.94. In the small ring (39-tooth), the nearest speed ratio would be in the 13-tooth cog (39/13) for a speed ratio of 3.00, or an increase of 0.06. If both Sam and Dean were riding at 20 mph, shifting as prescribed would result in a reduction in cadence of 1 rpm—practically identical.

![Graph](image_url)

**Figure 11.** Sam's (above the curve) and Dean's (below the curve) responses diagrammed on an effort curve. Initial gearing values are 50/18 and 53/18, respectively. The "right" answers are the ringed dots immediately to the right of these (34/12 and 39/13). Gearing paths described by each cyclist are marked with arrows.

**Shifting heuristic.** Neither Sam nor Dean approached the problem as a textbook math problem. Rather, both used the same shifting heuristic to arrive at their solution: one chainring shift = two cassette cog shifts. Both Sam and Dean alluded to this relationship
when they said they would "drop a couple" of cogs, meaning shift to a cog two sizes smaller than the initial one. For both of them, this was quantified as shifting into the 14-tooth cog. As Figure 11 shows, this reduced their speed ratios, resulting in an increased cadence. I argue that there are three explanations for the discrepancy between the heuristic solution and the "right" answer. Firstly, the heuristic is based on finding gearing that is "good enough". Dean's resulting gearing still placed him well within the cadence range the cyclists had established (and that has been discussed earlier in this chapter). That Sam's gearing put him outside this range brings me to the next explanation—the cyclists understood the problem not only as getting a "good enough" gear but also one that would prepare them for an oncoming hill. A decrease in speed ratio (and increased cadence) in anticipation of a substantial climb is certainly reasonable. Finally, the cyclists’ reasoning may account for dynamic speed in a ride. The effort curve plot assumes that speed is held constant. The dots in Figure 11 represent the relative values of each gear based on a speed of 20 mph. In describing his shifting strategy, Sam noted that he would not attempt a shift to the smaller chainring while traveling at his cruising speed but would wait until his speed “came down a bit” first. By waiting until his speed slowed, his final gearing would shift toward the center of the plot. Climbing the hill would further slow them and, thus, their cadence.

With the heuristic getting them into good enough gearing, the cyclists can apply their qualitative criteria to assess the fitness of the shift. As Sam said, "If you still find yourself pedaling too fast, drop it another one." Because shifting is a low-stakes activity, there is little need to make a perfect shift right off.
**Shifting strategies.** Even though they both arrived at essentially the same answer, Sam's response reflected a greater concern with the strategy for getting to the final gearing. Dean says that he would "want to go down a couple," and reports 39/14 as his final gearing (green arrow in Figure 11). This simple, resolution-focused response to the question provides just enough reasoning to justify the result.

Sam's strategy (black arrow in Figure 11) begins with shifting down two sprockets on the cassette. This increases the pedaling resistance (and reduces cadence). Next, he quickly drops into the smaller chainring, returning to a good-enough gear. In clarifying his response to this question, Sam said momentarily reducing his cadence via shift keeps him prepared for attacks (attempts to move up or separate from the group) from other cyclists—in his words, "You don't want to be spaghetti leggin' it."

**Summary.** Rather than a textbook, one-best answer, the cyclists used a constraint-satisfaction approach to solving the problem. In their solutions, the cyclists accounted for the problem constraint that the final and initial cadences be as close as possible and seemed to add the constraint that they be ready to climb the approaching hill. Based on their long experiences with cycling, both Sam and Dean invoked a 2:1 shifting heuristic to get into a good-enough gear. To these basic constraints, Sam added that he had to maintain his race readiness, which led him to adopt a specific shifting strategy. Having solved many textbook problems myself, I tend to doubt that a student would consider either the approaching hill or the effects of transitional states when developing their solution. Accounting for these constraints, I argue that the cyclists achieved their goal of finding a "good enough" gear.
The cyclists' strategies echo the intuitive strategies documented previously. Lave (1988) observed that grocery shoppers account not only for price but available storage at home and family brand preferences when selecting items for purchase. Brazilian candy sellers simplify their mathematical tasks by using a ratio-based pricing structure (Saxe, 1988b). Dairy packers leveraged the sizes of available products and boxes in packaging orders for shipment (Scribner, 1984). Similar "cheats" and departures from the "real" problem are also evident in the portioning strategies of Weight Watchers (de la Rocha, 1985), the dosing procedures of nurses (Hoyles, Noss, & Pozzi, 2001), and the measurements of carpet layers (Masingila, 1994). Even though the strategies employed by these various groups are not universally applicable (strictly speaking, the 2:1 heuristic does not work perfectly even in Sam's case), the research makes clear that these are legitimate ways of knowing and problem solving.

**Gearing Talk in the Wild**

The previous sections of this chapter have focused on demonstrating some of the distinct features of cyclists' ways of understanding mechanical advantage. The findings of those sections represent the accumulation of understandings over months and even years of participation. However, gearing knowledge can serve other purposes within cycling practice as well. This section provides an illustrative example of how mechanical advantage and gearing-related talk can emerge naturally in the course of a ride.

During a typical ride, spontaneous gearing talk was rare. This was likely due to a combination of the veteran composition of the group and the routine nature of the routes used by the group. In late September 2014, several members of the group climbed Military Ridge, a long, difficult climb about two hours from DTC. On the Wednesday
following, group conversation was dominated by gearing talk. The example below comes from a conversation between Sam and Allen, two veteran cyclists, during a rolling regroup following a brief climb.

During their brief exchange, which was captured on the GoPro POV camera, the pair discusses how difficult the Military Ridge climb was, and mechanical advantage plays a big role in communicating their experiences. Sam and Allen employ gearing knowledge in several ways: 1) as a rough quantification told through equipment-related shorthand, 2) as a means of contextualizing effort in a prior experience, and 3) as a reflection of the cyclists' practice-linked identities. The transcript is edited for clarity.

1. Sam: That was nothing like that Military Ridge last week...
2. Allen: My gearing was wrong, way wrong. I got a full-size ring... and my biggest back is 25. It was harsh.
3. Sam: That's what Ivan Basso would use on Alpe d'Huez. I have compact, 26. It was brutal enough... 34/26.
4. Allen: 34/26. So you went full compact?
5. Sam: Yeah.
6. Allen: That mid-compact just seems like it's just the right size.

**Quantifying Gearing.** When cyclists quantify their gearing, they use a two-number gear ratio (speed ratio, technically), presented as a front/back pair as Sam does at the end of line 3 ("34/26"—34-tooth chainring, 26-tooth cog). Using the two-number gear

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4 Ivan Basso was a rival of Lance Armstrong known for his climbing ability. Alpe d'Huez is a famous climb that is often featured in Le Tour de France.
ratio simplifies comparison among cyclists by maintaining links to their equipment, which allows the cyclists to quickly identify the mechanical similarities and differences between themselves and their counterparts. Alternatively, the chainrings may be referred to by industry size designations—standard, mid-compact, and compact—as Sam does earlier on line 3 ("compact, 26" instead of "34/26").

**Contextualizing Effort.** Referring to how gears feel (e.g., "hard" or "easy") is common among riders of all ages, as I have shown above and in previous work (Drake & Lee, 2013). Being able to talk about gearing also allows cyclists to compare their experiences. After identifying gearing he used ("full-size"/25—39-tooth chainring, 25-tooth cog), Allen said it was "way wrong" and "harsh" (Line 2). Sam established his own gearing, which was understood as better suited to climbing, and commented that his own experience was "brutal enough" (Line 3). In doing so, Sam implies that while the climb was difficult for him, he understood that Allen's climb was even more difficult by virtue of his higher gearing.

**Reflecting and Reinforcing Practice-linked Identities.** Part of a veteran cyclist's identity is being able to speak and understand the gearing shorthand described above, as Sam and Allen do. A further step is applying this knowledge to the setup of their own bikes at the time of purchase or through subsequent modifications. Allen cultivated a reputation as a fast, powerful cyclist. His "full-size ring" positioned him among the racers; his concession that the "mid-compact [seemed] like it's just the right size" (Line 6) showed just how much his experience on Military Ridge had shaken his self-conception—he was considering changing the gearing on his bike in an effort to climb faster and easier, a change that would have reduced his maximum gearing.
Sam provided further context to the climb when he compared Allen's gearing to that of Ivan Basso (line 4). This accomplished two, seemingly opposing aims. First, the comparison reminded them both that they are not professionals and that such gearing is better suited to the abilities of actual pros. On the other hand, because Sam admitted to having easier gearing, the comparison positioned Allen as a tough, strong cyclist because he climbed Military Ridge with the gearing of the pros.

This example illustrates the kind of posturing and validation that takes place in cycling groups, particularly among the veteran cyclists. Thus, we can see that knowing gears and the effects of the associated mechanical advantage are important not only for riding one's bike but also for claiming a position within in the larger community of cycling with its existing narratives and icons.

**Chapter Summary**

In previous studies, researchers have documented the role of setting in shaping the problems one might encounter, the strategies used to solve those problems and, thus, the understandings one may develop (Lave, 1988; Saxe, 1991). Textbooks promote particular ways of understanding their content and solving related problems. The content and problems in textbooks present mechanical advantage as a single-number: the ratio of the output force to the input force. Criteria for solving textbook problems involve knowing a combination of characteristics of the machine and the input or output forces. This approach facilitates comparison across different configurations and types of machines and focuses students' attention on scientific concepts, like work, force, and torque.

While broadly applicable strategies are often seen as ideal, “just plain folks” employ situation-specific problem-solving criteria and procedures (Lave, 1988; Ma,
These situational procedures are often inventive but effective, nonetheless (de la Rocha, 1985). Researchers have shown these strategies to be valid ways of knowing (Azevedo, 2013). This chapter has shown that long-term participation in cycling supported ways of knowing mechanical advantage that are distinct from the textbook criteria for knowing. Cyclists used mechanical advantage to achieve their goals related to various situations they encountered in their practice (e.g., climbing hills, going fast, or slowing down to match the group speed). Cyclists’ gear selection criteria were structured around the practice-linked goal of managing their perceived effort, a goal achieved by balancing cadence (a quantification of their pedaling rate) with pedal resistance (a purely embodied resource; Ma, 2014). Balancing these facets of their activity enabled cyclists to accomplish ride-level goals of maintaining sustainability of effort and stretching their effort over a multi-hour ride time.

In addition to its use in solving problems, cyclists’ mechanical advantage knowledge served a number of roles socially, as well. Cyclists used gearing to communicate toughness, whether through equipping a double chainring (as noted in Chapter 3) or using larger gears for climbing, as Allen did. In conversation, cyclists’ mechanical advantage knowledge was used to contextualize their effort in performance and to reflect practice-linked identities (Nasir, 2002), even those that were merely desired (Wortham, 2006).

The findings of this chapter indicate that knowledge of gearing and mechanical advantage was deeply embedded in cycling practice. This knowledge enabled the cyclists to effectively solve practice-linked problems using strategies that extended beyond
mathematical calculation and that were informed by a range of social and embodied resources. These resources also helped shape the riders’ identities as cyclists.

In the next chapter, I turn my attention to explaining the cyclists’ knowledge relating to air resistance and how it reflects and is reflected in cycling practice.
CHAPTER FIVE
AIR RESISTANCE

The previous chapter demonstrated how cyclists' gearing and mechanical advantage knowledge is informed by the cyclists' physical experiences with the phenomenon and the social norms and narratives of cycling practice. In this chapter, I present a discussion of the cyclists' practice-linked knowledge of air resistance. This discussion draws primarily on the analysis of the cyclists' responses to questions in the air resistance interviews, described previously in the Methods chapter (Chapter 2).

This chapter begins with an overview of the canonical science of air resistance, including a description of the factors that determine the magnitude of air resistance; its role in cycling; and means of mitigating it, particularly through drafting. Following this, I will describe how cyclists reason about air resistance.

**Air Resistance Overview**

**Drag**

When a body moves through a fluid, the fluid opposes that movement. This opposition is called *drag* or, when the fluid is air, *air resistance*. The magnitude of this resistance depends on several factors: the body's size and shape, the density of the fluid, and the relative velocity of the body relative to the fluid. Drag is calculated using the following equation:
\[ F_D = \frac{1}{2} \rho v^2 C_D A \]

Where \( F_D \) is the drag force, \( \rho \) is the density of the fluid, \( v \) is the velocity of the body relative to the fluid, \( C_D \) is the drag coefficient, and \( A \) is the frontal area of the object. The drag coefficient includes contributions from the surface features (e.g. smoothness, stickiness) and the shape of the object.

In addition to air resistance, a cyclist's forward motion is also opposed by rolling resistance and mechanical friction (Wilson, 2004). Rolling resistance and mechanical friction are independent of speed. Air resistance, on the other hand, increases with the square of velocity, as shown in the equation above. Since power is force times velocity, the power required to overcome rolling resistance and mechanical friction is proportional to velocity, while the power needed to overcome air resistance increases as the cube of velocity (Figure 12). At speeds over 15 mph, air resistance becomes the most significant resistive force.

**Mitigating Air Resistance**

Given the cyclists' desire to be efficient while moving quickly (shown in part in Chapter 4) and their understanding of the deleterious effects of wind and air resistance, mitigating these effects takes on special importance to the cyclists.
Air resistance has two components (Figure 13)—skin friction drag and pressure drag—which require different mitigation strategies. Skin friction is determined by how smoothly the fluid moves over the surface of the body. Wearing specialized, formfitting clothing can reduce skin friction (Lukes et al., 2005). However, because of the size and shape of cyclists, skin friction makes a relatively small contribution to overall drag in standard cycling situations (Wilson, 2004).
Figure 13. Airflow around a circular cylinder (Wilson, 2004).

Pressure drag is caused by the pressure differential between the high-pressure area in front of the body and the low-pressure turbulent air behind the body (Watkins, 2007). The magnitude of pressure drag is a function of the frontal area and shape of the body. Acknowledgment of this can be seen in the changing shapes of automobiles—from the boxy, angular shapes in the 60s to the sleeker shapes of modern cars. While cyclists can benefit from changing the shapes of their equipment—helmets, frame tubes, etc.—the cyclists themselves are the largest contributor to the air resistance opposing their motion. To overcome this, cyclists can change the position of their bodies on their bikes to minimize the frontal area that interacts with the air. Some repositioning is accomplished with the change from a city bike to a road bike (Kyle & Burke, 1984). More extreme aerodynamic positions are possible, but they can restrict the cyclists' ability to produce power, and cannot be maintained for long periods (Faria, Parker, & Faria, 2005). That is where drafting comes in.
Drafting

Drafting, or slipstreaming, is an effective, maintainable means of mitigating air resistance that is used in many sports where speed and endurance come into play (e.g., speed skating, stock car racing). In drafting, a body placed in the low-pressure, turbulent space behind another body. That drafting is one of the earliest skills taught to new cyclists (see Chapter 3) indicates its importance to cycling practice. In cycling, drafting can significantly reduce the effort required to maintain a given speed. At 20 mph, cyclists realized an average energy savings of 18% by drafting off one other rider; riding at 25 mph increased that benefit to 26% (McCole, Claney, Conte, Anderson, & Hagberg, 1990). The cyclists in the above study rode at 0.2 - 0.5 m behind the leading cyclists. The benefits of drafting diminish quickly with distance (Figure 14).

*Figure 14. Drafting effect vs. following distance for cyclists riding at 25 mph. CF_{draft} is the ratio of resistance when drafting to resistance when not drafting. VO_{2} ratio is the ratio of oxygen consumption when drafting to when not drafting. d_{w} is the distance between the lead rider’s rear wheel and the drafting rider’s front wheel in meters (Olds, 1998, p. 493).*
In the remainder of this chapter, I will explain the strategies cyclists use to optimize their drafting, including the general heuristics and the constraints that shape these strategies in practice. The bulk of this chapter comes from analyses of the cyclists’ responses to questions in the drafting section of the air resistance interview. A description of these questions follows.

**Drafting Problem**

The drafting section of the air resistance interview was intended to probe some of the particulars of what cyclists knew about drafting, including how it worked and what bearing positions and formations had on its effects. The main drafting question was adapted from a survey question developed by Hirsh and Levy (2013) but included several more formations.

**Question.** For the next few questions, I'll show you a few different cycling situations. I want you to compare the level of effort—who's working hardest—for the cyclists I show you and explain why. The formations included those depicted in Figure 15, below.

*Figure 15. Cycling scenarios discussed in the interview. (a) solo cyclist; (b) pair of cyclists; (c) line of four cyclists; (d) block formation from McCole et al. (1990); (e) hammerhead formation, an "invented tactic" from Hirsh & Levy (2013).*
**Answer.** The cyclists in the front (far right) are all working at approximately the same level of effort. According to McCole et al. (1990), at 25 mph, each of the drafting cyclists in (b) and (c) have energy savings of approximately 27%. Broker, Kyle, and Burke (1999) found that at 60 kph (37.3 mph) cyclists in the third and fourth position in (c) could experience power savings of an additional 6% compared to the second cyclist. The center rear cyclist in (d) would experience a 40% energy savings compared to the leads (McCole et al., 1990). Hirsh & Levy (2013) do not give efficiency data for individual formations in their study, like (e), but note that the best invented tactics showed a 20% decrease in time to complete a given course. This formation was included to see how the WNR cyclists reacted to and reasoned about it.

**Drafting Heuristics**

Across all of the interviews, the cyclists told a consistent story about the effects of drafting on the riders in Figure 15. At a high level, the cyclists clearly understood that drafting resulted in substantial decreases in air resistance and, thus, perceived effort (a familiar hobby-horse for cyclists, as described in Chapter 4). As with their mechanical advantage knowledge, the cyclists’ drafting strategies were shaped through years of cycling experience. Through their responses to the interview questions, I identified three main heuristics that the cyclists applied in deciding how drafting affected each of the depicted cyclists. These heuristics stated that drafting was better 1) close (to a leading cyclist), 2) farther back (in a group), and 3) behind something/someone big.

**Get Closer**

One way to identify veteran cyclists is by how close they get to the rider in front of them. Nearly all the DTC cyclists reported small following distances in an effort to
maximize their draft. Six of the cyclists reported maintaining a following distance within two feet of the back wheel of the lead cyclist. As Kurt explained, “There's a two-foot sweet spot, [where] you can take advantage of the draft, but after that, it's right back to if you were out front.” Five of the cyclists reported trying to draft at six to 12 inches, maintaining at least a 100% margin on the maximum extent of their sweet spots. Dean was one of these cyclists, reporting that he drafted within inches of another cyclist, adding, "the closer you can get the better." Similarly, Sam said he drafted within 10 cm of the cyclist in front of him. To justify this tiny following distance, he described the mechanics of drafting as follows:

The person behind is still going to have some wind resistance, because you're moving through air... but you're not moving through air that's moving as fast against you as the guy in front... I don't really know the Physics of it, but I can feel it... You're going to have a decreasing curve of energy savings... If you're back far enough, your wind resistance will be equal to the person in front of you, and as you come closer, the amount of wind resistance decreases because they're blocking it.

Sam’s explanation of how drafting works is similar to the descriptions given by the other cyclists. The explanation includes several key points. First, the lead cyclist has an antagonistic or violent interaction with the air. The most frequently used verb for this interaction was “blocking,” with all of the cyclists using it at some point. Other verbs included “splitting,” “hitting,” and “plowing.” Similarly antagonistic language was used to describe a solo cyclists’ interactions with air and as well as by triathletes in a previous study (Hirsh & Levy, 2013).
Second, this interaction results in a protected area behind the lead cyclist. This was Kurt’s “sweet spot,” or “zone of happiness,” as Celeste called it. In this protected area, the following/drafting cyclist experiences lower wind resistance. Sam explained that this was due to relatively slower air behind the lead cyclist. Alternatively, cyclists also attributed this reduction in resistance to lower air pressure in the wake of the lead cyclist. Both of these explanations align with the canonical version (Wilson, 2004). Sam’s slower air explanation is also supported by recent research (Blocken, Defraeye, Koninckx, Carmeliet, & Hespel, 2013).

Finally, as the distance between the lead and the drafter increases, the benefits dissipate. For Sam, this was explicitly a “decreasing curve of energy savings.” Most of the cyclists’ explanations (like Kurt’s, above) indicate a more discrete effect—a zone of relatively stable benefit surrounded by an area of negligible benefit. Comparing these explanations to the findings in the literature reveals clear parallels. Kyle (1979) found that reducing the distance between two co-aligned cyclists to zero resulted in a 44% reduction in air resistance for the drafting cyclist. At a following distance of two meters, this benefit dropped to 27%. This aligns with Olds (1998), who noted that the benefits of drafting are maximized and relatively stable out to a following distance of 0.5 m (1.6 ft) and begins falling off rapidly at distances over 0.75 m (2.5 ft). Rather than extensive reading of the literature, the alignment between the literature and the cyclists’ explanations is due to the aggregation of sensory experience in cycling groups.

Get Farther Back

Drafting as an interaction between two cyclists is the simplest of the many situations in which it occurs, and one that is relatively rare in group rides. As the drafting
The question described above shows, drafting can happen in all kinds of formations. During the WNR, the most common formations were the paceline (Figure 15, c) and the double paceline (Figure 17, b). The rotating paceline (or Belgian tourniquet; Figure 17, c) and echelon formations were used sporadically, but often enough that the cyclists all knew about them, if not how to enact them in practice.

The vagaries of cycling practice meant that the cyclists had experience in various positions within these formations and, thus, had developed a feel for the effects of drafting throughout the formations. In comparing the effects of drafting on the relative efforts of four cyclists in a paceline, Dean explained that drafting improves for cyclists farther back in the formation.

This [lead] guy's breaking so much wind for [the second] guy. [The third] guy has two people in front of him breaking wind and [the fourth] guy's got three people moving the wind less... so the guy [at the] back here is getting the best draft, obviously... Every time you're in a group, you drop back to the very back. It's so much better way back there.

Just as noted in the previous section, Dean describes an antagonistic interaction between the cyclists and the wind. Each of the cyclists worked to break the wind for the cyclists behind them. The lead cyclist worked the hardest against the wind, with each subsequent cyclist having progressively less air to move. As a result, the farther back one gets in the formation, the more benefit one gets from drafting.

All of the cyclists understood that, regardless of formation, the lead cyclist(s) worked the hardest and that the second cyclist experienced a substantial drop in effort to maintain their speed. Five of the cyclists reported expecting an improved draft farther
back in the group under ideal conditions. Some, like Dean, extrapolated that the benefit would continue to improve with additional cyclists. Sam was representative of the others, who claimed that the relative benefit of being farther back diminished to the point that "it's kind of a wash". As noted above, cyclists do benefit from being farther back in a formation to about the fifth position (Broker et al., 1999). After that, the benefits of drafting level off.

**Follow Big Things**

*E.g., large group.* One way of interpreting the “get behind something bigger” heuristic is that drafting in a larger group would result in increased drafting benefits. On a basic level, this interpretation seems to be getting at the same idea as the “move farther back” heuristic—a larger group (thus, a longer paceline) allows one to move farther back than would a shorter paceline. However, for cyclists, there is more to the size of the group than simply being able to sit as far back in the group as possible and benefit the most from the draft.

For one, larger groups rarely stay in one-dimensional formations for long. Either they break into smaller groups, or they expand into two-dimensional formations, like the double paceline, the rotating paceline, or what several of the DTC cyclists called “the peloton”—a mass of cyclists with no discernable structure. These 2D formations reduce the amount of road taken up by the group, but as Reba pointed out, they also have aerodynamic (and, thus, effort-related) benefits. In reasoning about the ideal position in the block formation (Figure 16), Reba identified the middle back position as the best.
Reba’s explanation of why the middle back position would be ideal for drafting in the block formation annotated

Reba noted that, in general, larger groups are fun and provide good windbreaks, particularly from crosswinds. She punctuated her explanation with gestures for various wind directions (Figure 16, items 4-7) that the other riders in the formation would block for the middle back rider. Kurt seconded this assessment with his own experience, saying, “I’ve got to where I don’t even have to pedal because it’s like being pulled or pushed.”

Reba’s and Kurt’s experiences and explanations were supported by the findings of McCole and colleagues (1990), who found that the back middle cyclist in the block experienced a reduction in energy expended by 39%.

Given the clear and substantial benefit of drafting, cyclists on group rides were expected to take a turn at the front of the group. To facilitate this, rotation was built into many formations, and all of those commonly used during the WNR (Figure 17). Cyclists
who avoided taking a turn were derisively referred to as "wheel suckers," though I never heard anyone called that to their face.

**Figure 17.** Formations used during the WNR. Rotation directions are marked with gray arrows.

In the single (a) and double pacelines (b), the lead cyclists rotated to the back of the pack after a turn up front. In the DTC group, the length of these turns was determined by the lead cyclist and ranged from a few seconds to more than 30 minutes. In his interview, Sam talked fondly about a ride where pulls were limited to 30 seconds, which resulted in the group speed approaching 30 mph.

The most extreme rotation was in the rotating paceline (c), where the entire group constantly rotated. Hausswirth and colleagues found that this formation, also called the “Belgian tourniquet,” resulted in the greatest energy savings across the entire group, but it required more skill to execute than the other formations (Hausswirth et al., 2001).

In a properly-rotating group, cyclists benefit not only from the instantaneous benefits of drafting but also from faster overall speeds and longer rest periods between
pulls. Celeste noted these benefits when comparing a four-cyclist paceline to a pair of cyclists (Figure 15, b and c) saying that the group of four "theoretically would go faster because they have all these riders to cycle through. They can take these nice short pulls, as soon as their legs start feeling tired, drop back." In addition to the previously stated benefits, cyclists in larger groups also can be expected to take shorter pulls, further saving energy. This benefit is especially prevalent in comparison with a pair of riders and is more substantial than the marginal benefits of drafting at the back of the pack.

**e.g., a bigger cyclist.** The other way to interpret the “get behind something bigger” is to get behind a bigger cyclist. Being behind a bigger cyclist was mentioned as the ideal drafting situation by each of the cyclists I interviewed. The importance of drafting off a large cyclist was underscored by the responses of three of the cyclists. Reba, for one, described her drafting strategy as looking for "the biggest person and [trying] to get behind them." Sam and Dean described their experiences with being on the lead side of Reba’s strategy. Sam, who was a smaller cyclist, said of his size, “I get flak for [being small] all the time. ‘I’m getting nothin’ out of you, Sam. Go to the back!’” Dean, on the other hand, said: “Everybody's always fighting for my bum because I'm a big wide guy.” Interestingly, in describing their attempts to draft behind a large cyclist (or being the large cyclist), none of the cyclists specifically mentioned considering the speed of the cyclist they attempted to follow. It could be that the cyclists so commonly rode with cyclists of equal or greater ability that speed became a secondary concern when they thought about drafting. Alternatively, considering the interview setting for the conversation, they could have tacitly applied an “all things being equal” assumption to the conversation to facilitate comparison.
If drafting behind a large cyclist is ideal, drafting behind something larger must also be at least as ideal. At its logical extreme, the large cyclist can be replaced with an automobile or truck in a practice known as “motorpacing.” The most enduring image of motorpacing comes from the 1979 cult classic “Breaking Away” in which a cyclist drafts off a semi-trailer truck and achieves a top speed of 60 mph before the truck is pulled over for speeding. In his interview, Sam recalled accomplishing a similar feat during T3. He and a friend slipped in behind a tour bus on a downhill and hit 60 mph briefly.

While Sam was clearly pleased with the effect of motorpacing on his speed, brief though it was, Dean was the biggest advocate for motorpacing of the cyclists in this study. He recommended that all cyclists try it at least once, so they could experience a "true draft." To his thinking, when the air closed behind the cyclist following a car, it provided a push in addition to the reduction in resistance. He called this the “wrap around effect.” While McCole and colleagues (1990) found that motorpacing could reduce air resistance by 62%, I could not find any evidence of this effect in the literature. As with Kurt’s experience at the back of a large group, the extreme reduction in resistance while motorpacing made gaining and maintaining speed easy enough that it gave the sensation of being pushed.

**Constraints**

While the above heuristics guided the cyclists’ drafting strategies generally, the cyclists also recognized that prevailing conditions had to be accounted for in determining exactly how to draft in any given situation. Despite differences in their own experiences, the cyclists consistently expressed a number of constraints that limited their ability to
optimize their draft position. For this dissertation, I have grouped these into three categories: safety, ability, and legality.

**Safety**

All of the cyclists recognized the practical benefits of drafting, with several citing effort savings of 30% both in the interviews and during rides. Despite these benefits, the feeling about drafting among the WNR cyclists was nicely summed up by Sam when he said, "Drafting is good as far as it goes, but it's just one thing." The cyclists understood that riding in a group is inherently risky (Albert, 1999). This risk was brought to the fore with cyclists wrecking in each year of my association with the DTC group. Early in the 2013 season, one cyclist was doored by a car on a solo ride. That July, Kurt wrecked immediately behind me when he crossed wheels with another cyclist in a patch of gravel. The next year, Dana crossed wheels with another cyclist on camera. In each case, the injuries they suffered kept the cyclists from participating for at least the remainder of the season.

Although wrecking was taken as an inevitable part of full participation, the consequences of wrecking led to many individual safety considerations intended to mitigate the risk. Reba noted that many of the cyclists that she knew that had gone down were later unable to draft as closely as they had previously. After a particularly severe crash, Sam gave up cycling for nearly a decade. Even a further decade removed from the crash, Sam was very selective in the cyclists he would follow at any distance. In her interview, which took place after her crash but before her return to cycling, Dana claimed a following distance of "about a wheel and a half," which amounts to approximately 1.1 m (43.5 inches) and was more than double the greatest following distance reported by
any of the other cyclists. The injuries Dana sustained when she wrecked ended her season and delayed her participation in the next cycling season. In describing her drafting strategies in light of her wreck, Dana said

I may not be in the best draft position, sometimes it will be the safer position for me not wanting to cross wheels with someone or wanting to give myself time to react, so I'm not always in that sweet spot.

By keeping her distance in the wake of her wreck, Dana increased her time to react to changes in the group at the expense of maintaining an optimal drafting position. As a result of her crash, Dana accounted for safety more aggressively than she had previously and more than most cyclists did under similar circumstances.

**Ability**

Crashing is not the only reason cyclists might change their drafting strategy, they must also account for their own abilities and the abilities of the cyclists around them. While purchasing the right equipment can help one look like a veteran cyclist (see Chapter 3), on-bike behavior was key to determining whether or not a rider is actually a good cyclist. Every cyclist I interviewed said that good cyclists were “smooth.” In recalling her experiences learning to draft (Chapter 3), Dana repeatedly noted that the model cyclists were smooth and that Kali corrected her when she was “unstable.”

Instability was a characteristic associated with new and inexperienced cyclists, who were described as "all over the bike... so they weave a lot." Small adjustments in body position—rotating one's hips to finish a pedal stroke or moving one's shoulders to add a little extra power—cause the bike to rock and weave. These movements make the cyclist more unstable and unpredictable, or "squirrelly."
In his interview, Sam defined smoothness as “no shoulder rock, no hip rock, totally stationary... just a machine.” Holding one's upper body still requires both core and leg muscle strength. More importantly, smoothness on the bike exhibits one's control over one's body and bike. Smoothness reduces inadvertent lateral movement and can help a cyclist maintain a consistent speed. The reduction in overall movement also aligns with cyclists’ desire for increased efficiency (Chapter 4). All these effects make a cyclist’s draft very predictable.

Cyclists’ drafting instruction, as reported in Chapter 3, is intended to help them develop a sense of comfort while drafting close behind another cyclist. By claiming to draft especially close, like Sam and Dean do, a cyclist is simultaneously claiming to be a good cyclist. Drafting close requires the same control over speed and lateral movement that is prized in lead cyclists. Phoebe tacitly acknowledged the relationship between close drafting and being (or wanting to be seen as) a good cyclist when she defined drafting as "following closely behind someone, like maybe six inches from their back tire to your tire. I probably never follow that close, it's more like 12 or more." Phoebe had internalized the “get closer” heuristic, noting an ideal following distance of six inches. However, she claimed to follow at a potentially less optimal distance, separating herself from the good cyclists.

Dean, on the other hand, claimed to draft within inches of another cyclist, adding the caveat that the other cyclist had to be "somebody I really trust." So, while Dean was confident enough in his own abilities as a cyclist to draft, he altered his following distance based on
On a ride in May 2014, a new (to the group) rider joined the WNR. As we were riding up a small hill, I found myself positioned behind her. In my field notes for the day, I recorded that "Dean came up to me and told me, be careful. And said that [she] would take me down and made a wiggling motion with his hands" (field notes, 5/28/2014). His wiggling motion was like the ASL for *fish*. His implications were clear—I would wreck if I got too close to the newcomer because she was all over her bike and did not maintain her line. This demonstrates that when cyclists choose people to draft, the abilities of the rider in front of them was key in determining how well they can optimize their draft position.

When the drafting situation extends beyond a pair of cyclists, the abilities of the individual cyclists can be compounded farther back in the formation. All of the cyclists cited a phenomenon they referred to as the “yo-yo effect.” Yo-yoing begins when a gap forms between a drafting cyclist and the cyclist in front of them. This initial gap can be caused by squirrelliness on the part of one or several cyclists near the front. It can also occur when the lead cyclist rides at a speed that the cyclists behind them are unable to maintain. When the drafter accelerates to close the gap, reaction time results in a slightly larger gap forming between them and the cyclist behind them. This continues through the end of the formation and can result in the trailing cyclist being separated from the group by several yards.

With constant speeding up and braking cycles, yo-yoing makes riding at the back of a large formation "almost not worth the windbreak that you're getting" according to Reba. To counter the yo-yo effect, the cyclists used two general strategies—1) stay close to the third or fourth positions in the formation, or 2) maintain a larger-than-normal
following distance. The first strategy allowed the cyclists to benefit from the increased drafting benefit farther back in the formation while staying far enough forward that the yo-yo effect was at an acceptable level. The second strategy essentially trades potential drafting benefits against the deleterious effects of frequent accelerations.

**Legality**

Limitations related to safety and ability are imposed by the cyclists themselves. The third category of constraints, legality, is externally imposed. In the area where the DTC cyclists rode, cyclists were expected to follow the same laws as automobiles when using the road, including obeying traffic signs and signals. In addition, cyclists were also expected to follow two laws specific to them: 1) cyclists must ride as close to the righthand side of the road as "practicable"; and 2) cyclists must ride no more than two abreast, and then only when there is no automobile traffic.

Cyclists have developed a reputation of playing fast and loose with the law (e.g., Basford, Reid, Lester, & Thomson, 2002; Horton, 2007). Though the cyclists of the DTC group were generally law-abiding, this reputation was warranted to some degree. On the WNR, the cyclists rarely stopped at stop signs and never stopped at empty intersections. During the warmup, their loose formation took the entire lane. These behaviors would occasionally elicit comments or actions from passersby. In my field notes, I recorded the following exchange during a warmup, not far from DTC.

A guy yelled from the sidewalk, "What's wrong wit' y'all?" I'm guessing it was in response to our rolling through stop signs when there were no intervening cars...

A guy in a car behind us asked, "Why don't you try to take the whole road?" To which one of the riders said, "We're trying." (Field notes, 4/23/2014).
Outbursts like these were emblematic of the irritation that other road users likely felt at the cyclists' behavior, if not with their mere presence. This irritation was also manifest as drivers passed the group aggressively, including passing too close (a common occurrence; see K. H. Taylor & Hall, 2013), accelerating and revving their engines, and blowing thick exhaust smoke on them (also known as “rolling coal”). This behavior is sometimes excused based on cyclists’ bad reputation.

This reputation is not entirely warranted, however. Earlier in this chapter, I described Reba’s examination of the pack formation (Figure 15, d), in which she said that riding in center-rear blocked the wind from all directions. Before offering this explanation, Reba said simply, “You're just going to get pulled over.” She had to be convinced that the roads were closed to other traffic before proceeding. Celeste responded similarly, saying, "The middle guy is pretty happy other than he's probably worried that the cop is going to pull them over." Even though the group may take other liberties with the law, the two-abreast law at least warranted consideration when determining in-ride actions.

This consideration was also evident when examining the formations the cyclists typically used (Figure 17, a, c, d). Each of these formations—the paceline, double paceline, and rotating paceline—were no more than two-abreast. The echelon formation (Figure 17, b) was a notable exception. In the echelon formation, the cyclists ride in a diagonal line parallel to the perceived direction of the wind (the forward movement of the cyclists plus the direction of the wind). In races on closed roads, echelons stretch across the entire width of the road. Even a four-cyclist echelon can take up a whole lane. Because it violated the two-abreast law, the echelon formation was only used in
extremely strong side winds. As a result, while the DTC cyclists were familiar with echelons, they were not skilled in its implementation in practice. On one particularly windy day, a visiting cyclist tried to teach a small group of DTC cyclists, including me, how to echelon. "Do you know how to ride in an echelon?" he asked. Then, while making diagonal slashes across the road, he added "Four. Four. Four" indicating that we should make rows of four cyclists each. "Make as many as you need," he said, signaling that we should not go over the center line (field notes, 7/30/2014). Even in cases where the cyclists exceeded the two-abreast limit, they adjusted their drafting formations to fit within the constraints of a traffic lane.

Chapter Summary

Air resistance is a phenomenon that cyclists experience constantly throughout their participation in cycling practice. At a high level, there are a few points that are important to understand: 1) fluids (including air) oppose a body's motion through them, 2) resistance is related to the size and speed of the body, 3) a low-pressure area forms behind the body, and 4) a body positioned in the low-pressure area (aka drafting) experiences greatly reduced air resistance.

As with their understanding of mechanical advantage, the cyclists’ physical experiences with and attempts to mitigate air resistance play a key role in the way that cyclists understand air resistance and drafting, in particular. Although cyclists’ drafting knowledge was based primarily on these experiences and tips from other cyclists, their knowledge closely mirrored the outlines of the phenomenon developed in the literature. They made this understanding actionable through the employment of a few heuristics that guided their attempts to optimize their drafting position. Following these heuristics, the
veteran DTC cyclists placed themselves well within the 0.5-m drafting range identified by Olds (1998); chose to position themselves farther back in groups, per Broker, Kyle, and Burke (1999); and favored drafting behind larger cyclists, automobiles, or in larger groups, as in McCole et al. (1990). Under ideal conditions, a strategy based on these heuristics maximized the cyclists’ efficiency, enabling their participation in group rides and races with other cyclists who might otherwise have ridden away from them.

As an intellectual pursuit, understanding the effects of optimal drafting position requires controlling for many variables that are beyond a cyclist’s practical control, including the skill level of the other cyclists in the group and environmental concerns including wind direction and road conditions. Studies involving air resistance and drafting cited herein have occurred in relatively controlled environments, from carefully selected participants in on-road measurements to computational fluid dynamics simulations on models of still cyclists. While the weekly WNR ride provided greater freedom for the cyclists generally, the ride was situated in established practices while moving through specific physical spaces that circumscribed the cyclists’ mobility in particular ways. These constraints necessarily change the way cyclists reason about and approach air resistance is practice. The cyclists’ draft optimization strategies included responses to constraints clustered around maintaining safe positioning in light of their own and other cyclists’ abilities and the local laws regarding road use. Because they had to account for these constraints in their drafting reasoning, the cyclists drew on a richer set of criteria when determining not only how they draft, but who they draft, and when they draft as they work to increase their efficiency.
CHAPTER SIX
DISCUSSION

This dissertation has dealt with two primary concerns: 1) What counts as knowing? and 2) Where and how can we see learning taking place naturally?

Traditionally, knowing has been split into theoretical and practical knowledge, as Scribner (1984) has noted. In this dichotomy, theoretical knowledge, described as rational and universal, has held a privileged place in textbook and research approaches. Practical knowledge, on the other hand, is knowledge applied by “just plain folks” (Lave, 1988) in solving problems they encounter in practice. Because practical knowledge is characterized by its situatedness, it has been seen as inferior to or less desirable than theoretical knowledge. In focusing their analytic attention on everyday knowledge, Scribner, Lave, and others showed not only that practical knowledge was worthy of their attention, but that it was also effective and valuable within the scope of their use. These studies demonstrated that people of all educational backgrounds employed situated problem-solving strategies, particularly when efficiency and accuracy are key (e.g., de la Rocha, 1985; Hoyles et al., 2001; Masingila, 1994).

The literature has repeatedly demonstrated that these practical strategies are not simply “hacks” or “workarounds” but legitimate, alternate ways of knowing. A basketball player who struggles in math class can still use statistics to assess his own performance or that of his idol (Nasir & Hand, 2008). Although an engineer may calculate rocket stability using simulations and a formula, a model rocketeer might determine whether her rocket will fly by swinging it over her head or by comparing it to other rockets that are known to fly well (Azevedo, 2013). Saxe (1991) showed that unschooled candy sellers were more
proficient in mathematics than were their schooled counterparts when the problems were based in the local currency system. What these and many similar findings (e.g., Schademan, 2011; E. V. Taylor, 2009) show is that there is more to knowing than is commonly valued. As a result of a too-restrictive view of knowing, many people with productive but nonstandard ways of knowing are denied opportunities they might otherwise qualify for (Stevens, 2013).

Broadening our views of what it means to know necessitates a broadening of where one can know and come to know. Schools certainly can and do provide great opportunities for learning. Intentionally designed informal learning spaces like museums (e.g., Davis et al., 2013; Schauble, Leinhardt, & Martin, 1997) and after-school clubs (Rahm, 2002) can provide novel learning opportunities for students otherwise not well served by formal education to engage in unexpected ways and on their own terms (e.g., Kafai & Peppler, 2008). This finding mirrors the learning that takes place spontaneously in children through extended play (e.g., Stevens et al., 2012; Vygotsky, 1978). This rule-guided play helps children navigate the rules of the "real" world, where they will "play" at dairy packing (Scribner, 1984), insurance claims processing (Wenger, 2000), and nursing (Pozzi, Noss, & Hoyles, 1998), copier repair (J. S. Brown & Duguid, 1991), or managing finances and feeding a family (Lave, 1988). The social practices inscribed on these settings support and shape the knowing that takes place therein.

The goal of this dissertation was to investigate how learning and knowing were supported in a practice where high levels of physical effort were necessary for participation—specifically, cycling—and how the practice might shape that learning and knowing. In my examination of cycling, I focused on three research questions:
1. What are the characteristics of participation in a cycling community of practice? And what opportunities exist or are created for learning through participation?

2. How do cyclists describe and explain mechanical advantage? And how is it related to their participation in cycling practice?

3. How do cyclists describe and explain air resistance? And how is it related to their participation in cycling practice?

The findings for these research questions were presented in the three chapters immediately preceding this one. This chapter will present my interpretation of these findings and their significance in light of the relevant literature.

**Summary of Findings**

Cycling practice is centered around the weekly group ride, which had a typical recurring structure with different phases being characterized by changes in group speed and formations. These phases shape the learning opportunities available to new cyclists. During stationary phases (i.e., gathering and regrouping), veteran cyclists provided verbal instruction highlighting general behavior and safety issues. When in motion, veterans provided *ad hoc* scaffolding focused on helping new cyclists increase their control over their bodies and their bicycles, including an appreciation of the physical sensations related to the skillful use of their bicycle in practice.

For the cyclists in this study, skillful performance included valued characteristics such as smoothness and efficiency. By maximizing their efficiency, cyclists were able to push the limits of the distances they could travel at speed, which was a goal of all the cyclists. As a result, managing instantaneous effort (which included being smooth on the bike) was key to skillful cycling. In relation to mechanical advantage, the DTC cyclists
defined instantaneous effort as a combination of cadence (pedaling rate) and pedal resistance (Chapter 4). Cyclists’ gearing-related problem-solving strategies centered around balancing cadence and resistance to minimize their instantaneous effort to maximize the sustainability of that effort. The relationship between gearing and effort as understood by the cyclists helped contextualize a cyclist’s performance when relating a past ride.

Mitigating instantaneous effort (and increasing efficiency) was the primary driver behind the practice of drafting. Cyclists looked for pockets of calmer air behind other cyclists that were associated with sensations of reduced effort—less perceived wind, lower heart rate, easier pedaling. Learning to leverage changes in these sensations to optimize one’s draft resulted from a combination of direct instruction and aggregate experience. When drafting and considering drafting situations, cyclists effectively employed heuristics developed in practice while working within constraints imposed by the realities of that practice. Although the cyclists' actions and reasoning did not always result in the mathematically optimal behaviors relating to either gearing or drafting, their decisions resulted in sufficiently effective resolutions within situation-specific patterns of constraints.

**Making Sense of Cycling**

In responding to practice-linked problems related to mechanical advantage and air resistance, the cyclists often drew on hard-won experience gained through countless hours of solo and group riding over years of participation in the sport. Each of the cyclists generalized their experience based on common physiological and kinesthetic responses of their bodies, which could then be used for explanation and problem solving. Sam made
this observation explicit when he said, “I don’t know the Physics of it, but I can feel it.” In the context of a “science-y” interview on a university campus, the cyclists hedged their explanations by saying they only knew what their bodies told them.

However, as the findings presented above showed, although the cyclists used the responses of their bodies in optimizing their position (for mitigating air resistance) and their gearing, their strategies accounted for both the physical phenomenon they considered and the particulars of the social situation in which they found themselves—e.g., the norms and goals of the group with which they were riding, their personal goals and desires to be (seen as) a certain kind of cyclist. Although the body and its feedback take primacy in the cyclists’ understandings, these understandings are the result of socially-mediated embodiment, rather than a “purely” embodied experience, if such a thing can be said to exist.

While studies into socially situated cognition have typically overlooked or de-emphasized the role of embodiment and vice versa, researchers have begun to recognize the important role of each influence on the other (e.g., Barsalou, Niedenthal, Barbey, & Ruppert, 2003; Rambusch & Ziemke, 2005). Recent studies have been explicit in recognizing, for instance, that learning that engages the whole body can also be shaped by the social production of space during learning activities (Ma, 2014), or that students’ engagement in full-body, rule-based play can be a powerful experience in learning physics (Enyedy et al., 2012) and programming (Lu, Kang, Huang, & Black, 2011). In these and other studies of embodiment, the primary goal is to leverage learners’ proprioception and other embodied resources (Ma, 2014) to scaffold their adoption of culturally valued ways of knowing. This goal is accomplished by having the students
interact with specific technologies and artifacts (e.g., Nemirovsky, Tierney, & Wright, 1998; Tscholl, Lindgren, & Johnson, 2013) and cooperating with (e.g., Ma, 2014) or competing against other students (e.g., Johnson-Glenberg, Birchfield, Megowan-Romanowicz, & Snow, 2015).

In helping students arrive at valued understandings, these studies of embodiment employ many of the same methods of enculturation as have been documented in naturalistic settings (e.g., Nasir & Cooks, 2009). In studies of these settings, researchers often use “embodiment” to refer to the degree to which a person internalizes and enacts the values of their community (e.g., Holland et al., 1998; Lave & Wenger, 1991). This version of embodiment can be seen in the cyclists’ adoption of cycling clothing and equipment norms, their dedication to finding time to ride throughout the year, and their recognition of “smoothness” on the bike as a measurement of skillful participation.

However, beyond acting in ways that reflect accepted community values, participation can also reshape the way one understands their body’s responses to stimuli in the setting (Becker, 1963). Among athletes, this shift in understanding changes the way one uses one’s body to improve performance. This shift in the way one appreciates and reacts to embodied resources through participation in social practice is what I mean by “socially-mediated embodiment.”

In the DTC group, being recognized as a cyclist requires a rider to reinterpret their in-ride kinesthetic experience. What was once uncomfortable becomes pleasurable as they push their abilities further and further. This reinterpretation comes as new riders observe and interact with veteran cyclists over months and years of participation. Veteran cyclists scaffold new riders’ participation with combinations of verbal instruction and
physical correction (e.g., pushes, pulls, and touches). These actions serve to highlight proper on-bike behavior and, given the continuous effort of cycling, help the rider associate proper and improper behavior with the movements and sensations that produced them. In doing so, the new riders are able to “make sense” (Abrahamson, 2015) of cycling values.

The social and embodied nature of the cycling mindset is clear in their gearing and drafting strategies. For example, that the cyclists favored higher cadences was most often a result of years of trained participation in practice that resulted in them riding at cadences that aligned both with the expected behavior of veteran cyclists and with efficient cadences identified in the literature (e.g., Abbiss et al., 2009). Drafting properly also requires the cyclists to value the performance benefits of drafting over the innate response of keeping one’s distance, which also further reinforces “smoothness” as a measure of skill.

Because participation inherently limits action (Wenger, 2000), socially-mediated embodiment also indicates a limitation on the kinds of embodied sensations that can be considered. Because of legal constraints on the breadth of a cycling formation, some of the cyclists would not consider some drafting situations even hypothetically. Additionally, several of the cyclists discounted the effect of tight clothing on air resistance, citing instead its importance to cycling identity and comfort as the reasons for the kit’s continued use.

**Conclusion**

The findings presented in this dissertation provide another glimpse into the many factors that shape learning and knowing. Following Azevedo (2013), this study demonstrates that
effective and skilled participation in practice has the ability to support distinct ways of knowing. As Saxe (1991) and Nasir (2000) showed, these ways of knowing are shaped by the goals of the individual participants and the norms of the community. This dissertation extends these studies by examining the way that long-term participation in a physically demanding practice influences the way participants understand the phenomena they experience. By employing ethnographic methods, I was able to examine the mutually constitutive nature of embodiment and practice in how cyclists engaged with the world. This “socially-mediated embodiment” may provide an interesting analytical lens in future studies, but it also urges caution. As external technologies and practices are appropriated for classroom or other direct instructional purposes, researchers and educators need to recognize that this appropriation changes the goals and practices around the embodied experience of using the artifacts. This, in turn, can change the nature of the learning that takes place.

Limitations

Population

Over the two years of observation, I had 30 consented participants, with seven cyclists agreeing to formal interviewing. Most of these cyclists had several years of experience riding in the WNR. This \( n \) is small for developing generalizability. However, small-scale studies are common for this type of work. For example, Nasir (2000) used players from two basketball teams. Azevedo (2011) observed three rocketry sites, but maintained relationships with three confederates.

That said, extending the sample to include active racers or newcomers could provide additional insights. For example, one racer I chatted with (who was consented
but left the country immediately after) expressed nuanced strategies for selecting gearing equipment based on race-specific criteria.

**Observation**

Cycling is a difficult practice on which to perform ethnographic fieldwork. The observation-related limitations for this study are threefold. Firstly, I focused my observations on the Wednesday Night Rides. The cyclists also participated in *ad hoc* weekend rides and individual, small group, and charity rides throughout the week. Secondly, I had one POV camera for half of one season. Adopting video recording for capturing rides earlier may have provided some additional details I missed.

**Comparison**

To establish the peculiarities of the candy sellers' mathematical knowledge, Saxe (1991) compared their interview responses with those of non-selling, school-educated children of similar ages. While this did not capture the richness of the school environment for learning, Saxe's studies were focused entirely on the candy sellers; the school children provided an acceptable baseline population for comparison. Including the school children allowed Saxe to determine what shifts in thinking might be particular to the practices of selling. This study did not include a comparison group, so ascribing any shifts in reasoning to cycling participation needed to be based on other evidence and a degree of conjecture.

**Interviews**

Many questions in the interviews were designed to elicit narratives relating to the cyclists' individual approaches to various situations. This more ethnographic approach to the interviews provided a great deal of material for characterizing cycling practice and
how it influenced some aspects of cyclists' reasoning relative to mechanical advantage and air resistance. The interviews could have included additional questions further examining the dynamics and extent of the cyclists' understanding of the phenomena.

**Suggestions for Future Research**

**Expand population**

To include a wider swath of cyclists, including active racers and beginners, a future study could employ a mixture of direct participant observation and the mobile video ethnography methods described by Spinney (2011). Rather than limiting observations to groups the researcher can keep up with, cyclists are instrumented with multiple cameras and each ride is followed by a video-elicitation interview relating to their experiences. Given the similarities between the groups observed in this study, by Albert (1991) and by O'Connor and Brown (2007), direct observations can move between different cycling groups and focus on any peculiarities in practice rather than documenting the practice in its entirety.

**Add a comparison group**

To capture and analyze functional shifts in understanding particular to cycling, interviews could be conducted with a comparison group, such as mechanical engineers (professionals, students, or both) or general physics/engineering students. While this population should, ostensibly, have knowledge that approximates the canonical version of both mechanical advantage and air resistance, it is not necessary for the comparison.

**Observe the shop**

Given the importance of the shop in the practice of the WNR group, interviewing and observing shop mechanics and the owner relative to practice and the phenomena
would be beneficial. These observations could further clarify the role of the sales force in shaping and enforcing the norms of the group.

**Expand the Physics interviews**

The interviews could include more questions testing conceptual and quantitative knowledge relating to both mechanical advantage and drafting. These could include more gearing comparison questions, more prodding at the explanations for why a gear is easier or harder, air resistance at various speeds, more questions about the influence of skin friction, and more about how air moves (as in Hirsh & Levy, 2013). This would further facilitate comparison to a non-cycling population.

**Explore other aspects of practice**

While this study included many hours of observation and interview data, the richness and complexity of cycling practice make it impossible for any one study to more than scratch the surface. There remain many other aspects of practice that could potentially be explored. One of these is nutrition. All of the cyclists shared nutrition tips, some traded recipes, several of them reported "experimenting" with various nutritional strategies both on and off the bike.
REFERENCES


Marchal, P., & Huynh, J.-B. (2012). Dragonbox. WeWantToKnow.


APPENDICES
Appendix A: Summary of the Data Corpus
The tables below provide summaries of the group ride and interview data corpus, respectively. The ride data table provides information regarding the date of the ride, the total time for the ride and the state of field notes for the date. The interview table shows the date of the interview, the subject of the interview, and the length of the interview.

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Appendix B: Audio Jottings Example
Good evening and welcome to another exciting edition of the Wednesday Night Ride postgame show. So, tonight... was rather fun. Um... it was a good crowd, all of whom were consented, so awesome on that part.

Let's see. Tonight we had Kurt and, um, Celeste, and Michelle (briefly) and Phoebe and Leanne and Dean and Dan and Matt and Allen and James. Fun times.

[1:17] So, I got there early to make sure I could discuss with Kurt the arrangements for Saturday. They're planning a ride down in Shelbyville area and it sounded like a blast, so I, as soon as I found out I could go for sure, I told them that I wanted to go. And, uh, anyway, it turns out there's a huge storm coming on Saturday which is the day we're supposed to be riding. It's supposed to get nasty as of Friday and, um, yeah, so in an effort to miss that, we may only be riding locally. Anyway, so there's still some debate about that, um...

[2:39] So, we talked about that for a little while. Yeah, um, Celeste's trying to sell her bike to Michelle, so she prevailed on Michelle to get her to trade bikes for the evening. So they went and swapped bikes, swapped pedals, or were supposed to be doing that. Um, a few minutes before the ride. So, the ride to a few extra minutes to get going. While we were out there, we discussed the accuracy of weather forecasts and um, things of that nature.

[3:55] Then, um, after we did that for a while, we decided to head out. Celeste came back out with her old bike, and she apparently hates it because it's heavy and the top tube's too long, and the handlebars are too wide and the wheels, I said the wheels are too heavy.
Anyway, so she complained about that for a little while. Anyway, we headed out to west. We did the Little Tourmalet again today. Michelle turned around after not, before we even got out of town, um, because she couldn't get out of the pedals they put on. Apparently they didn't swap hers off, they just tried a different, same model, but different pedals and they were too tight for her, so she bailed on the ride.

Today, I basically tried to hold my place. Dan kept the ride going pretty fast for the whole night, um, until he dropped us at South Valley Middle School, which was a boon for the rest of us. Matt, yeah. At South Valley, Allen went back to see if he could find Michelle, and uh, because she sounded like she was going to catch us. But, with Dan leading the pack, it would have taken somebody of Matt's caliber or better even, to catch the group, especially given the kind of lead that swapping pedals would have allowed us. So, my guess is she probably abandoned the ride entirely. Um, let's see, what else happened...

Yeah, oh, so Allen went back, but, uh... Any way, Dan and Matt and James decided they were going to go climb the hills, Little Tourmalet, and um, after about a minute, everybody in the other group decided that they were ready to go and decided that Allen had gone with the other group even though I told them that he hadn't.

So, we started off and when we reached the intersection where we were supposed to meet the other group, they realized, that was when they accepted that Allen was gone, but they overlooked the fact that I told them Allen had gone the other way. Um, any way, they talked about how they had previously chided Allen for doing exactly what we did tonight. Someone joked that we were teaching him a lesson.
[8:09] Anyway, then Allen caught us and kept going and rode off by himself. I don't know if he was pouty or just decided since he was riding by himself anyway that he would try to put the hurt in on us. And, he did. Matt pulled the whole way through there. I got stuck at the back of the pack and there was quite a bit of yo-yoing going on, so on one of the corners I kind of attacked and moved up in the group. I was behind Celeste and Phoebe and I passed them and then hopped in behind Leanne and then passed her as we turned toward Harrison Dam. I think I descended that about as well as I ever have, certainly as fast as I ever have.

[9:30] Anyway, then I, as we were headed past Harrison Dam, the park, I noticed, I yelled that we had dropped the women in our group and everybody else in the group rode off anyway. Phoebe caught up to the group and I dropped back to help Celeste and Leanne. But then, only after allowing the rest of the group to get far enough away that it was hard for me to catch up to them again, Leanne announced that she was heading off. Celeste went with her. So, I rode furiously to catch the group to tell them that Celeste and Leanne had headed off on their own. We rode in on Hollow Road.

[10:35] As far as all that goes, I felt pretty good tonight. I wasn't sure I would. After the VITAL meeting, I was feeling pretty sapped. The discussion that we had during the meeting was quite draining. So, I didn't know if I was going to have it in me, kind of like last week and then about a month ago when I turned around after being dropped.

I've been eating better since then, so I certainly had the physical energy. Once I got on the bike and started thinking about biking, I felt fine. I think the ride down from the University kind of helped with that, helped recenter me. And besides, it was biking, it's late, the weather was perfect. There aren't going to be too many days like this,
especially after the big rainstorm that's supposed to start blowing in on Friday, and it was
good company, so there's that too.

[12:05] I caught some good shots of Allen and Dan and Celeste or Dean up in
front of me and they all had different cadences. Allen is definitely a gear masher. He
rides at a much lower cadence. I think it was Celeste that was in front of me at that point,
but it was good. So, I'll try to see what their cadences were and see if I can ascertain what
gears they were in.

Dean was freaking out at the beginning because his bike computer was telling him
that he was going about twice as fast as he was. It sounded like he had two magnets on,
but we couldn't find two magnets on his wheel when we stopped, so I don't know what it
was because that would require a much smaller wheel.

[13:35] Um, let's see. Anything else exciting? Oh, on Hollow Road, um, well, first
on the way out west, there was kind of an echelon-ing thing going on. But, there was no
discernible side wind, so I'm not sure what that was all about.

Then, uh, as far as, on Hollow Road, we were doing our customary racing down
the road thing. There was a constant shifting of personnel, of leaders. Dean pulled for
quite a while. I think James did too. Allen for sure did, and then he dropped back. He
can't sustain that for the whole ride. I pulled out after Allen did. Anyway, after I started to
fade, James passed me and I hopped into his wake, and was able to speed up again, which
was pretty cool.

[15:05] Heading into the middle school there was a brief Belgian Tourniquet,
rotating paceline, or whatever you want to call it that kind of formed spontaneously and
I'm not sure why it did. We were going pretty fast. Yeah, I'm not really sure what that was for.

That was the ride.

[15:49; end]
Appendix C: Field Notes Example
Preride

I arrived intentionally early so I would be there to discuss the plans for the special ride that was supposed to take place on Saturday.

The weather was a bit warm to begin with. I was a bit worried about the temperature, given that I had a 20-oz bottle and a 24-oz bottle (rather than my typical 2 24-oz bottles). I realize, writing that, that the 4-oz difference doesn't seem like a lot, but
whether it's a psychological thing or an actual problem, it was a definite concern, especially if we were planning to do Newton again.

When I arrived, Kurt's bike was in the rack outside the shop. Kurt was inside chatting with the staff. I positioned myself in the shade across from the back door to the shop. I thought several times about moving inside. I had my camera rolling and felt a bit foolish recording an empty parking lot, but I didn't really want to fool around with the camera in front of the other riders, so I held my ground.

After a few minutes (that seemed longer than they actually were), Kurt came out and we started discussing the previous week's ride. He said he had missed because it was his girlfriend's birthday, and he thought that would be a more effective way to spend the day rather than riding with us.

During our conversation, several other riders arrived—Celeste, Michelle, Dan, Leanne, James. As they arrived, the conversation shifted to the plans for the ride on Saturday. The group had been planning one last long ride before the weather turned nasty. Since the weather has been unseasonably warm for the last few weeks, it seemed like a great time to do it. However, the weather forecast predicted that a massive cold front would come in accompanied by heavy rains. I checked my weather app while we talked and noted that it said there was an 80% chance of rain.

The conversation continued for a bit more while the other riders pulled into a circle around us. For the first several minutes, Leanne and Dean stayed hidden behind her van.

When the group had formed, Kurt repeated that he was concerned about the weather forecast for Saturday, but he wasn't willing to cancel the ride just yet. During
this conversation, I pulled out my phone to make sure I knew James's name. James said he wished he had a job where he only needed to be right 40% of the time to be considered successful. I told him to play baseball. Dean recalled a time when the forecast for the next day called for heavy rains but the actual weather was clear and beautiful the whole day.

Sometime during this conversation, Michelle pulled up next to Celeste. Celeste insisted that she and Michelle trade bikes for the day. Apparently, Michelle had expressed interest in buying Celeste's bike. Michelle was reluctant to make the trade. I couldn't hear whether this was related to the fact that the ride was about to start or to her actual desire to purchase the bike. In an apparent effort to get Michelle to assent, Celeste said they could just swap pedals if Michelle was willing to ride at Celeste's seat height for the day. The two of them took their bikes and disappeared into the shop.

While they were gone and after the conversation had flagged, I asked if we were going to be able to choose a route without Celeste. Dean said we should be able to do so. Kurt said that the wind was coming out of the south, though several other riders questioned that observation. I couldn't tell that there was any wind at all. He said that our route should depend on whether we wanted to go into the wind at the beginning or on the way home. As is customary, consensus dictated we shoot for the potential of a tailwind on the way home.

With that in mind, we decided we would be doing Little Tourmalet today. Shortly thereafter, Michelle and Celeste emerged from the shop. Celeste was riding her old Giant that she said she hadn't even touched since she bought the other bike. She started complaining about the bike almost immediately.
Matt pulled up right as we were headed out and hopped onto the back of the group.

**Heading out**

Almost immediately after Celeste and Michelle emerged from the shop we started rolling out. As I caught up to her, I asked Celeste what was wrong with her bike. She said that the wheels were heavy, the top tube was too long, and the handlebars were too wide. She said a better question would be what was right about the bike.

After that brief exchange, we all dropped into our customary paces as we meandered through town and out west. Before we made it to the Aquatic Center, word spread through the group that Michelle had dropped out of the ride because she couldn't get out of the pedals that they had put on Celeste's bike. To save time, instead of swapping pedals straight across, they threw some similar pedals onto Celeste's bike without testing whether they would work for Michelle. Evidently, they did not work. They said that Michelle was going to try to catch the group, but that we were to keep riding without her.

The rest of the jaunt through town was pretty uneventful. However, for what may have been one of very few times, we caught the light on Tenth perfectly and everyone made it across quickly.

After some initial smushing, we all fell into single file line behind Dan and trekked west. As usual, Dan pushed the pace. Like last week, the quicker pace out to west didn't feel like it was particularly onerous. I was fourth in line, with Allen and Celeste riding ahead of me.
Although I couldn't feel a side wind, Allen and Celeste were riding in echelon behind Dan, with Celeste riding near the shoulder of the road. I didn't feel any particular need or desire to ride out on the far edge of the road, so I aligned myself with Allen's line and tried to keep from overlapping Celeste's wheel. When riding with Dan, I usually note how fast his cadence is. Today was no exception. This time, however, I had Celeste's and Allen's cadences to compare it to directly. Allen clearly pedaled much slower than Dan did, which is probably why he's great in sprints and over shorter distances but doesn't have the stamina for longer rides. Celeste's cadence was considerably faster than Allen's, but still slower than Dan's, probably in the realm that "normal" people consider comfortable.

Although the pace was quite fast on the way out, when we turned south, the group was still pretty much intact. A few people slowed up trying to see if Michelle was close enough to warrant waiting. Although, at the pace we were going it would have taken a superhuman effort to catch us. A group of fast cyclists may have been able to catch us, but Michelle riding solo would have had a hard time doing it. Dan slowed down a bit but was still going faster than the rest of the group. Celeste and Dean accelerated to chase him down, and I followed suit. Soon the entire group had reformed and picked up the pace.

Once on the highway to Wellsville, Dan pulled away again. Matt led the group in the chase, and we soon overtook Dan. I expected him to accelerate and drop back in front, but he continued to drift back to the back of the group. I was in second position behind Matt when we hit the small hill that always seems to blow up the group. It's only a small rise in the road, but if you go too slow, the group sprints past. If you go too fast,
you end up by yourself. The hard thing is that the appropriate speed seems to change every week. This week, Matt and I climbed it at about 20 mph, which is usually on the fast side, but not impossible. Once we crested the hill, Matt turned to look and saw that we had dropped everyone. He said we should slow down to wait.

We didn't have long to wait. Dan, Kurt, Allen, and Dean all came quickly up on our left. We accelerated to join the group. They pulled away from me a bit, but I realized that it really didn't matter, since by this time the Middle School was right in front of us, so I pulled up and coasted in to the pull off.

**Waiting at the Middle School**

As we pulled into the Middle School, several of the riders behind me yelled to stop. So, I did. Dan and Matt continued coasting down the road toward the hills, leading some to wonder aloud whether they had heard the direction to stop. After riding quite a ways down the road, they turned around to see what was going on.

Kurt told Matt and Dan that we were planning to head down the easy way through town. Since Dan and Matt wanted to climb the hill, Kurt said we would meet them at the intersection of Mount Silver Road. Before last week, I probably wouldn't have known which road that was. Kurt said that we would probably beat them to the road, since we waited there last week for several minutes. Allen and Matt noted that they thought we were going to meet them at the top of the hill last week, so they waited at the top as well.

Dan and Matt took off toward the hills, and James jumped in to follow them. After waiting for a few minutes, the riders in our group began the pre-departure checks to make sure everyone was ready to go. One of them asked where Allen was. I said he had gone back to check for Michelle. Dean rode back down the road for a bit to see if he
could see him. Several of the other riders were convinced that Allen had gone with the faster people. I asked if Allen had ridden past while I wasn't looking because I saw him ride back to check for Michelle.

**Through Wellsville**

After Dean came back and said he hadn't seen Allen, Celeste said she was pretty sure he went with the other group. With that, the group decided to leave. As usual, I started out behind everyone. The alternate Tourmalet route drops down into Southtown and rides down Main Street and crosses the highway at the Park and Ride. Through town, it's mostly downhill, but on the edge of town it starts climbing. Dean and Kurt led the group through town. When the road started climbing, they pulled off and let Celeste and Phoebe lead. They didn't stay in the lead for very long, and then Leanne and I led.

Somewhere before the highway, Leanne crosstrained her chain—had it in the big ring and big cog. When I do that, it makes a little extra noise, but I can get it to quiet down by using the trim stop on the front derailleur. Leanne's was so loud it sounded like the drivetrain was completely misaligned. Dean and Kurt talked about it behind me. Kurt noted that Leanne couldn't hear her chain because she had her earphones in. Dean said he didn't know how people could ride with earphones in.

Leanne started slowing down and I continued past her. Phoebe caught up to me on the final climb up to the highway. We noticed a police officer across the street. I said we should probably stop (a "cop stop"). Phoebe said she kept hearing about cyclists who got pulled over for not stopping at stop signs. I said I had heard the stories, but I have never actually seen it happen or met someone who actually got a ticket. While we waited, the
rest of the group caught us and rode through. Kurt said we could go and didn't bother stopping. The officer's attention was focused on the drivers coming down the canyon.

The road on the other side of the highway is a bit steeper and the group started breaking up as we rode up. I rode slowly for the first little bit. Phoebe started climbing away from the group. I held back until Dean passed me, then I started climbing faster. By the time we reached the intersection, I had caught Phoebe.

**Regrouping at Mt. Silver Road**

Matt and James were waiting for us when we arrived at the intersection. Matt told us that Dean decided that he would continue on without us because he had to get home. As we began to regroup, one of the riders in my group asked where Allen was. Matt said that Allen hadn't gone with them. Kurt joked that we had just done to Allen the exact same thing they had yelled at him for for the past few years. (I don't know that I have seen Allen actually ride off without anyone else. He's definitely been "itchy" and pacing around on his bike during stops, but I've never seen him actually leave without anyone that I can remember.)

They joked that they were teaching him a lesson. (I immediately thought of Arrested Development). Dean turned back to check whether Allen was coming or not. Given that we had already been waiting for a few minutes, and we kinda sorta took our time getting up the road, I figured that he wasn't too far down the road. Dean rode just barely out of sight. Shortly thereafter, he returned and said that Allen had just crossed the highway and was on his way up.

We waited a few more minutes until he crested the hill. As he rounded the corner, Kurt yelled that we thought he went with the other group. Allen responded with
something like "Oh, I see" and kept riding. As we started, Kurt said, "Well, I apologized."

By the time I got on my bike, Allen was quite a ways down the road, well ahead of the rest of us. I wondered if this was Allen's way of saying, "Thanks a lot for ditching me" or if he just figured that everyone would catch on soon enough.

As we continued riding, it was clear that he wasn't going to make it easy for us to catch him, certainly not before the park at the reservoir. Matt lead the group in a paceline in pursuit. I was in the back of the pack, with Leanne, Phoebe, and Celeste immediately in front of me. With Matt driving the group in pursuit, the pace was very fast. That meant that there was a whole bunch of yo-yoing at the back as the weaker riders (weaker than Matt) strained to keep up.

I stayed at the back trying to deal with the yo-yoing for a while, but eventually I decided it was harder to try to keep up yo-yoing than it was to just jump up the way a bit. So, when a gap opened up in front of me on a turn, I pulled out and around Phoebe and Celeste and dropped in behind Leanne. I thought it was interesting that there was less yo-yoing behind Leanne, even though I would put Phoebe and Celeste up as stronger riders.

I sat in behind Leanne until we started riding down the last straightaway toward the dam descent. At this point, the group usually starts breaking down any way, and tonight was no exception. I waited until the group started to morph into its descending "amoeba" formation. I usually position myself far enough away from other riders that I don't have to worry too much about my line while I go down.

I thought I descended fairly well. I only braked a little. At the bottom, I had caught up to Matt in a sprint. We were right behind the others, who were slowing going around the turn before the straightaway to the park entrance.
Passing the Park

At the park, no one even bothered asking if anybody needed water; we just kept going. By the time we passed the park entrance, I was last among the men in the group. After climbing the hill just past the park, I looked back and noticed that we had dropped the women. I yelled ahead that we had dropped the women, but the group continued on.

I dropped back a bit to make sure I could help them catch the group. Phoebe passed me and joined the group. I sped up a bit, thinking all was well. As I came up behind Kurt, he said he could always tell when it was me coming, thanks to the GoPro on my helmet. I said there was no stealth mode for me.

I noticed that Celeste and Leanne were still behind, so I dropped back again to allow them to catch up. Celeste came up first. She said that she was being entirely selfish when she said she was slowing down to help Leanne. In fact, she said, she was only giving her legs a rest. She had tried to drop back earlier in the ride, thinking there might be a group that had dropped back. However, when she got to the back of the pack, she realized that no one had dropped off, so she had to keep up. By keeping up, she was making sure that no one could/would drop off.

We soft pedaled for a while until Leanne caught up. All the while, the rest of the group was riding away from us. Shortly after she caught up to us, Leanne said that she was planning to turn off early. Celeste said she would follow suit. She said I should catch up with the rest of the group and let them know that they had turned off. Of course, by this time, the rest of the group was quite a ways down the road.

After making sure that they were turning, I rode quickly toward the trailing group. Matt decided he was going to ride to Paradise. He had asked James back at Mt Silver if
he wanted to go with him. I never heard a response. Since James was still in the group, I figured that he had decided not to.

I caught them at the intersection with the highway by Mountain Peak. Dean was telling Phoebe that the call as to whether to go down to Hollow Road or straight in was hers to make. She decided to hit Hollow Road, so we headed down our normal way toward the canyon.

I fell to the back of the pack as we prepared to descend, as is my custom. At the corner of Hollow Road, I took an inside line and passed Phoebe. As usual, the group started sprinting as we moved down the road. Dave and Kurt led the way. They pulled first. When they dropped back, Allen took over. Allen quite naturally upped the pace. As Allen dropped back, James took over. I was still behind Phoebe in the line. As James faded back, Allen again surged forward. I hopped in his wake and allowed him to pull me to the front of the group.

Once at the front, I sprinted past Allen and tried to keep the pace up. After a while, my pace slackened (to about 24-25 mph) and James passed me. I jumped in behind him and was able to speed up again. It was amazing how much difference there was in dropping behind him. I've drafted off people many times, but the effect during sprinting is always impressive.

After we hopped onto the highway, we rode single file down the road to the light at Maverick. There, we turned up and rounded the round about. As we cruised up 100 E, Dean pulled up next to me and said it was a great day for a ride. The weather had cooled slightly. We really couldn't have asked for better weather.

Shortly thereafter, the group broke up and we headed home.
Appendix D: Relationship to Cycling Interview Protocol
This interview is intended to cover the cyclist’s history with the sport, their sense of place in the group, their perceptions of what it means to be a successful, capable cyclist, and their relationships with other members.

1. What got you started in cycling?
   a. How long have you been cycling?

2. What inspired you to try group riding?
   a. What was your first group ride like?
   b. Who was it with?
   c. What did you learn about biking [riding in a group] that day?
   d. Have you noticed a difference between solo riding and group riding?
   e. How long have you been riding in groups?

3. What got you started riding with Joyride?
   a. How did you find out about it?
   b. How was it pitched to you?
   c. Why do you keep riding with them?
   d. Are there particular people you look forward to riding with? Why?
   e. Is there anyone in the group you interact with outside of the rides? What do you do?
   f. If you had a friend who was looking for a cycling group, how would you pitch the Joyride group to them?

4. How would you describe your skills as a cyclist?
   a. If you had to name one cycling skill that you were best at, what would it be?
      i. Why did you pick that one?
      ii. How did you learn to do it?
   b. Is there a cyclist in the group whose skills and riding style you think are close to your own?
   c. When you’re out riding, are there cyclists you gauge your performance against, who you’re competitive with (even if they don’t know it)? Who? Why?

5. How do you think others in the group would describe your skills as a cyclist?

6. Who would you say is the best cyclist in the group? What is it that makes you say that?

7. Let’s say a new cyclist comes to the group. How do you size them up as a cyclist while waiting for the ride to begin?
   a. Is there anything in particular you look for?
   b. (How) does it change once you’re out on the road?
   c. Let’s say there’s a new person who joins the group. They seem to be keeping up with the group just fine. (How) can you tell if they are new to the sport or experienced?

8. After a few weeks, the new cyclist comes up to you for advice on picking a new bike. [S]he says she has enough money to get whatever bike is necessary, but doesn’t really want to buy “too much” bike.
   a. [S]he doesn’t race now, but wants to leave the door open
   b. Upgrades are okay
c. Definitely wants to be able to participate in the Joyride group and not look too out of place.

9. Who do you go to for advice or if you want to know something about cycling? Why them?

10. What would you say is the most important thing you’ve learned about being a cyclist?
   d. When did you learn it?
   e. How did you learn it?

11. What was the most recent thing you learned that helped you improve your performance?
   f. When did you learn it?
   g. How did you learn it?
   h. What about the thing before that? And before that?

Bike Comparison Images (Question 8)

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<tr>
<td>Color</td>
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<tr>
<td>Weight</td>
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<table>
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<tr>
<th>Brand</th>
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<tr>
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<td>Carbon, Standard frame</td>
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<tr>
<td>Crankset</td>
<td>105 50-34T</td>
</tr>
<tr>
<td>Cassette</td>
<td>105 11 speed, 11-28T</td>
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<tr>
<td>Derailleurs</td>
<td>105</td>
</tr>
<tr>
<td>Brakes</td>
<td>Axis 1.0</td>
</tr>
<tr>
<td>Wheels</td>
<td>Axis 2.0</td>
</tr>
<tr>
<td>Tires</td>
<td>Specialized Turbo Pro 700x25</td>
</tr>
<tr>
<td>Color</td>
<td>Black</td>
</tr>
<tr>
<td>Weight</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Brand</strong></td>
<td>Scott Contessa Speedster 35</td>
</tr>
<tr>
<td>-----------------</td>
<td>----------------------------</td>
</tr>
<tr>
<td><strong>Frame Material</strong></td>
<td>Aluminum, Standard frame</td>
</tr>
<tr>
<td><strong>Crankset</strong></td>
<td>Shimano FC-R453 50-39-30</td>
</tr>
<tr>
<td><strong>Cassette</strong></td>
<td>Shimano HG50 9 speed, 11-30T</td>
</tr>
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<td><strong>Derailleurs</strong></td>
<td>Shimano Sora</td>
</tr>
<tr>
<td><strong>Brakes</strong></td>
<td>Tektro SCBR-525</td>
</tr>
<tr>
<td><strong>Wheels</strong></td>
<td>Syncros Race 27</td>
</tr>
<tr>
<td><strong>Tires</strong></td>
<td>Kenda Kriterium 700x23</td>
</tr>
<tr>
<td><strong>Color</strong></td>
<td>Purple/White</td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td>21.38 lbs (9.70 kg)</td>
</tr>
</tbody>
</table>
Appendix E: Mechanical Advantage Interview Protocol
Materials List
- Video camera
- Tripod
- Wide angle lens
- Shotgun mic
- Whiteboard
- Whiteboard markers
- Whiteboard eraser
- Set of wooden gears (TBD)
- Maps and Elevation Profiles
  - Little Pyrenees
  - Little Mountain
  - Empire Pass
  - Newton

Mechanical Advantage
General bike knowledge
1. Could you draw me a picture of a bike and tell me about the different parts?
2. How does pedaling make a bike go forward?
3. [So, bikes have lots of gears—18, 22, 27.] What are all the gears for?
   a. [if they talk about gears making it easier to go up hills] What makes it easier? Why can’t you just stay in the easy to pedal gear all the time?
   b. [if they talk about gears making it so they go faster] How do gears make it so you can go faster? Why would you ever want to change into a gear that makes you go slower?
4. How do you pick which gear to use?

Ride-specific gears
5. Let’s say you’ve decided to ride up “Little Mountain.” [show map/elevation profile/picture] You’re coming at it from Trenton. Can you tell me how you shift as you approach the hill and as you climb it?
   a. What gear do you start in?
   b. (How) do you change it before you start climbing?
   c. What do you do as you climb?
   d. How do you decide when to shift?
6. We ride “Little Tourmalet” every so often in the summer. [Show map/elevation profile of the Little Tourmalet Climb with average grade] What gear are you usually in during the climb?
   a. Could you pick it out of these gears?
   b. What’s it like?
   c. Why do you use that gear?
   d. [if they say it’s their easiest] Would you change into an easier gear if you had it? What gear would that be?
   e. Why not something like [pick a gear harder/easier out of the cut ones based on their response]?
7. Have you ever ridden Empire Pass? [Show map of the Military Ridge with average grade]
   a. I’ve never ridden it. What was it like?
   b. Do you remember what gear you were in? [Could you pick it out?]
   c. Why were you in that gear? [probe any differences]
   d. If you could have changed to an easier gear, would you have? What gear would that be [have them pick it]?
   e. Why not something like [pick easier/harder gear]?

8. Another ride we do all the time is the ride out to Neuberg. On the highway from Valley View to Neuberg, what gear(s) are you usually in?
   a. Could you pick it out?
   b. What’s it like riding in that gear?
   c. Why do you pick that[those] gear(s)?
   d. Does it matter if you’re riding with other people or by yourself?
   e. Why not something like [pick a gear]?

**Gear ratio specific questions**

9. You said your bike has a [standard/mid-compact/compact] crankset. So, it has chainrings this big:

<table>
<thead>
<tr>
<th></th>
<th>Big</th>
<th>Little</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>53</td>
<td>39</td>
</tr>
<tr>
<td>Mid-Compact</td>
<td>52</td>
<td>36</td>
</tr>
<tr>
<td>Also</td>
<td>52</td>
<td>34</td>
</tr>
<tr>
<td>Also Also</td>
<td>50</td>
<td>36</td>
</tr>
<tr>
<td>Compact</td>
<td>50</td>
<td>34</td>
</tr>
</tbody>
</table>

[they may have a really weird custom set up, but keep the question to these sizes]

   a. If you were in [X gear], is there a comparable gear in the [small/big] ring?

<table>
<thead>
<tr>
<th></th>
<th>Big</th>
<th>Little</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>53/18-26</td>
<td>39/13-19</td>
</tr>
<tr>
<td>Mid-Compact</td>
<td>52/19-27</td>
<td>36/13-19</td>
</tr>
<tr>
<td>Also</td>
<td>52/18-29</td>
<td>34/12-19</td>
</tr>
<tr>
<td>Also Also</td>
<td>50/18-26</td>
<td>36/13-19</td>
</tr>
<tr>
<td>Compact</td>
<td>50/19-28</td>
<td>34/13-19</td>
</tr>
</tbody>
</table>

**Weird drivetrains**

There are always people trying to change what a bike looks like, how it’s driven. I’m going to show you a few of these so we can talk about them.

10. Here's one take on a chainless bike.
179


b. How could you make it more like a regular bike?

11. This one is a “treadle bike”

12. I saw a bike online with with gears like this:

a. What do you think riding this bike be like?
b. How would it compare to a bike with these gears?

i. Would it be easier or harder to pedal? Why?
ii. Would it be faster or slower to ride? Why?

13. If I were to give you a million dollars to build up the bike of your dreams, what gears would you pick for it?
   a. Why would you pick those gears?
   b. Why not go with a triple or even a quadruple in the front?
   c. Are there any gears you’d pick that I don’t have here?
Ride Segments

**Little Tourmalet**

<table>
<thead>
<tr>
<th>Distance</th>
<th>Avg Grade</th>
<th>Lowest Elev</th>
<th>Highest Elev</th>
<th>Elev Difference</th>
<th>Climb Category</th>
<th>Attempts By People</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 mi</td>
<td>5%</td>
<td>4,560 ft</td>
<td>4,834 ft</td>
<td>274 ft</td>
<td>4</td>
<td>704</td>
</tr>
</tbody>
</table>
Little Mountain

Distance: 1.1 mi  
Avg Grade: 5%  
Lowest Elev: 4,454 ft  
Highest Elev: 4,758 ft  
Elev Difference: 304 ft  
Climb Category:  
1,212 Attempts By 330 People
Military Ridge
Neuberg Time Trial
Bear Mountain
Appendix F: Air Resistance Interview Protocol
Materials Needed
• Video camera
• Tripod
• Wide angle lens
• Shotgun mic
• Whiteboard
• Whiteboard markers
• Whiteboard eraser
• Magnetic cyclists (cyclists.pdf)
• Printout of birds_v_cyclists.docx
• Printout of upgrades.docx cut into individual upgrades

Air Resistance
1. So, you’re riding along, by yourself, no wind. [Place a magnetic cyclist on the board]. Tell me what’s going on with the air.
   a. How does that change when you start going faster?
   b. How can you tell?
   c. Is there anything you can do about it?

2. Could you explain, in your own words, what drafting is?
   a. How does it work?
   b. How do you know when you’re doing it right?
   c. How does drafting change the way the air moves?
   d. How close do you have to be to make it work? Does that change with speed?
   e. How did you figure out that drafting was helpful?

3. So, besides just riding in a straight line, what other drafting tactics do you know? (You don’t have to know the names of the tactics, if you can just describe how they work) [If it helps, they can use the cyclist magnets].
   a. Are there times when one tactic is better than another? When?
   b. Are there times when it’s more helpful to draft than others? When?
   c. How do you know?
4. For the next few questions, I'll show you a few different cycling situations. I want you to compare the level of effort—who's working hardest—for the cyclists I show you and explain why. [arrange magnetic cyclists for each situation] [as it may prove fruitful, ask the interviewee how they would react to being a particular cyclist in the examples]

a. A single cyclist vs. a two cyclists drafting.

b. A single cyclist vs. four cyclists in a line.

c. Two cyclists following at a distance vs. two cyclists close together

d. Four cyclists in a line vs a pack of cyclists

e. Cyclists rotating the lead

f. A large heavy cyclist vs a small, light cyclist

g. Cyclists in f. riding up a 5% grade
5. Let’s say we have three cyclists, all exactly the same—same size, fitness, ability, equipment, everything—they ride a 40 km out-and-back time trial at the same power (level of effort). [place 3 magnetic cyclists on the board]

![Wind](image1.png)

Wind ←

Wind →

a. One rides out and back with no wind.
b. One rides with a headwind on the way out
c. One rides with a tailwind on the way out

What order would they finish in? Why?

6. [Show pictures of a peloton and a flock of birds] Can you find two similarities between a flock of birds and a group of cyclists?
7. Lots of cyclists I know are gear junkies. Every bit of gear promises some benefit in performance. I’ll give you a few of these ‘upgrades’ that a new cyclist might invest in. I’d like you to tell me how each of these might improve a new cyclist’s performance, particularly aerodynamically, and how much they might help (this can be relative to other items on the list).

- Baggies to fitted kit
- Standard helmet to aero helmet [helmet upgrade]
- Standard to deep section carbon rims [wheelset upgrade]
- Round tube to carbon frame
Rim to disk brakes

8. One last question. You saw me wearing the GoPro all last year. One of the guys suggested that I shave my legs to offset the penalty for wearing the GoPro. Would that work?
Appendix G: Informed Consent Form
INFORMED CONSENT

Goal formation and pursuit in athletic groups

Introduction/Purpose Dr. Victor Lee and Joel Drake in the Department of Instructional Technology & Learning Sciences at Utah State University are conducting a research study to find out more about how goals are established and pursued in the context of an athletic group. You have been asked to take part because you ride with a cycling group that was identified for study. There will be approximately 30 total participants in this research.

Procedures If you agree to be in this research study, you will continue to participate in your cycling group as you would normally. A researcher may:
1. Record notes about some of the observed activities from your ride.
2. Record short videos from the rides to capture important activities or conversations related to the goals of the group.
3. Ask you to participate in one or more formal interviews that involve questions related to your athletic activity, your goals and habits as a cyclist, and your relationship with the group. These interviews are voluntary and should take no more than 60 minutes. These interviews may be video recorded.

Risks Participation in this research study is considered minimal risk; however, there is a possible risk for breach of confidentiality. Some of the data obtained may be shown to other researchers at professional meetings or presented in written reports. The researchers have taken steps to minimize risk and more information may be found below under “Confidentiality.”

Benefits There will be no direct benefit to you, for participating in the research. Researchers however, hope to learn and understand how athletes form and pursue goals as part of a group.

Explanation & offer to answer questions A researcher has explained this research study to you and answered your questions. If you have other questions or research-related problems, you may reach Victor Lee at (435) 797-7562 or Joel Drake at (435) 770-2398.

Payment/Compensation You will receive a $10 Amazon.com gift card for each interview you are asked to complete in your participation in this study.

(Note: If you will receive payments, gift cards or similar items of value for participating in this research, the Internal Revenue Service (IRS) has determined that if the amount you get from this study, plus any prior amounts you have received from participating in research studies at USU since January of this year, total $600 or more, USU must report this income to the federal government. If you are a USU employee, any payment you receive from this study will be included in your regular payroll).

Voluntary nature of participation and right to withdraw without consequence Participation in research is entirely voluntary. You may refuse to participate or withdraw at any time without consequence or loss of benefits. If you wish to withdraw from this study after it has begun, you may email the principal investigator at victor.lee@usu.edu. Should you receive compensation before requesting withdrawal from the study, you may still keep your compensation.
INFORMED CONSENT

Goal formation and pursuit in athletic groups

Confidentiality Research records will be kept confidential, consistent with federal and state regulations. Only the investigator and research personnel will have access to the data which will be kept in a locked file cabinet, in a locked room, or on a university-owned password-protected computer to maintain confidentiality. To protect your privacy, a pseudonym will be used in any written reports of your cycling activity or presentations that result from this work. If any images are published from this research, your face will be blurred using photo-editing software. If any video excerpts are presented at research meetings, the excerpts will last at most a few minutes, and your name will be replaced with a pseudonym. Any research records, such as recorded notes or video footage, will be stored on a password-protected computer owned by Utah State University and backup copies will be kept on a secure server or in a locked office. We will destroy any identifiable records of you within 10 years of study completion.

IRB Approval Statement The Institutional Review Board for the protection of human participants at Utah State University has approved this research study. If you have any questions or concerns about your rights or a research-related injury and would like to contact someone other than the research team, you may contact the IRB Administrator at (435) 797-0567 or email irb@usu.edu to obtain information or to offer input.

Copy of consent You have been given two copies of this Informed Consent. Please sign both copies and keep one copy for your files.

Investigator Statement “I certify that the research study has been explained to the individual, by me or my research staff, and that the individual understands the nature and purpose, the possible risks and benefits associated with taking part in this research study. Any questions that have been raised have been answered.”

Victor Lee, Principal Investigator
(435) 797-7562
victor.lee@usu.edu

Joel Drake, Student Researcher
(435) 770-2398
jrichdrake@gmail.com

Signature of Participant By signing below, I agree to participate.

Participant’s signature Date

V7 06/15/2011