How high school biology students epistemically frame project-based learning

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HOW HIGH SCHOOL BIOLOGY STUDENTS EPISTEMICALLY FRAME

PROJECT-BASED LEARNING

BY

Vincent Amodeo

A Dissertation

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Dedication

To my sons Andrew and Luke for their unending support, continuous understanding, and unconditional love.
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I would like to thank my advisor Alan Oliveira for his tireless support and guidance and his insistence on excellence. Alan pushed me to continue working on this extremely difficult task. He never gave up on me even when I felt like giving up on myself. I would like to thank Professor Jianwai Zhang who worked with me during the early stages of this process. Both of these professors have been generous with their time and advice, almost to the point of frustration.

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Lastly, I would like thank my life-long partner and future wife, Jessica whose enduring support and love has allowed me to persevere.
Abstract

This research investigated how high school biology students epistemically framed their learning as they engaged in Project-Based Learning. The hypothesis is that as students participated in Project-Based Learning activities, the language they used would reveal how they epistemically framed their learning. By analyzing students’ language, it would be possible to determine where they are in their epistemological development and follow them to see if they progress along an epistemological development continuum. One group of four students were audio-videotaped as they completed a Project-Based Learning activity. A theoretical framework of discourse analysis guided the analysis of speech elements generated by the students during the activity. The students’ utterances were classified in one of 23 speech element categories which were aligned with four epistemological development categories. There were two specific speech element categories, hedges and interrogatives which were significant in driving the prevalence of certain epistemological development categories. What evolved from this study is that position in an epistemological development category is stable; that epistemological development is not always forward, that there is regression to a previous stage; and that there is minimal fluctuations in day-to-day epistemological development categories.
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CHAPTER ONE: INTRODUCTION

Introduction

This study examines how high school biology students epistemically frame project-based learning. The study will investigate the epistemic developmental changes that students experience as they make their way through their projects. Indicators for these developmental changes will be the utterances students make and where this language places them in the hierarchy of developmental positions elaborated upon by Perry (1968).

Perry described four positions of epistemological development that take place as students progress through school. The first phase is dualism where students see things as being absolute: they are either right or wrong. The second phase is multiplicity where students reluctantly open themselves up to the existence of other possible answers, opinions, ideas and points of view, but still remain loyal to authority, be it an individual or text. Perry’s third position, relativism is where knowledge and learning are something to be analyzed and evaluated based on its context. Commitment is the fourth of Perry’s positions. In this position, students feel the need to define their personal choices, thereby establishing themselves in terms of their identity and their position in the community.

The study focuses on epistemic framing and project-based learning because it is believed the synergistic effect of these two constructs leads to academic success for the subject group. While each construct has been studied extensively independent of the other, the interaction between the two has not been studied. The sample group is a class of students at a unique public high school in upstate New York that is very successful in biology as measured by the state exam. The primary form of instruction for these students, and the school as a whole, is project-based learning (PBL).
The core argument in this study concerns how students epistemically frame their learning while they are engaged in PBL. I maintain that epistemic framing is related to developmental changes in students’ epistemology as they progress through PBL and that this is a major factor in their academic success. In an effort to find evidence in support of this thesis, I studied how the students’ language used during their PBL tasks is related to their epistemological framing. This analysis will include evaluating the linguistic elements of the epistemic framing and demonstrating which types of language are associated with the developmental positions outlined by Perry (1968): dualism, multiplicity, relativism, and commitment. This is important for instructors because it will enable them to monitor the language elements used during PBL and to intervene when necessary to help guide students toward a productive PBL experience. This work will also benefit academic researchers as it will serve to strengthen the connection between the two constructs.

Herron (2010) emphasizes the significance of epistemological transformation for students: “the shift from objectivism to relativism in epistemic cognition development is a desirable experience for high school and college students in order for them to achieve academic success (p.103).” Sandoval (2014) also weighs in on the significance of a developmental theory. Understanding a developmental theory such as this would make it possible for educators and researchers to create effective instruction, and enable them to provide evidence for epistemological development and point out its consequences for individual students (Sandoval, 2014, p. 386).

**PBL**

In the early 20th century, John Dewey recognized and wrote about the value of PBL. Having assailed the failings of the traditional school, with its teacher-centric, didactic approach,
his criticism was not seen simply as a condemnation of the “old education,” but also as an opportunity to increase awareness that education may be “intelligently conducted upon the basis of experience” (p. 33). Dewey’s notion of education by experience can be thought of as today’s PBL, and the social process component of that experiential learning can be found in epistemic framing. These two constructs form the basis of this investigation. Dewey emphasizes the importance of communication in education, pointing out that “education is essentially a social process” (p. 58). He affirms what is central to PBL: “[W]hen education is based upon experience and educative experience is seen to be a social process, the situation changes radically” (p. 59).

Project-based learning examines poorly structured or “messy” real-world problems through concentrated, hands-on activities and mental attention, group problem-solving, and collaborative innovation (Ashman, 2012; West, 2013). The practice of PBL also requires critical thinking skills and employs various forms of communication.

It has been demonstrated that PBL increases student engagement and the modeling activities of practicing scientists (Ashman, 2012). Tal and others (2006) identify the hallmarks of PBL as the extended engagement of students to solve a driving question through (1) authentic investigations; (2) collaboration; (3) communication of ideas and solutions; and (4) the creation of a product or artifact that demonstrates understanding and could serve as a focal point for discussion, feedback, and analysis (p. 724). Cheung (2011) reports that PBL is a feasible method of improving real-world proficiency in a variety of academic fields (p. 844).

From collaboration to assessment, there is ample evidence that project-based learning is at the heart of STEM education. For instance, efforts are underway by some teachers to use PBL as the mechanism to integrate STEM into their curricula. Other endeavors have included collaborative unions between teacher organizations and STEM professional development businesses.
working to nurture a cooperative culture. This is where teachers work alongside employers from government agencies and private industry to develop PBL opportunities allied with the real world of science and engineering (2013, NSTA). In addition, PBL is considered as one of the four critical elements to advance STEM learning no matter what the industry focus is. When PBL’s are well-designed and integrated into the curriculum, they bring rigor and importance to learning. Additionally, when industry partners are involved in project design, as in the case of the nano biology project at the PBL school, students are given the chance to experience real-world applications (Hoachlander and Yanofsky, 2011).

The integration of PBL and STEM also has a role in assessing teacher performance. The Aggie STEM Center at Texas A & M University reports how the value of PBL for STEM has been enhanced by its use as an observation instrument to evaluate how teachers implement PBL in their classrooms, “PBL has undeniably become an important concept in our field, and the authors provide a useful way to provide teachers with feedback on their classroom activities, particularly following professional development” (Raju, 2012).

The strength of the synergy of PBL and STEM can be seen by the inclusion of PBL in national standards. The Next Generation Science Standards cite PBL, specifically project-based science learning, as one of the elements of its three-dimensional learning (italics in original). PBL is used as a rubric element to determine if lessons align with NGSS and are consistent with NGSS Science and Engineering Practice 3 “planning and carrying out investigations” (Krajcik, 2015, p. 25).

Studies have reported that when students integrate PBL activities into STEM, they
demonstrated a significant shift in their attitudes. This was seen in the students’ recognition of the importance of STEM in science and engineering fields (Tseng et al, 2013, p. 87). Other studies cite PBL as a way to improve the United States’ position in the world in the four core STEM subjects (Meyer, 2007, p. 35). Still another study demonstrated the positive influence for STEM in PBL on students’ cognition and behavioral intentions (Lou et al, 2011).

The acronym STEM stands for Science, Technology, Engineering, and Mathematics, and it originated in the 1990s at the National Science Foundation. At that time, STEM referred to the four distinct fields for which the letters stand, but today the acronym implies the integration of these disciplines (Sanders, 2009). A STEM education is important for preparing workers in related fields for which there are not enough laborers with the required skills. A recent Brookings Institute report showed that “STEM skills are in high demand relative to supply and the problem is especially acute in certain metropolitan areas…” (Raju, 2012).

Project-based learning allows students to acquire 21st-century skills, such as the ability to collaborate and work in teams, and to employ innovation and creativity, critical thinking, technology and information literacy, and self-direction (www.p21.org). With such sought-after skills in high demand, it behooves educators to obtain a deeper understanding of the connections between PBL and epistemic framing.

**Epistemic framing**

Epistemic framing is the means by which an individual or a group makes sense of an event, vocalization or situation. The process of epistemic framing allows an individual to interpret the event, speech or situation based on his or her prior knowledge or experience (Shaffer, 2006). Nash and Shaffer (2011) have identified epistemic framing in professional settings.
such as urban planning and architecture, and maintain that experts have particular ways of thinking and making decisions based on established values. The attributes of epistemic framing seen with professionals include specific modes of argumentation and standards of evidence (p. 175).

Epistemic framing happens when we compare our impressions of something new with our prior knowledge of the world; framing in this way helps bring understanding to our lives. A person will respond to an event in a manner that is conducive to the expectations related to that situation. For example, when a supervisor gives a gift to an employee, the employee may frame this event as a pleasant surprise or as an unwelcome charity. When a student is given math problems to solve, he or she may frame the assignment as an opportunity for understanding or as an example of “busy work” (Scherr & Hammer, 2009).

Epistemic framing is significant for learning, and science educators should be concerned about it because it may contribute to academic success. Epistemic framing allows students to recognize the connections between situations or circumstances, and between current events and past events that happened to them or those they had heard about before (Tannen, 1993). The ability of students to epistemically frame their learning is critical for academic success in PBL classrooms. Epistemic framing provides the context for a witnessed or experienced event, allowing students to process this knowledge into something they can talk about, something they can verbalize—an important step in sharing knowledge in PBL environments (2014, October 13).

In a PBL classroom, student collaboration is a key component along with learner-centered instruction, driving questions, production of artifacts, and extended time frames (Colley, 2008). All of these characteristics are the norm for classes at the school where this study was conducted. Epistemic framing is important to these classes because it not only “sets the stage”
for conversations, but it can also be used as an indicator of collaboration. Epistemic framing enables listeners to comprehend what they hear and prepare a response based on the manner in which they are operating (Tannen, 1993).

Epistemic framing is ensconced within communities of practice; therefore it is valuable to assess the foundation for their existence. Different forms of knowing—knowing *with*, knowing *where*, knowing *how*, knowing *when*, and knowing *that* (italics in original)—are part of that foundation (Shaffer, p. 227, 2006). Each of these ways of knowing is associated with particular communities of practice. So when a student engages in epistemic framing, that process justifies, explains, and represents that student as he or she orchestrates strategies for determining questions, collecting data, and evaluating results (Shaffer, p. 228). In sum, epistemic framing is the glue, or the organizing action, that hold the community together.

**Framing BPL**

Epistemic framing may also include physical activity. Scherr and Hammer (2009) explain that the way in which students frame an activity affects what they observe, the knowledge they access, and how they think to respond to that activity. Students’ physical actions can be studied to reveal the connections between distinct patterns of behavior and epistemic framing. This is valuable for science educators to recognize because it would enable them to modify or adapt the classroom context and content, thus encouraging inquiry learning. These are all important features of students’ collaborative behavior in PBL environments.

These studies provide evidence that epistemic framing makes effective communication possible among PBL participants. There have been two parallel and concurrent lines of research on this subject: one focuses on epistemic framing, and the other focuses on PBL. The majority of research examines either epistemic framing or PBL, but there is scarce research on epistemic
framing in PBL classrooms. The available literature does not link these two important constructs, and current research fails to examine whether or how epistemic framing influences PBL.

This a significant gap in understanding because if communication is key to PBL, then epistemic framing could be used as an indicator of the success, depth, and form of that level of communication. Instructors and teachers might be able to identify those indicators and step in to direct students to more productive discourse during the project. More accurate and insightful models of the interactions between these two constructs are needed for practitioners of PBL at all instructional levels. The following section explains how the present investigation addresses this deficiency in the research on epistemic framing in PBL.

Research questions

The present study examines how students epistemically frame PBL. Its research design utilizes discourse analysis in order to identify the developmental stages that characterize epistemic framing created during PBL. The analyses focuses on the seven steps involved as students completed their projects while being observed in a PBL Biology class. The target group in this study is 32 members of a PBL Biology class in an innovative high school in upstate New York. The school is unique in that it is a “public” high school run collaboratively by three separate entities, where students are selected by lottery, and where instruction in all disciplines is project-based.

Project-based learning is clearly connected to the academic success of students. However, epistemic framing while equally important to academic success, is rarely, if ever, connected to PBL. This intersection of epistemic framing and PBL is the focus of this study.
The overarching question this inquiry explores is the following: How do students epistemically frame PBL? This study is also an opportunity to examine sub-questions that relate epistemic framing to PBL. These secondary questions include: How does Perry’s (1968) scheme of epistemological development relate to epistemic framing? How does epistemic framing in PBL affect academic achievement? What are the language elements found during epistemic framing?

The objective of this study is to determine what role epistemic framing plays in making these students successful in a PBL Biology class.

CHAPTER TWO: LITERATURE REVIEW

Introduction

The scholarly literature highlights the dual nature of the term “epistemic frame.” As a noun, epistemic frame has the meaning of how one interprets or comprehends an event or situation. For example, when a student is given an assignment by his or her teacher to learn the systems of the human body by creating a matching column of system and function, the student creates a mental construct that pulls together all of the learning cues, including visual, auditory, and physical to help them understand the teacher’s directions and the learning task they are about to do.

As a verb, framing epistemically refers to the communication of understandings to others. For instance, in the above example, if the student were to ask the teacher a question as to how the matching column were to be set up, and then he or she commented to a fellow student about the assignment, the student would be demonstrating the active form of the term as he or she epistemically frames the learning activity.

This chapter reviews the literature related to this theoretical notion and further clarifies the above distinction. The focus of the first section will delve into the origin of students’ episte-
mological beliefs and the effect they have on their learning. From there, there will be a discussion of the next step in the epistemological development process, the creation of epistemic frames and how they influence the learning process. The chapter will then analyze the communication aspect of “epistemic frame”, what language the students use to epistemically frame their learning. Finally, consideration will be given to the ultimate goal of the research, epistemological development based on Perry’s (1968) scheme.

**Epistemic beliefs**

The basic understanding of epistemic frames rests in individuals’ epistemology: their beliefs about knowledge and how they come to know information. There is a certain trajectory that is followed where one’s beliefs influence their perceptions of his or her environment, where beliefs then affect learning processes and outcomes, and then how those beliefs may sway how he or she responds to convincing and challenging situations. The effect of these beliefs becomes apparent in how students interpret and respond to certain instructional materials and approaches (Alexander & Dochy, 1995, p. 414)

Students’ beliefs are thought to originate from their experiences, where one construct can be distinguished from another based on the formal nature of the experience (Hofer & Pintrich, 1997; Brownlee et al., 2009; Brownlee et al., 2002; Sandoval, 2005). That is, knowledge comes from schooling, and beliefs are derived from everyday events (Alexander & Dochy, 1995, p. 424).

Alexander and Dochy report that an individual’s definition of beliefs tends to include personal goals, intentions, and decision making, suggesting that beliefs play a large role in actions and behaviors and help explain the reticence of people to let go of them. Set against this backdrop is the question of what is the relationship between this personal constellation of knowledge
and beliefs, and epistemic beliefs and the process of epistemic framing. The answer to this question lies in the evolution of epistemic framing from epistemic beliefs, which originate from students’ beliefs about learning and knowledge.

Personal epistemological beliefs are crucial to the development of the knowledge process. Yet the very nature of learners’ epistemological beliefs and their role in inquiry learning is debatable (Sandoval, 2005). Sandoval reports that research on students’ scientific epistemologies has basically ignored inquiry-learning contexts (p. 634). Sandoval further argues that a contradiction exists in terms of inquiry learning and epistemology: while students’ scientific inquiry skills are enhanced, there is little effect on their epistemology.

Students’ epistemological beliefs can be thought to fall into four areas: (1) certainty of knowledge, (2) simplicity of knowledge, (3) source of knowledge, and (4) justification for knowing (Yang & Tsai, 2008; Hofer & Pintrich, 1997). Studies on beliefs and knowledge have shown a range of understandings, from where the two are seen as separate entities to where there is an overlap between them to where there is a distinct relationship between them (Alexander & Dochy, 1995).

There is an argument that knowledge is a subset of beliefs, that all understandings are beliefs, but not all that one believes is, or has been, externally confirmed (Alexander & Dochy, p.428, 1995). Alexander and Dochy’s findings also highlight the overlapping of these two concepts: knowledge affects what one believes and what one believes shapes what becomes known (1995, p. 429).

In order for this dichotomy to be valid, there must be some capability that drives a student or learner to initiate and establish this intentional connection—that force is epistemic beliefs. When the learner no longer sees his or her learning as simply the regurgitation of facts, but
rather as the construction of meaning, the learner establishes his or her epistemic beliefs through which all learning then proceeds. Thus it can be said that there is a direct connection between how students approach learning and their epistemic beliefs. Eventually, these beliefs will influence how they develop their epistemic frames. The evidence for these epistemic beliefs comes in the form of how the students epistemically frame their learning.

Epistemic beliefs then are influenced by one’s knowledge and beliefs about knowledge. Such beliefs influence how one learns and can be divided into four categories. Personal experiences, goals, and intentions are the fuel from which beliefs develop and for which school and everyday experiences are the context.

**Epistemic frame theory**

In this section, I will connect students’ epistemic beliefs to Epistemic Frame Theory. Epistemic Frame Theory articulates the nuances of what it means to be a professional such as a scientist, to think like a scientist. It subscribes to the importance of experience, cognition, skills, behavior, and communication which are as integral to the nature of the student becoming a scientist as they are to the scientist themselves.

Epistemic Frame Theory considers what students experience as they learn. The theory integrates old experiences with new ones, and the individual within the community of practice. Epistemic Frame Theory focuses on expertise in a subject area, interactions with others with shared perspectives that become engrained, and complex problem solving. The theory implies that complex cognition can be made coherent in terms of the connections among the integral parts or “frame elements”: various skills, knowledge, values, identities, and epistemological rules within a specific discipline (Orrill & Shaffer, 2012).
Epistemic Frame Theory considers learners’ basic knowledge and abilities, and the setting in which they occur. It also includes the relationships between knowledge and abilities, and the manner in which decisions are made and actions are rationalized, all occurring in an environment with intricate, real-life situations (Hatfield, 2011, p. 7).

Epistemic Frame Theory reasons that expertise, such as the kind seen in sophisticated thinking and problem solving, basically involves varied and dynamic interrelations between different ways of knowing and acting, which follow the norms and principles of a specific community. This is an argument that Redish and Hammer (2009) make in their study after they sought to reform physics instruction to better suit college Biology majors.

Epistemic Frame Theory presumes that “thinking like a scientist” translates to knowing about science, acting like a scientist, and understanding what matters to scientists. These abilities, values, and understandings are made feasible by viewing the world in a unique way—by justifying certain actions and specific methods as a scientist does. There is an argument that Epistemic Frame Theory is used to examine the development of this kind of complex thinking and problem solving (Hatfield, 2011).

Epistemic Frame Theory assumes that in order to utilize complex thinking, one needs to proceed beyond basic facts and skills. The theory offers a framework to comprehend STEM concepts and supports the need for a shared knowledge base and skills, and an understanding of the values that guide the decisions made during problem solving. Epistemic Frame Theory emphasizes the connections among the various elements of problem solving: values, skills, and knowledge (Third International Conference on Interdisciplinary Social Sciences, 2008).
Epistemic Frame Theory reasons that expertise, such as the kind seen in sophisticated thinking and problem solving, basically involves varied and dynamic interrelations between different ways of knowing and acting, which follow the norms and principles of a specific community. This argument was made in a study that sought to reform physics instruction to better suit college Biology majors (Reddish & Hammer, 2009). They cite that an implicit component of course content is a conflict related to epistemology. This conflict centers on fundamental questions such as: How do we know what we know? How do we construct new knowledge through problem solving? How do we make inferences and make sense of situations?

These questions regarding epistemological “logic” comprise the tacit side of traditional courses and result in weak approaches to learning and diminished appreciation for experiential learning and intuition (Reddish & Hammer, 2009, p. 629). Epistemic framing provides the scaffolding that is an essential part of instruction and problem solving in that it would subsume these implicit elements.

In conclusion, Epistemic Frame Theory is composed of several factors: experiences, basic knowledge and skills; connections between different ways of knowing; sophisticated thinking and problem solving; adopting a professional persona; and communication. Each of the above components make it possible for students to create epistemic frames as they attend to their PBLs. Epistemic Frame Theory helps to explain sophisticated thinking complex problem solving, the kind of activities that are thought to occur during PBL.

**Epistemic frames**

In this section, I will discuss the nature of epistemic frames and their relationship to epistemic framing. There are two ways to consider the term “frame.” One is to treat it as a noun as an interpretation of something such as an event or setting. The other, is to consider it as a verb, to
indicate an action, in the case of this research, to communicate meaning from one person to another. A thorough discussion of frames comes from Bateson (1972) who utilized analogies to explain the structure and function of frames and who for the most part treats epistemic frames as the noun form.

A review of Bateson’s (1972) discussion of “psychological frames” provides the backdrop necessary for understanding epistemic frames. According to Bateson, a psychological frame identifies a set of messages or meaningful actions (p. 186). He argues that the psychological frame has some level of reality to it, that it is consciously recognized, and that it can be represented by language. Frames can possess a dual nature of being exclusive as well as inclusive (Bateson, 1972). This kind of selective permeability limits which messages are part of the psychological frame. This quality is useful in understanding the messages that are typically found in each specific frame within the PBL classroom.

Bateson (1972) denotes that frames are “psychological concepts” (p. 186) using the analogies of mathematical sets (abstract) and picture frames (concrete) to discuss them. He goes on to state that a frame is for communication, “it is (or delimits) a class or set of messages (or meaningful actions)” (p. 186). Using the example of play between two individuals, for which I would substitute PBL between two (or more) individuals, play/PBL would be defined by the set of all communication between the individuals. And this would apply even more so to the PBL classroom because Bateson adds the additional qualifiers of actions happening within a limited period of time (like a class period) and being modified by the premise or assumption of a PBL class.

According to Bateson, psychological frames contain a certain degree of reality, where one is cognizant of the frame and that a frame can be represented in language. He also alludes to
the possibility that a frame may be devoid of language and an individual may not consciously recognize it (p. 187).

Bateson argues that the benefit of the picture frame analogy is that people tend to function more easily in contexts where some of their thought processes can be externalized; this is what I propose happens in the PBL classes. In a categorization of psychological frames, Bateson indicates that frames are exclusive, or using my term, selectively permeable - some messages are excluded while others are included.

Elaborating on the picture frame analogy, Bateson promotes the notion that the picture frame is intended to focus the attention of the viewer, “Attend to what is within and do not attend to what is outside” (p. 187). This segues into another feature of psychological aspect of frames, “premises.” “Premises” or assumptions means that when a person is viewing a framed object, the belief is that the viewer is not giving the same attention to the framed object as to the wall the frame is hanging on.

Applying Bateson’s math analogy for frames seems more apt for the present discussion because it invokes the mental image of like objects enclosed by an imaginary line. A similar condition exists in the classroom, where the students are defined by their shared common ground in a shared physical space.

Bateson blends the noun and verb forms of frames indicating that there is integration of the two, “The frame itself becomes part of the premise system. Either, as in the case of the play frame, the frame is involved in the evaluation of the messages which it contains, or the frame merely assists the mind in understanding the contained messages by reminding the thinker that these messages are mutually relevant and the messages outside the frame may be ignored” (p. 188).
Bateson goes on to state that frames are meta-communicative, meaning that the frame itself is defined by the messages it conveys, “any message, which either explicitly or implicitly defines a frame, *ipsa facto* gives the receiver instructions or aids in his attempt to understand the meanings included within the frame” (p. 188). This aspect of Bateson’s frame is significant because explicitly relayed messages, i.e., utterances, not only assist in comprehension of bigger ideas, but also provide concrete way to examine epistemological development.

Epistemic frames have been defined as: “how students understand their own activity with respect to knowledge and knowing” (Hutchinson & Hammer, 2009). Nash (2013) supports this definition by indicating that epistemic frames are constructed from the constellation of many elements: skills, knowledge, identities, values, and epistemologies that professionals use to think creatively (p. 746).

Tannen’s (1993) definition more than adequately covers and does so in a succinct fashion, similar terms of frames, scripts, and schemata. Her definition is based on the premise of the power of expectation. Expectations are the result of our measurement of a “person, object, or event as unique or separate” against what we have come to know about the world from prior experience. Tannen argues that expectations are the only way we can make connections between things and between items and events in the present with what we learned growing up in a specific culture. An expectation is created the moment we measure a new perception cast against our previous experiences. So, we are building our understanding of epistemic frames on the creation of expectations.

Basically epistemic frames refer to how students perceive knowledge, including how much or to what extent their surroundings or environment contribute to their frame (Murphy, 2012). In comparing the settings for epistemic frames between a PBL classroom and a traditional
learning style classroom, the assertion is that students in the PBL class will view their learning opportunities differently than those in the traditional class, and they will have different epistemic frames. It is inherent in the different forms of learning that distinct settings for learning will dictate separate epistemic frames.

For example, it has been argued that the epistemic frame of a profession is the combination of linked and interrelated “values, knowledge, skills, epistemology, and identity that professionals use to see and solve problems” (Shaffer, 2006, p. 175). This is parallel to the functioning of epistemic frames in a PBL classroom where these same characteristics help to define students and their role in problem solving.

The same notion holds true in the relationship between epistemic frames and the community: epistemic frames “are the shared perspective that individuals internalize as they become acculturated” (Hatfield, 2011, p. 8). Epistemic Frame Theory implies that unique communities of practice yield appreciably different combinations of epistemic frame elements. Therefore, such differences should be evident in comparisons between the communities of two different schools (Nash & Shaffer, 2011, p. 181).

“Premises” (Bateson, 1972) and “expectations” (Tannen, 1993) share a commonality in that they both direct the subject to focus on and interpret what is contained within a particular frame, meaning that one frame requires a certain type of interpretation while another frame requires a different interpretation. The strength of a frame’s “premise” is evident because the frame is involved in the evaluation - it helps decode the messages contained within the frame.

Frames have been referred to as being “meta-communicative,” (Bateson, 1972) meaning that by the frame’s very nature, messages within it default to a specific setting for that frame.
This default setting provides aid to the receiver of any messages in his or her attempt to understand the messages included within the frame (p. 188). Bateson states that the converse is also true—just as the frame defines the messages, so to do the messages define the frame (p. 188).

A similar phenomenon has been reported which equates a “situational perspective” with reality, meaning that what one attends to is often juxtaposed against what others are attending to: “[M]y perspective is situational, meaning here a concern for what one individual can be alive to at a particular moment, this often involving a few other particular individuals” (Goffman, 1974, p. 8). Goffman (1974) argues that the situation elicits from the individual a probing question: “What is it that’s going on here?” Somewhat tacitly or with uncertainty, the individual then engages with others to proceed with a search for the answer.

This is exactly the situation that occurs with students in their groups during PBL. A definition for “frame” that applies here has a certain scaffolding quality to it, “I assume that definitions of a situation are built up in accordance with principles of organization which govern events—at least social ones—and our subjective involvement in them” (Goffman, 1974, p. 10). This definition is appropriate because it provides structure and shape to the epistemic frames found in environments like the PBL classroom.

As stated previously, Bateson (1972) used the analogy of a picture frame to explain epistemic frames. Bateson’s idea of a picture frame to represent epistemic frames corresponds to Tannen’s (1993) notion that subjects, events, objects, and people (as portrayed in a framed picture) can trigger an individual’s expectations about something familiar to him or her in the real world.

We can add to our understanding of epistemic frames by considering a similar approach. Goffman (1974) writes that when a person recognizes a specific situation, his or her response to
that situation is conducted through one or more frameworks, or schemata, which allow him or her to interpret the event (p. 21). He refers to these as “primary frameworks” or the manner in which we perceive events; the type of framework we use offers us a way to describe the event referenced by the framework (p. 24).

The function of epistemic frames can be thought to be a way of representing knowledge in a more manageable, understandable fashion (Minsky, 1975). Minsky looked to manipulate reasoning, memory, language, and perception into larger, more structured “chunks” of knowledge. He thought these features needed to be more closely connected, such that they could explain the strength and quickness of cognitive activities.

Minsky (1975) saw epistemic frames as a movement away from traditional attempts to represent knowledge as simple and distinct fragments. This notion makes sense, especially when combined with Tannen’s (1993) idea of expectations. Thus, when both ideas are linked, they thoroughly describe epistemic frames, which are neither simple nor distinct concepts. Rather, epistemic frames are complicated structures that allow students to engage in a myriad array of contexts. Students are able to respond to and engage in these contexts because they utilize not only verbal exchanges, but also physical gestures and visual responses.

Epistemic frames are characterized as data structures for representing stereotypical situations. Embedded within the frame is the information for the student that would help him or her know how to use that information, what might happen next, and what the possible reactions might be. Related frames could be joined together to create a “frame system” enabling the student to easily operate within the frame and focus on the event (Minsky, 1975). Minsky believed the power of the theory rested on ways of incorporating expectations and assumptions—a kind of “default” mechanism with an ability to match identifying elements of the frame. It is possible
that epistemic frames symbolize the close affinity between practices and ways of knowing—a “common-law” relationship within the context of individual communities of practice (Shaffer, 2006, p. 232).

The “frame system” of Minsky (1975) can be extended to a concept with more variety. This would be the “resource model” of epistemic frames which explains the variation seen in students’ actions and responses within epistemic frames (Scherr & Hammer, 2009). This model is based on the belief that students have a variety of resources upon which to draw from. The model involves the different ways students conceive of knowledge and their understanding of epistemic activities, facts, stories, and so forth—in short, their expectations. The “resource model” concept integrates well with the variety of beliefs that students might hold about the nature of knowledge, such as how knowledge is handed down from authority, or that it is certain or simple (Hofer & Pintrich, 2002).

Thus we have the two treatments of the term frame; one, the noun, defines the notion of a frame in terms of a set of meaningful messages (Bateson, 1972) and the other, the verb, defines frame as the use of language to convey meanings (Tannen, 1993). We have established the nature of epistemic frames: how students use them as interpretations of their learning environment (Hutchinson & Hammer, 2009; Nash, 2013); that epistemic frames function in communities of practice (Hatfield, 2011); that epistemic frames provide structure through “primary frameworks” (Goffman, 1974); and that epistemic frames are psychological and “meta-communicative” (Bateson, 1972).

We have seen epistemic frames represented in a singular way by Bateson (1972) and Tannen (1993) who favor a one-to-one correspondence between epistemic frames and specific linguistic and behavioral elements and how this view has been expanded to the “resource model”
(Scherr & Hammer, 2009) which provides for more variety in students’ responses to how they epistemically frame their learning. There was also consideration of a complex view of epistemic frames as a system (Minsky, 1975) which enabled a more involved approach to dealing with knowledge. In the following section, I’ll explain the connection between epistemic frames and epistemic framing.

**Epistemic framing**

To complete the trajectory of this investigation that began with epistemic beliefs, we are brought to the action form of “frame”, epistemic framing. Epistemic framing contains the indicator system which this research is based on. In this section I will examine the evidence that supports the existence of epistemic framing. That evidence is the linguistic indicators of Tannen (1993) and myself, set within the matrix of Perry’s (1968) epistemological development positions.

Tannen (1993) offers a systematic way to investigate epistemic frames based on the premise that the features of expectations mediate between a person and his or her perceptions and between those perceptions and the telling of them (p. 41) and the manner in which an event is described indicates a person’s expectations about specific events portrayed in it (p. 35). The formation of expectations make interpretations possible and in the process they reflect back on perception of the world to validate that interpretation (p. 21).

So here we have a connection between the noun and verb forms of “epistemic frame.” When individuals implement communicative and affective actions using objects, symbols, images, tools, and technologies they are able to make sense or “frame” activity in the world.

Tannen offers for consideration the notion that expectations (and therefore frames) affect language production, or, what one expects affects what one says. This is a function of any speech
event because that event does not occur in a vacuum. Rather, it is the product of “overlapping and intertwining of many relations concerning the context as well as the content of communication” (Tannen, p. 22). For example, one common or simple object “triggers expectations about similar events, objects and people in the real world” (p. 22).

Discourse Theory (Gee, 2005) contributes to our understanding of epistemic framing because, like Tannen above, it incorporates ways of communicating - reading, writing, speaking, and listening, all essential components of this process. It also blends together cognitive functions such as acting, interacting, believing, valuing, and feeling (Gee, 2005, p. 7).

Discourse Theory fits well with epistemic framing because it involves a systematic transformation across information that already has meaning and that agrees with a schema of interpretation. While this transformation is occurring, the participants openly acknowledge that it is taking place and I propose that students’ epistemological position is transforming as well.

This is where the act of epistemic framing is most relevant to the understanding of epistemological development. There will be designated cues for when the transformation begins and ends. These cues are the linguistic indicators put forth by Tannen (1993) and to which I added. These indicators will serve as the evidence for the students’ transformation along Perry’s epistemological positions.

Other evidence for framing was found in the behavior of students as they collaborate (Scherr & Hammer, 2009). Scherr and Hammer (2009) draw on the work of Bateson (1972) and Tannen (1993), among others, by pointing out that when someone frames an event, situation or utterance, the person does so by taking into account his or her prior experiences. The process of framing accents Tannen’s (1993) “expectations” related to the event, vocalization or situation and inherently determines an appropriate course of action for the student to take.
The findings of Scherr and Hammer (2009) support Tannen’s (1993) and Bateson’s (1972) views of how individuals create an awareness of situations with respect to objects, people, and knowledge by accessing knowledge and information from their past experiences (p. 149). Scherr and Hammer (2009) were able to elaborate on four distinct patterns of students’ behavior, which included their postures, gestures, vocalizations, and visual changes. In their research, video analysis was conducted as college physics students engaged in a small-group collaborative learning assignment. Evidence such as this serves to strengthen what epistemic framing can do.

A connection was made between speech patterns with physicality; thus each feature reinforced the other and added to the cohesion of the participant’s framing. For example, a student’s eye contact, gestures, and tone of voice demonstrate his or her participation in the frame and engagement in discussion. Similar responses from others in the group solidify agreement and understanding with this type of frame.

There is a belief that what people say and how they say it are directly related to the clues and cues present in frames (Scherr & Hammer, 2009, p. 150). Thus, to guide us in our understanding of epistemic frames and epistemic framing, there is psychological evidence (Bateson, 1972), sociolinguistic evidence (Tannen, 1993), and behavioral evidence (Scherr & Hammer, 2009).

In light of previous discussions and findings regarding epistemic frames, it is possible that epistemic framing allow students to act and learn within the varying contexts of the PBL classroom. Student responses to learning in different contexts are influenced by their previous experiences, which serve to foreshadow their expectations of what the context entails and allow them to engage with others in the setting with confidence and without fear of failure.
This confidence is important to the success of students in PBL classrooms class that this study is based on. Students in PBL classrooms do not have the familiar schema of the “traditional” classroom on which to rely. Thus, they are able to rely on expectations derived from epistemic frames enabling them to work toward the goals of the project.

How students epistemically frame their learning will be revealed during the seven steps of the PBL project these students will work on: (1) project roll-out, which includes the entry document; (2) accessing the project toolkit; (3) working in small groups; (4) determining “knows” and “need-to-knows”; (5) conducting research; (6) creating the artifact; and (7) presentation. The language used by the students will enable me to determine how they are framing their learning and to follow their progression along Perry’s (1968) positions of epistemological development.

**Epistemological development**

As a student begins a PBL and epistemically frames the experiences within it, he or she might modify their absolutistic right-wrong outlook to make room for one with multiple viewpoints. Perry (1968) believed that this dualism in thought is the starting point in students’ epistemological development.

As students epistemically frame their learning in the PBL classroom, they will be demonstrating through their language use, their position along Perry’s (1968) continuum of epistemological development. This continuum reveals how a student’s thinking about their knowledge changes over time. The developmental aspects of students’ thinking would be influenced by the demands they face in the classroom as they pursue their PBL.

Perry (1968) sought to demonstrate how students responded to the influences of scholarly and ethical environments. He felt that he could get a sense that there was a common sequence of challenges for students that they reported on as they made their way through college. I would
like to apply the same reasoning to the students in the PBL classroom. Just as the students in Perry’s (1968) study showed coherent development in their intellectual function, I predict that the students in the PBL class will follow a similar developmental path: dualism, multiplicity, relativism, and commitment.

**Conclusion**

Epistemic Frame Theory can shed a light on what is occurring in the PBL classroom. This theory provides an understanding of the interactions in the classroom and it is the principle that guides students as they engage in the business of learning. In this study I intend to show that: (1) students progress through specific epistemic developmental stages or positions as they work on PBL projects; (2) student utterances are indicative of epistemic frames; (3) the theoretical grounding for Epistemic Frame Theory is the students’ epistemology; (4) there is a “resource model” by which students choose how they select, enter, and operate within an epistemic frame; (5) epistemic frames enable students to determine “what is it that is going on here?”; and (6) much of what happens within epistemic frames is based on expectations, where expectations are a result of our perceptions of a “person, object, or event as unique or separate” measured against what we have come to know about the world from our previous experience.

**CHAPTER THREE: RESEARCH METHOD**

**Introduction**

This chapter describes the methodology used in this study and the research questions that guide it. The chapter explains discourse analysis as the research method that was employed. Profiles of the teachers who cooperated with the study are included here as well as the rationale for selecting this particular school and Biology class. In terms of evidence collection, the data-gathering instrument used in the study is also described.
The purpose of this research is to determine how students epistemically frame their project-based learning activities. The kinds of language used by the students served as indicators of the stage of development of their personal epistemology according to Perry’s (1968) scheme. The overarching questions anchoring the investigation asks the following: Do students advance through Perry’s positions of epistemic development as they carry out their PBL activities, and if so, how does student language function as an indicator of this trajectory?

Underlying these comprehensive questions are additional questions that I will attempt to answer: (1) How does each stage in the PBL project compare in terms of students’ epistemic development? (2) Are there “micro” positional shifts within each PBL project compared to a larger transition between the first project of the year and the last? (3) Does the kind of language and, therefore, the position in Perry’s development scheme change as the students progress through their PBL projects, and if so, how and in what way?

Discourse analysis was chosen as the research design method because it is based on language, the focus of this study. Discourse analysis can be used to “describe, interpret, and explain the relationships among language and important educational issues” (Rogers, 2004, p. 1). The prevailing view of discourse analysis is that it is the study of language in use (Gee, 1999; Rogers, 2004). The language of students as they pursue their projects can be unique, a view that Lemke (1990) endorses, “Students use their own language to put together a view of the subject that can be very different” (p. x). Gee (1999) also points out the significance of the variety of language, “all forms of language…get their meaning from the games or practices they are used to enact” (p. 7). This stance highlights the implications that project-based learning has on language production in the biology classroom of this study.

Lemke argues for the importance of language, stating that it is “a system of resources for
making meaning” (p. ix) and that it serves as the foundation for our efforts to communicate science (p. x). Because this study takes place in a classroom community, a social setting, the communication of science knowledge is accomplished by creating and controlling social situations within this community. Gee (1999) also acknowledges the significance of the context in which discourse occurs, “the theory of language…is that language has meaning only in and through social practices” (italics in original) (p. 12).

The analysis of discourse is all about patterns. The goal of discourse analysis is to examine the relationships between language form and function in order to understand why and how some patterns are favored over others (Rogers, p. 4). There is a belief that the linguistic pattern of relationships of meanings is constant and that this arrangement is the scientific content of what is said and written (Lemke, p. x).

Since this classroom is not isolated from the norms, values, and social concerns of the larger community, the constellation of discourse markers the students speak reveal not only a pattern of relationships of meanings, but also their epistemological growth. Gee speaks to this extension into the bigger world that language subscribes, “These things we do and are (identities) then come to exist in the world and they, too, bring about other things into the world. We use language to build things in the world and to engage in world building” (p. 16). Lemke argues that by mastering the meanings of linguistic patterns, then students will have then mastered the language of talking science. I would argue that there is a commensurate epistemological development to go along with this mastery.

How students in this classroom manipulate and interpret words on a particular subject create thematic patterns of which there may be several within the class (Lemke p. 99). So, the linguistic patterns in the class ultimately determine the thematic pattern in the class. This pattern
of methodically organized groups of statements provide meanings and values to a community (Rogers, p. 6). One takeaway in understanding the language of the classroom is that students’ initial understanding of concepts begin with colloquial language first, later substituting scientific words for their vernacular (Lemke, p. 173). Thus, there is another possible way to interpret and monitor student language, looking at how students’ language transitions during project-based learning.

Tannen (1993) lists 16 different types of language evidence occurring in dialogues that can reveal epistemic frames: (1) omissions—leaving details out; (2) repetition—restating to emphasize the main interpretation; (3) false starts—when a statement is made or begun and then immediately changed; (4) backtracking—when a mistake is made and the backtrack constitutes a correction; (5) hedges and other ways to qualify statements—measures the word or idea against what is expected; (6) negatives—made when the affirmative is expected (7) contrastive connectives—this marks the denial of an expectation; (8) modals—reflect the speaker’s judgment according to his or her standards; (9) inexact statements—events are collapsed to convey the significant outcome; (10) generalizations—when one or more objects or actions is reported as more than one; (11) inferences—statements that could not be known simply from observation; (12) evaluations—the quality expressed reveals some comparison with what might have been expected; (13) interpretations—when a noun is used for a character or object that represents more information than is presented; (14) moral judgments—speaker’s frames or knowledge imposed on events; (15) incorrect statements—represent false memories; an operation of expectations resulting in negative statements; and (16) additions—the mention of a person or event that is not present (p. 41).
In order to account for utterances that Tannen’s compilation of 16 speech classifications evidence did not encompass, more classification groups were needed. I supplemented the speech classification groups that Tannen was using as linguistic evidence for epistemic framing with seven additional categories. These additional elements were: (17) interrogatives—questions seeking clarification from speaker(s); (18) acknowledgement/agreement—defines one’s personal choice by stating acceptance; (19) incomplete statements—statements that drop; incomplete thoughts; (20) exclamations—single words or a few words, indicating one’s response to a speaker; (21) instructive—giving directions to the speaker; (22) declarative—statement of facts; and (23) justification—providing rationale for speech.

I felt the need for additional classifications because as initial coding of the transcripts was conducted, I would notice multiple occurrences of speech elements that did not fit Tannen’s scheme. For example, in the following brief excerpt of ten student utterances with 15 classifications, only 3 of those classifications are covered by Tannen’s scheme, while the remainder are attended to by the additional 7 classifications I added.

<table>
<thead>
<tr>
<th>Utterance</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start off with like….</td>
<td>19</td>
</tr>
<tr>
<td>Go get candy</td>
<td>21</td>
</tr>
<tr>
<td>Yeah Kevin, you need to go buy some candy</td>
<td>18, 21</td>
</tr>
<tr>
<td>Technically it’s 12 by 5, but….</td>
<td>7, 19</td>
</tr>
<tr>
<td>And then, because the head’s smaller than the body</td>
<td>23</td>
</tr>
<tr>
<td>So look for 12 by 4</td>
<td>21</td>
</tr>
<tr>
<td>I think it’s somewhat?</td>
<td>8, 12</td>
</tr>
<tr>
<td>I mean I’ll find out</td>
<td>22</td>
</tr>
<tr>
<td>So why are we doing this?</td>
<td>17</td>
</tr>
<tr>
<td>We had an interesting time; it’s not the purple one, it’s the green one</td>
<td>6, 12, 22</td>
</tr>
</tbody>
</table>
The necessity for the additional classifications is borne out by the incidence of these speech elements in the overall project. For example, the speech element classification Declarative, which was a category I added, accounted for 68% of all speech elements in the developmental category of Dualism. Or in the developmental category Relativism, Tannen’s classification Hedge, accounted for only 18% of the utterances, while my classification of Interrogative occurred more than three times that rate with almost 55%. While these two examples were at the extreme end of prevalence, there were instances of classifications from both of us that were more evenly matched, but still showed the need for my additional categories. This was seen in the developmental group, Multiplicity where Tannen’s classification groups of Generalizations and Interpretations accounted for 21.4% and 27% respectively and my classification group of Incomplete Statements weighed in with 28.9%. These 23 elements provide linguistic evidence of the existence of epistemic frames, and were used to analyze the seven steps that constitute the PBL activities in the Biology classroom of this study.

Classifying students’ utterances into speech element classifications can be accomplished with varying levels of complexity. Three accepted methods for establishing reliability and validity of the observations or scoring of an event by observers are: the percentage of absolute agreement, variations of Cohen’s kappa, and intra-class correlation coefficient (Graham, Milanowski, and Miller, 2012). For this study, since as I was looking for a simple means to establish validity with the classifications, I decided to use percentage of absolute agreement. For this task, I simply calculated the number of times the other rater and myself agreed on a rating, then divided that number by the total number of ratings.

A random sample of 100 consecutive utterances was chosen from one of the observation days. One hundred utterances were chosen for two reason: one to simplify the math and two, I
felt that with 23 classification categories, there was a greater probability that each category would be present at least once, if not more, thus providing more opportunity to compare classification between the two raters.

The process began by my explaining the classification scheme to the other rater. I offered an explanation for the meaning of the classification along with an example. We then classified the utterances independently and conferred at the end to discuss our choices. The first round of classifying yielded an agreement of a little less than 80%. We then reviewed the statements where we disagreed, debated our rationales for our decisions, and determined a solution upon which we agreed. This process was repeated with a second sample of utterances and an improved inter-rater agreement of approximately 89%.

Setting and subjects

This study took place at a unique high school in upstate New York. This public high school, open to any student from one of seven local counties, differs from other public schools in that it is not under the control of the school district in which it is located. Rather it is cooperatively managed and overseen by two local Boards of Cooperative Educational Services (BOCES) in a joint venture. It is the uncommonness of this school that makes it appealing for investigation. The school’s success with helping its students to achieve academically is the most compelling reason to choose it as the site for this study. Also the administrative hierarchies that encumber traditional public schools do not bind this school, and its instructional approach embraces PBL.

This high school places a strong emphasis on PBL as a preferred method of teaching, and as a result, PBL is used in all science and humanities courses. Teachers and administrators at the school seek out and take advantage of numerous collaborations with K–12 public schools, colleges and universities, businesses, organized labor, and government. These efforts enhance the
quality of the PBL instruction.

The selection of this particular Biology class for this study was due in part to its success as measured by the New York State Regents Living Environment exam. This class covers the same curriculum that I do in my own teaching. Yet the disparity of results on the state exam between the two classes piqued my interest to study this particular group. The following table shows test results for the Living Environment exam for the last five years that data was available.

Table 1: Comparison of passing rates on state exam

<table>
<thead>
<tr>
<th>School Year</th>
<th>My School % (Jan, Jun, Aug)</th>
<th>PBL School % (Jun only)</th>
<th>State Average %</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008-2009*</td>
<td>59</td>
<td>97</td>
<td>80</td>
</tr>
<tr>
<td>2009-2010</td>
<td>56</td>
<td>94</td>
<td>78</td>
</tr>
<tr>
<td>2010-2011</td>
<td>54</td>
<td>100</td>
<td>81</td>
</tr>
<tr>
<td>2011-2012</td>
<td>51</td>
<td>100</td>
<td>79</td>
</tr>
<tr>
<td>2012-2013</td>
<td>40</td>
<td>93</td>
<td>76</td>
</tr>
</tbody>
</table>

*First year exam was offered at PBL school

The students who are the focus of this study are 10th graders in the school’s Biotechnology class. This is a two-credit course, with one credit awarded in Biology and the other in Bioengineering. The course of study for the year covers units in Ecology, Cells and Microscopes, Nanotechnology, Stem Cells, Evolution, Anatomy, and Biochemistry.

The class is co-taught by two experienced educators. A biographical profile provided by the school’s website indicates that the Biology teacher, “Ms. Parsons,” joined the faculty when the school opened in 2007. She has extensive experience teaching biology, chemistry, and mathematics as well as facilitating PBL. She designed and implemented an Advanced Placement (AP) environmental science curriculum at her previous school. She was also the founding director and mathematics and science teacher at an independent school. She has a B.A. and an M.A.T., and she has completed post-master’s work in biology.
A biographical profile of the second classroom teacher, “Ms. West,” indicates that she teaches biotechnology and has been with the school since the start of the 2009–2010 school year. She has previously taught at two other public schools in the region. She has a B.A. in Chemical Engineering from MIT and a master’s degree in Education. Prior to teaching, she had worked in private industry for more than a decade.

At the beginning of the study, Ms. West introduced me to the class. At that time I provided a brief overview of the project. In an attempt to encourage the students to develop a vested interest in the project, I offered a small monetary incentive in the form of a gift card to those students who ended up being recorded.

Formal classroom observations began following IRB approval. The observations occurred during the regular class meeting time. The school uses a block-scheduling format in which the class meets three times during the week with each class lasting two hours and thirty minutes. The classroom observations began immediately following Christmas vacation as the students began a four-week long PBL on the microscope.

I observed and video-recorded one randomly selected group of students during each phase of their project. Groups usually have four students and projects typically run from four to six weeks. The amount of time required to collect data for this PBL was approximately two hours per observation, three times a week, for four weeks. This amounted to twenty hours of taped observations.

The project steps were identified based on a discussion I had with Ms. Parsons regarding this research and are described as follows:

1. Project rollout and entry document: Each project in PBL begins with an introduction to a specific problem. This introduction can take multiple forms, though more often than not, it
begins with a letter from an individual or group requesting/soliciting help in addressing a unique situation. The entry document provides background information for the students as to the nature and origin of the problem. The document discusses the scope of the problem and a desired solution. An invitation is extended to the students inviting them to participate and submit their findings for consideration. The entry document for this project is shown below.

Figure 1: Entry document for project (Photo taken by author)

2. Accessing the Project Toolkit Project Toolkit: The Project Toolkit is an online repository of templates for the students to use to complete their PBLs.

3. Working in Small Groups: students are assigned to their groups by the teachers. New group assignments are created for each new PBL. The students decide among themselves what tasks need to be accomplished and which task each student will do for each particular project.

4. Creating “Knows” and “Need-to-Knows”: The entry document segue ways into this next step. At this time the teacher(s) prompt(s) the students to brainstorm individually or collectively as to what prior knowledge regarding the problem they might already have and what
knowledge they feel is necessary in order to find a solution to the problem. This information could include content knowledge, for example how bacteria live and grow, how antibiotics work, and formulas for surface area (This is the type of information needed for their PBL on nano biology). The information could also be about a process, for example how to use Adobe Flash to create a video. At this point the students can request to have a “workshop” where the teacher(s) would deliver a lecture specific to the students’ knowledge deficit indicated by their “Need-to-knows.” The teacher may offer to have an “expert” come in and deliver a talk on either the content or process.

5. **Conducting Research:** Students are given class time to research the problem. At their disposal are textbooks, ancillary materials, and the internet. Each student is provided with a laptop computer their freshmen year. This facilitates the research process.

6. **Creating the Project Artifact:** students are given time to work in the shop or lab, depending on the project, to create their artifact. Past artifacts have included microscopes, miniature solar panels, electrophoresis chambers, and video games.

7. **Presenting the Project:** teachers assign dates for which presentations of the groups’ artifact are due. Students present their projects in front of the class and are graded based on a rubric. The school also holds a yearly exposition in which guests, family, and friends are invited to attend. At the exposition, students display their project artifacts and deliver a short summary of the project to individuals who stop at their table to learn more about the project.

**Data collection**

The data collection instrument (Appendix A) is a table used to record the linguistic elements during the various stages of the different projects. The table reflects the 23 lexical features that serve as evidence of the epistemic frames and which were present in the PBL Biology class.
These language indicators were tracked during the seven project stages. This table derives from the work of Tannen (1993), who recommends a specific method of examining epistemic frames. This method involves looking at which elements in a set of responses or dialogues the speakers in a group employ (p. 52). Tannen argues that close examination of the kinds of linguistic evidence that the chart is based on can reveal the epistemic frames that created them (p. 53).

An example of how the table in Appendix A will be used is described as follows. A conversation among four students was recorded during the project rollout phase of a PBL activity on nanotechnology. The transcript is shown below:

Transcription: Nano Project Rollout

Ms. Parsons: “I want you to come up with a visual representation that makes this size seem understandable to your classmates. That depicts the meaning of the word “nano.” It is a size that is somewhat inconceivable in our regular everyday thinking. I want you to come up with an explanation that makes this size understandable. Each team will have 10 minutes to come up with this representation and 1 minute to present it. Your resources are each other, the project briefcase, and the Internet.”

S1 = “Elizabeth”; S2 = “Hunter”; S4 = “Shane”; S5 = “Rachel“

Time: 1:22
S1: I was thinking like the comparison of like a person or like a house compared to the rest of the earth
S4: yeah, I was thinking that too, like take a globe…
S1: you can’t even see me right now; I’m standing right here pointing to another mini-earth on this globe, that’s what a nano-person…
S2: All right guys, one cm is 10 million nanometers. How many…alright, so let’s, want to do a Sun versus Earth comparison? Or like…planets?
S4: Like Earth versus…the object
S1: no, measure meters around the earth, or kilometers
S4: it doesn’t have to be exact; we’re just trying to show “big” “small”
S1: I know, but if we do that…
S2: a grain of sand versus the earth
S1: yeah, pretty much. But, I think I’m concerned that that’s going to be too small
S2: [Writing on paper] How many grains of sand…
S1: …would fill up the earth? Would it take to fill up the earth?
S2: we need some math all up in this
S1: I’m just like worried that a grain of sand would be too small
S5: yeah
S1: in comparison to Earth
S5: and I don’t think there’s a set size, they’re all really different, like there’s no set size; like a sandy stone and then there’s more like a rock
S2: you know what I mean though
S5: yeah
S2: like a grain of sand on the beach versus the Earth

<table>
<thead>
<tr>
<th>CODE</th>
<th>Moral Judgments</th>
<th>Generalization</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Inexact Statement/Repetition</td>
<td>False start/Backtracking</td>
</tr>
<tr>
<td></td>
<td>Hedges &amp; Other Qualifiers</td>
<td>Negatives</td>
</tr>
<tr>
<td></td>
<td>Contrastive Connections</td>
<td>Interpretations</td>
</tr>
<tr>
<td></td>
<td>Hedges &amp; Other Qualifiers</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Repetition</td>
<td>Modals</td>
</tr>
<tr>
<td></td>
<td>Negatives</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Repetition/Negatives</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Hedges &amp; Other Qualifiers</td>
<td>—</td>
</tr>
</tbody>
</table>
S5: but wait, okay.
S2: but philosophically, it’s…you…
S1: okay, so the earth in diameter is 12,756.2 km in diameter times, what did you say, a million?
S2: 10 million
S1: 10 million in a centimeter?
S2: 10 million in a cm
S1: So we have to figure out how to convert 10 million nm/cm into km
S2: times, what?
S1: if there’s 10 million nm in a cm, and the earth is 12,756.2 km, we have to convert that
S2: I’m confused
S5: find out what the earth’s diameter is in cm
S2: not diameter, how big is the earth in cm? [as he’s writing on the paper]

The entire conversation lasted almost 21 minutes. A transcription of the conversation was six pages in length with 316 individual utterances made. These statements were then coded using the table in Appendix A. The table was modified from Tannen’s original 16 forms of linguistic evidence to include a total of 23 indicators in order to account for the wide variety of parts of speech detected during the observation. The number of each coded statement was recorded on the table. Next, the number of times each language indicator was recorded was placed in Table 2, which separates the type of language indicator into the associated Perry category.

Data Analysis

Analysis of the collected data proceeded as follows. As the transcription from the video tape is reviewed, tallies were made for each linguistic element in the chart (Appendix A) under the phase of the project that corresponds to that transcription. The number of utterances in each category were totaled and then compared across each of the steps of the project. This summary data was analyzed for any trends that appear. Any apparent trends were compared among the group members being observed. The data was then examined to determine which linguistic indicators of epistemic frames were present in each step of the project and whether different PBL steps had language elements that are unique or common to those steps. A second stage of the
data analysis was to examine where the language indicators fall within Perry’s epistemic development scheme.

A table (Table 2) was constructed that placed the linguistic indicators within Perry’s (1968) epistemological development positions. The total number of each language indicator is recorded in its respective position on the chart. The language indicators were placed in Perry’s positions based on how closely they correlated with a position’s characteristics. For example, the language indicators Backtrack, Negatives, and Moral Judgment all share a connotation similar to that of Perry’s Dualism, because they infer a distinction between absolutes, that is, right or wrong, good or bad. This table shows the number of utterances that were assigned to each of Perry’s developmental positions. In this way, it is possible to see if there is any definitive position in the students’ epistemic development at this point in the project and then track progression by the students in their epistemological framing as they complete the rest of the steps in their PBL projects. A similar process was conducted for all seven steps of the students’ projects.

Table 2: Perry’s epistemological positions and language indicators

<table>
<thead>
<tr>
<th>Perry’s Epistemological Positions</th>
<th>Linguistic Indicators</th>
<th>Number of Occurrences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dualism</td>
<td>Backtrack</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Negatives</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Contrastive connections</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Moral judgment</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>Declarative</td>
<td>14</td>
</tr>
<tr>
<td>Multiplicity</td>
<td>Omission</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>False Starts</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Generalizations</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Interpretation</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Incorrect statements</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Addition</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Incomplete statements</td>
<td>12</td>
</tr>
</tbody>
</table>
A graph (Figure 2) was created to display this data. It is interesting to note from this image the prevalence of select language indicators within three of Perry’s four epistemological positions. In the Dualism position, Moral judgments is most prevalent; in Relativism, Interrogative occurs the most; and Repetition occurs the most in Commitment.
Figure 2. Perry’s epistemological positions and language indicators

An overview of the sample transcription shows four students trying to find a way to illustrate the meaning of the term “nano.” The students’ efforts include the use of analogies and mathematical relationships. There is much cross talk and overtalk along with false starts. There is some reluctance on one group member’s part to engage in determining a mathematical relationship: “We are way overthinking this.” The conversation also reveals the difficulty students have with mathematical conversions and scientific notation, as well as disagreement among the group members as to the most effective analogy to use.

Scherr and Hammer (2009) conducted their research on epistemic frames in a study of physics students in a similar manner. They chose to study students in situ as opposed to disrupting students with specialized surveys or interviews. Scherr and Hammer (2009) were looking for four distinct patterns of students’ physical behavior. In a similar way, I am looking for distinct patterns of students’ verbal activity. Just as these authors posit a relationship between students’ physical behavior and epistemic framing, I propose that a relationship exists between students’ speech patterns and epistemic framing.

At this point, a couple of questions are brought to light. First, how do these dialogues reflect epistemological development? And second, what can they tell us about the positional location of these students in their epistemological development?

These questions can be answered by examining Table 2. This table shows that in this sample transcript, there were 69 utterances in Perry’s Dualism category, the first position of a student’s epistemological development. In the three remaining positions, Multiplicity, Relativism, and Commitment, there were 24, 48, and 50 utterances respectively. Based on this initial sample, this group of students was clearly in Perry’s Dualism position.
In terms of validity and reliability, one of the concerns in this study is the subjective nature of coding. Coding is the crucial tie between collected data and providing an explanation for that data. This crucial tie is due to connections being made between meanings and perspectives and certain terms and phrases (Charmaz, p. 47). It is important that the researcher realizes that it is impossible to disregard his or her own language meanings based on his or her personal experiences when assigning codes. This is an important issue for this study, for the direction one takes with coding student utterances as belonging in one category versus another could have a significant impact on what conclusions are made.

In order to minimize the bias inherent with only one coder, a second coder was recruited to assist in analyzing the data. This should promote interrater reliability. Another validity strategy is to collect writing artifacts from the videotaped students. Writing samples that students created as part of their project assessment and that were related to the project will be used to strengthen the findings of the discourse analysis.

Conclusion

This chapter examined discourse analysis as the research method that was used in the study. In addition the research instruments were described as well as their role in the study. Finally, the data analysis section explained how the accumulated data was analyzed and how reliability and validity were addressed.

The following chapters report the results of the study and interpret the findings. Chapter Four summarizes and analyzes the study’s data closely following the research questions. Chapter Five elaborates on the essential points previously made, namely that: (1) students’ epistemic developmental position affects how they frame their PBL experience; (2) students epistemically
frame different stages of PBL projects differently; (3) students’ epistemology serves as the theoretical grounding for Epistemic Frame Theory; (4) there is a resource model whereby students choose how they select, enter, and operate within an epistemic frame; (5) epistemic frames aid students in determining what is taking place in the classroom; (6) expectations based on prior experiences are measured against what students have come to know about the world; and finally (7) this research contributes to the understanding of epistemic frames, and there are specific implications for the findings.

CHAPTER FOUR: RESULTS

Introduction

This chapter describes the findings of this study as they pertain to the research questions posed earlier. The basic question behind this investigation is: How do students advance through Perry’s epistemological development stages as they engage in a Project-Based Learning activity? If there is a change in epistemological development during a Project-Based Learning activity, how does students’ language during this exercise serve as an indicator of their progress? The accumulated data is also used to examine students’ positioning during each step of the PBL project and to assess the extent to which their positioning can be thought of as incremental shifts within the activity.

The first section will look at the activities occurring on the days observations took place and how the utterances were classified into epistemological development groups. Next, I will review the percentages of speech elements over the course of the observations. Then, I will review the individual students’ progress throughout the observations.

Frequencies of speech elements
There were a total of 7,454 speech elements coded into 23 types of utterances. These utterances were then separated into Perry’s four epistemological developmental categories, namely Dualism, Multiplicity, Relativism, and Commitment. The complete collection of speech elements coded is summarized in Tables 4.1 through 4.4.

In terms of the number of speech elements in each category, there were a total of 2088 in Dualism; Multiplicity had the fewest with 881; Relativism had the largest number of utterances with 2433; and Commitment had 2052 elements. The speech elements were recorded while the students were engaged in various activities as they strove to complete the PBL. These activities included researching questions on enzymes, diffusion and organelles; conducting experiments on lenses and models of cell membranes; and, designing and building their microscope. These activities are summarized in Table 3.

Table 3. Summary of PBL activities.

<table>
<thead>
<tr>
<th>Day</th>
<th>Activity</th>
<th>PBL Step</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rollout</td>
<td>Rollout/Entry Document</td>
</tr>
<tr>
<td>2</td>
<td>Diffusion Lab</td>
<td>Working in Small Groups</td>
</tr>
<tr>
<td>3</td>
<td>Engineering Design Process</td>
<td>Knows/Need-to-Knows</td>
</tr>
<tr>
<td>4</td>
<td>Microscope Design</td>
<td>Conducting Research</td>
</tr>
<tr>
<td>5</td>
<td>Technical Drawing</td>
<td>Conducting Research</td>
</tr>
<tr>
<td>6</td>
<td>Microscope Design</td>
<td>Creating Project Artifact</td>
</tr>
<tr>
<td>7</td>
<td>Microscope Construction</td>
<td>Creating Project Artifact</td>
</tr>
<tr>
<td>8</td>
<td>Microscope Construction</td>
<td>Creating Project Artifact</td>
</tr>
<tr>
<td>9</td>
<td>Teamwork Time</td>
<td>Creating Project Artifact</td>
</tr>
<tr>
<td>10</td>
<td>Presentation Day</td>
<td>Presenting Project</td>
</tr>
</tbody>
</table>
Table 4.1 presents the five types of speech elements that comprise the epistemological category of Dualism and which account for roughly 28% of all statements. Declarative comments, those that are statements of facts, constitute the bulk of these utterances. Declarative statements were found on all observation days.

Table 4.1. Summary of utterances by speech element for group.

<table>
<thead>
<tr>
<th>Code</th>
<th>Backtracking</th>
<th>Negatives</th>
<th>Connective</th>
<th>Moral</th>
<th>Declarative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>1</td>
<td>3</td>
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<td>4</td>
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<td>51</td>
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<td>62</td>
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<td>3</td>
<td>59</td>
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<td>23</td>
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<td>Totals</td>
<td>15</td>
<td>386</td>
<td>222</td>
<td>52</td>
<td>1413</td>
</tr>
</tbody>
</table>

Category Total 2088

Table 4.2 summarizes the speech patterns recorded for the epistemological development category of Multiplicity. Seven classification groups are included in Multiplicity with its total speech elements accounting for less than 12% of the overall total comments. In a category that is
supposed to represent pluralism of answers, opinions, ideas, and perspectives related to problems and issues faced by students, there appears to be a lack of robustness in its contribution.

The highest percentages of utterances in Multiplicity were driven by three classifications: generalizations with 183 (20.8%); interpretations with 292 (33.1%); and incomplete statements with 310 (35.2%). Even though generalization was one of top classification, it was not always present for each student on each day. For instance, Kevin’s percentage for generalization was almost 31%, but there were four days when no utterances were classified in this group. For Sara, the example is more dramatic because for her, there were only two days where utterances were classified as generalization.

*Table 4.2. Summary of utterances by speech element for group.*

<table>
<thead>
<tr>
<th>Day</th>
<th>Omissions</th>
<th>False Starts</th>
<th>Generalizations</th>
<th>Interpretations</th>
<th>Incorrect Statements</th>
<th>Additions</th>
<th>Incomplete Statements</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>15</td>
<td>18</td>
<td>40</td>
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<td>0</td>
<td>61</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>15</td>
<td>18</td>
<td>88</td>
<td>1</td>
<td>0</td>
<td>47</td>
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<td>41</td>
<td>0</td>
<td>0</td>
<td>47</td>
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<tr>
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<td>16</td>
<td>44</td>
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<td>0</td>
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<td>45</td>
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<tr>
<td>5</td>
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<td>13</td>
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<tr>
<td>8</td>
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<td>15</td>
<td>12</td>
<td>24</td>
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<td>33</td>
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<tr>
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<td>0</td>
<td>13</td>
<td>36</td>
<td>12</td>
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<td>11</td>
</tr>
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<td>Totals</td>
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<td>95</td>
<td>183</td>
<td>292</td>
<td>1</td>
<td>0</td>
<td>310</td>
</tr>
</tbody>
</table>

Utterances are sorted into six classifications in the epistemological development category of Relativism (Table 4.3). The comments in this category amount to almost 33% of the overall total. By and large, interrogatives or questioning make up the bulk of these speech elements. As
a matter of fact, interrogatives was the predominant speech element on any given day of observation regardless of the activity the students were engaged in. Interrogatives led the way in Relativism by having a 51% share of all comments. This percentage is supported by the students’ individual values. Kevin had an average of 39.39% interrogatives; Sara had a 47.46% average; Theresa had 47.21%; and Jessica had the greatest average in this classification of 73.62%.

4.3. Summary of utterances by speech element for group.

<table>
<thead>
<tr>
<th>Code</th>
<th>Hedges</th>
<th>Inexact</th>
<th>Inferences Statements</th>
<th>Evaluations</th>
<th>Interrogatives</th>
<th>Instructive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 1</td>
<td>57</td>
<td>24</td>
<td>2</td>
<td>32</td>
<td>216</td>
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<tr>
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<td>63</td>
<td>17</td>
<td>10</td>
<td>57</td>
<td>306</td>
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</tr>
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<td>3</td>
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<td>0</td>
<td>55</td>
<td>140</td>
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<td>11</td>
<td>39</td>
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<td>14</td>
<td>11</td>
<td>5</td>
<td>34</td>
<td>71</td>
<td>7</td>
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<td>17</td>
<td>4</td>
<td>5</td>
<td>7</td>
<td>51</td>
<td>13</td>
</tr>
<tr>
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<td>25</td>
<td>9</td>
<td>6</td>
<td>16</td>
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<td>55</td>
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<td>9</td>
<td>5</td>
<td>1</td>
<td>0</td>
<td>4</td>
<td>32</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>34</td>
<td>21</td>
<td>1</td>
<td>18</td>
<td>91</td>
<td>21</td>
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<tr>
<td>Totals</td>
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<td>127</td>
<td>46</td>
<td>317</td>
<td>1242</td>
<td>334</td>
</tr>
</tbody>
</table>

Category Total 2433
A little more than one-fourth (27%) of overall speech elements in the study resulted from a contribution by the epistemological development category of Commitment (Table 4.4). Characterized by a sizeable contribution from the classification of acknowledgment which accounted for almost a third of all speech elements in this category, Commitment, like the category of Dualism, had only 5 classification groups of speech elements.

A total of 2052 utterances in this category were split up among the five classification groups. Modals and acknowledgement accounted for the bulk of the classifications with 761 (37%) and 664 (32%) comments respectively. Sara had the greatest percentage of modals with 46.64% and Jessica had the highest average for acknowledgement with 33.67%.

Table 4.4. Summary of utterances by speech element for group.

<table>
<thead>
<tr>
<th>Code Day</th>
<th>Repetition</th>
<th>Modals</th>
<th>Acknowledgement</th>
<th>Exclamations</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16</td>
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<td>143</td>
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<tr>
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<td>18</td>
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<td>4</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>47</td>
<td>43</td>
<td>5</td>
<td>47</td>
</tr>
</tbody>
</table>
Longitudinal Trends in Epistemic Categories

Table 5 summarizes the incidence of speech elements for the student group over the duration of the observations. For each epistemological development category, percentages of speech elements were calculated for each day of observations. The average percentage of speech elements for the group are relatively even with Dualism, Relativism, and Commitment having roughly the same percentages of items at 28.5%, 32.5%, and 27.4% respectively. The exception is Multiplicity which is at only 11.7%. On a day-to-day basis, Multiplicity consistently had the least percentage of speech elements of the four categories.

Table 5. Changes in percentages for group over 10 observations in each epistemic development category.

<table>
<thead>
<tr>
<th>Category</th>
<th>Day 1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>AVG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dualism</td>
<td>28.96</td>
<td>27.56</td>
<td>27.32</td>
<td>27.76</td>
<td>22.0</td>
<td>33.64</td>
<td>27.67</td>
<td>28.91</td>
<td>31.08</td>
<td>29.84</td>
<td>28.47</td>
</tr>
<tr>
<td>Relativism</td>
<td>31.11</td>
<td>35.16</td>
<td>34.02</td>
<td>29.3</td>
<td>28.4</td>
<td>29.66</td>
<td>39.48</td>
<td>35.94</td>
<td>29.05</td>
<td>32.46</td>
<td>32.46</td>
</tr>
<tr>
<td>Commitment</td>
<td>28.45</td>
<td>26.4</td>
<td>26.34</td>
<td>31.01</td>
<td>35.8</td>
<td>25.76</td>
<td>23.34</td>
<td>24.01</td>
<td>27.71</td>
<td>25.13</td>
<td>27.40</td>
</tr>
</tbody>
</table>

For the category of Dualism, there was very little change from Day 1 to Day 10 in terms of percentage of speech elements. The percentage on Day 1 was 28.96% and on Day 10 it was 29.84% with an average of 28.47%. The highest percentage in this category was 33.64% occurring on Day 6. The lowest percentage, 22.0% occurred on Day 5.

In the category of Multiplicity, there was a similar pattern, that being there was very little change. The beginning percentage on Day 1 was 11.48%, the ending percentage on Day 10 was
12.57%, and the average was 11.74%. The highest percentage, 13.8%, occurred on Day 5 and the lowest percentage, 9.51%, happened on Day 7.

The category of Relativism showed a bit more variable pattern. Day 1’s percentage was 31.11% while a peak of 39.48% occurred on Day 7 and a low of 28.4% on Day 5, hence giving a range of 11.08%. This difference was more than three times the range in Dualism and Multiplicity. The final percentage on Day 10 was 32.46% and the category had an average of 32.46%.

Commitment began with a percentage of 28.45%, ended with 25.13%, thus averaging 27.40%. The highest percentage in this category was 35.9% on Day 5; the lowest, 23.34% on Day 7; an average of 27.40%; and a range of 12.46%. It is interesting to note two features in the data. First on Day 5, Dualism had its lowest value of 22.0% the same day that Commitment had its highest value of 35.9%. On Day 5 students were engaged in the lab activity on Technical Drawing. On Day 7, a similar phenomenon occurred where there were offsetting extremes: Commitment had its lowest value and Relativism had its peak. On Day 7, the students were engaged in constructing the microscope.

When the average percentages for the epistemological categories during the 10 observations are compared to the same categories represented by the post-observation reflection, we see that there was a 2.55% decrease in Dualism; a 6.19% increase in Multiplicity; a 2.99% increase in Relativism; and a 6.62% decrease in Commitment.

**Review of the Students’ Activities, Utterances, and Epistemological Development Positions**

We begin on Day 1 when the students were engaged in the project rollout featuring the entry document. Of the 1148 speech elements made that day, there was an even split between Dualism at 28.96% and Commitment at 28.45%. Multiplicity has the lowest percentage for the four epistemological developmental categories at 11.48%, but Relativism topped all categories at
Kevin

On this day, Kevin made the most statements in the Relativism category, 134. More than half of these (72) were interrogative or question statements. The questions Kevin asked ranged from the generic type such as “Anyone else have any suggestions?”, “How do we measure it? and “What?” to activity-specific queries such as “Could you explain the osmosis diagram?” and “Two different kinds of cells?” Other examples of general types of questions in this category like “What was the first one?” which was a request by Kevin to another group member to repeat her last comment, and the utterance “Do you want three days?” which was an inquiry to the group regarding how many days were needed to complete their homework assignment. Even though Kevin had the greatest number of utterances in the Relativism category, the number of his comments in Dualism (121) and Commitment (111) were not far behind; only his comments in Multiplicity were half as great (52).

On the second day of observations, the students were engaged in two laboratory investigations, diffusion through a membrane and determining the magnifications of a lens. Here, Kevin was prolific with his utterances in that they accounted for more than one-third (35.8%) of the group’s total comments.

The proportions of how the utterances were divided up among the four epistemological was similar to that of Day 1. Kevin’s 171 utterances in Relativism were slightly edged out by his 188 comments in Dualism, while speech elements in Commitment came in at 135 and Multiplicity again had the lowest tally with 62 utterances. A closer look at Kevin’s speech on Day 2 within the four knowledge categories shows that declaratives, statements of facts, had the great-
est number of all speech elements (144) across all categories. Interrogatives was next with 83 utterances and acknowledgement in Commitment was next with 46 utterances. Kevin’s declarative statements included comments like “we’re at 30 centimeters” referring to one of the variables for image distance during the microscope lab, and “the second one, 2X…and the last one, 1X” referring to the magnification of the lenses the group was using.

In regards to the questions Kevin had during the lab, many were procedural, “Okay….so now we have to put it in here; just throw it in?” and “So, where’s the distilled water we’re using? Is this the distilled water or are we using tap water?” Kevin’s acknowledgement comments were typically about procedures, “oh, okay, I thought you meant the bottom of this” or generic responses such as “yeah” or “uh huh.”

On Day 3, Kevin was involved in the engineering design process lecture and assisting in generating “knows” and “need-to-knows” lists. At this time there was a noticeable change in Kevin’s comments. The number of comments he made on Day 3 decreased from the previous day from 144 to 82, a difference of 43%. On Day 4, Kevin was engaged in a technical drawing lab and in creating a poster of a microscope that included a labeled diagram of a microscope with explanations of functions of each part. Here, Commitment had the highest percentage, 33.84% supported by 42.3% modal and 15.4% acknowledgement classified utterances. Kevin had his greatest ratio percentages on Day 5. These values are attributed to declarative statements in Dualism where there were 13 of 21 (62%) of utterances were declarative and 19 of 30 (63%) of utterances in Relativism were interrogative.

Examples of his declarative statements include, “already done that” spoken in response to Theresa about the need for the group to have completed their Microscope User Guide. Also, Kevin acknowledges that he has an outstanding assignment that requires his attention: ”Oh, it
looks like I need to finish the New York State science lab.” Kevin’s interrogative speech elements on Day 5 were ones that, for the most part, sought clarification from the group as to what other tasks needed completion. For example, “Do we have a planning document?” and “what are we supposed to be doing on this?” which he said regarding the microscope lab packet. For Kevin on Day 5, the two classifications in Commitment, modals and justification had the same quantity, 6. Kevin’s modal speech elements included words such as “might”, “just”, “should”, “could”, and “like.” A sample of the context these words occurred is “we could let them fall out” which Kevin said to the group regarding the pellets used to stuff the teddy bear and “I forgot, but it might say right here” which was his response to a question from Theresa about how to perform the calculations for the object distance for the magnification of a lens lab.

Again, as Kevin was interacting with the guest students, he would make comments that provided a rationale for speech. Such as the case when he was explaining to the guest where to place the parts for their model cell, “So put these in your cell... anywhere” and “if you want, you can use more than one to spread it out a little bit.” When compared to Theresa and Jessica, Kevin’s use of justification was much higher. Jessica had 5 out of 16 utterances and Theresa had only 8 out of 50 utterances in this classification.

In similar fashion with Theresa and Jessica, Kevin’s 71 declarative utterances accounted for 72% of speech elements in this category. Kevin as well used these utterances to explain cell organelle function: “These things called lysosomes will take that waste and blow it out of the cell” and “The thing with cells is that the organelles can go anywhere in your cell.” Also, some of Kevin’s comments were explanations to a teacher about how their microscope functions: “You just pull it out, put the new one on and put it in.”

In Relativism, which had the next highest of Kevin’s percentages, interrogatives again
represented the largest number (29) of speech elements, but not by much. Also in Relativism, there were 22 hedges, 13 interpretations, and 15 instructive. Like his peers, Kevin’s questions were involved with either quizzing the guest students about cell organelles, “Do you know what the cell membrane is?” asking Jessica if she could help a guest, “Can you help her build a cell?” and working out last-minute details about their presentation, “Can I see your phone?” (The group used a cell phone as a light source).

For Kevin, the category of Commitment had 34 of his 75 speech elements (45%) classified as justification. Again, as Kevin was interacting with the guest students, he would make comments that provided a rationale for speech. Such as the case when he was explaining to the guest where to place the parts for their model cell, “So put these in your cell…anywhere” and “if you want, you can use more than one to spread it out a little bit.” When compared to Theresa and Jessica, Kevin’s use of justification was much higher. Jessica had 5 out of 16 utterances and Theresa had only 8 out of 50 utterances in this classification.

The following table illustrates the changes in the percentages of Kevin’s utterances over the ten observation days. The table shows the percentages of speech elements classified in each of the four epistemological developmental groups that occurred on each observation day. The table also shows the average percentage for each category. The “REF*” column refers to the writing piece the students did for the post-PBL reflection. Similar tables for Sara, Theresa, and Jessica present the same types of data.

Table 6. Kevin’s profile.

<table>
<thead>
<tr>
<th></th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
<th>Day 6</th>
<th>Day 7</th>
<th>Day 8</th>
<th>Day 9</th>
<th>Day 10</th>
<th>AVG</th>
<th>REF*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dualism</td>
<td>28.9</td>
<td>33.81</td>
<td>29.8</td>
<td>24.3</td>
<td>64.06</td>
<td>35.71</td>
<td>30.37</td>
<td>31.09</td>
<td>30.77</td>
<td>37.4</td>
<td>34.62</td>
<td>32.07</td>
</tr>
<tr>
<td>Multiplicity</td>
<td>12.4</td>
<td>11.15</td>
<td>15.76</td>
<td>13.88</td>
<td>9.38</td>
<td>11.9</td>
<td>7.41</td>
<td>11.94</td>
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<td>1.91</td>
<td>10.79</td>
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</tr>
<tr>
<td>Relativism</td>
<td>32.1</td>
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<td>26.93</td>
<td>27.98</td>
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<td>33.3</td>
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<td>33.33</td>
<td>32.69</td>
<td>32.06</td>
<td>29.09</td>
<td>32.08</td>
</tr>
</tbody>
</table>
Commitment 26.6 24.28 27.51 33.84 21.88 19.04 25.19 23.63 24.34 28.63 25.49 18.87

*REF – Post-PBL reflection

Kevin began the study with percentages of 28.9, 12.4, 32.1, and 26.6 for Dualism, Multiplicity, Relativism, and Commitment, respectively. By the end of the observation period, the percentages for these categories were 37.4, 1.91, 32.06, and 28.63 respectively. Three of the categories saw an increase in percentages: Dualism increased by 3.17%; Multiplicity increased by 4.58%; and Commitment increased by 2.03%; Relativism decreased by 0.04%. The average values for these epistemological categories were Dualism - 34.62%; Multiplicity - 10.78%; Relativism – 29.09%; and 25.49% for Commitment.

The ranges for Kevin’s values were as follows: In the category of Dualism, a low value of 24.3% occurred on Day 4 and a high value of 64.06% on Day 5 which yielded a range of 36.75%. The magnitude of the range for this category was the greatest of all categories for all students. In the category of Multiplicity, Kevin had a low value of 1.91% on Day 10 and a high value of 15.76% on Day 3 giving a range of 13.85%. A range of 32.35% resulted from Relativism’s low value of 4.69% on Day 5 and its high value of 37.04% on Day 7. In the category of Commitment, the high value of 33.84% on Day 4 and the low value of 19.04% on Day 6 produced a range of 14.8%.

For Kevin, Day 5 was a day of extremes in terms of his epistemological development stage. On this day he had a peak percentage of 64% for Dualism, the highest percentage for Kevin in this category for the duration of the study. On the same day, Kevin had the lowest percentage during the study of 4.69% for Relativism. Even though Kevin’s highest average percentage was Dualism, it was Relativism that had the highest percentage in his post-PBL reflection writing.

Jessica
The project rollout on the first day found Jessica make a total of 127 utterances; significantly less than Kevin’s 418, Sara’s 368, and Theresa’s 265. The major classifications for Jessica’s speech elements in each epistemological development category were 24 declarative comments (62%) in Dualism; 9 utterances in Multiplicity (56%) characterized as incomplete sentences; 25 interrogative statements (71%) in Relativism; and 15 utterances (41%) identified as acknowledgment in Commitment.

For Jessica, her declarative comments were ones that spoke to her status of understanding. “Jesus, I forgot osmosis” and “I don’t know how to spell this word” which she said as she was trying to record the verbal notes on macromolecules, or “fats, oils, and …” as she repeated the types of biological molecules that are found in cells.

Jessica’s level of comprehension was also revealed by her utterances in Multiplicity. Her confusion or lack of clarity regarding the properties of lipid macromolecules can be seen in her comments as she tried to understand the notes during the sharing of information by the group: “So lipids…” or a revealing “Well…”

In the category of Relativism, the bulk of Jessica’s interrogative comments sought clarification on the groups responsibilities for their lab packet of research notes, “So, we have two sets of research notes?” and “What do we need to be focused on right now?”

Some of Jessica’s questions related directly to completing the tasks of the microscope measuring lab, “How about we use the 30, 35, 40 because that goes into the scope length?” Other questions were more mundane, “Why can’t you just go with the flow?” Some of her questions sought to clarify the findings of the lab, “Was that the thing?”, “So it was upside down? How is that possible?”, and “And it was inverted?” In Commitment, Jessica’s utterances were short and direct, “Yeah” and “Yes, that’s what I have” which she spoke in response to confirming what she
had written down as the function and structure of macromolecules.

For Jessica, on Day 2, the other two categories of Dualism and Commitment had totals of 75 and 70 speech elements respectively. In the Dualism category, 73% of Jessica’s comments were identified as declarative. In Commitment, speech elements were evenly split among modals and acknowledgment with 23 elements, each accounting for approximately 33%. Jessica’s comments in these categories were statements like “yeah, just use a ruler” and “we have to start on the other one”, demonstrating the presence of modals “just” and “have to” and the routine acknowledgement, “okay.”

Day 3 was a review of the design process and Jessica had similar results as the previous day. Declarative statements made up almost 52% of her utterances in Dualism; her comments in Multiplicity were split between incomplete statements and generalizations; hedges and interrogatives were most prevalent in Relativism; and modals, acknowledgments, and justifications were basically even in Commitment.

After the project rollout on the first day, Jessica’s Relativism had the highest percentage of speech elements compared to the other three categories for the rest of the project including the post-PBL reflection piece. Table 5 presents these findings. Each day was similar to the rest in that the greatest numbers of utterances were identified as belonging to declarative, interrogative, modal, and acknowledgement.

On this day, Jessica made 93 utterances and almost 42% of these were in Relativism, of which 64% were classified as Interrogative, 7 were Instructive, 4 were Hedges and 3 were Evaluation. Several of Jessica’s questions had to do with constructing the microscope. For example, “How are we going to hold the slides in then?” and “Is it going towards the top or the bottom?” also referring to the placement of the microscope stage.
Sixty-four percent (15 out of 28) of the utterances in Commitment were classified as modals, figures of speech that reflect the speaker’s judgment. Many of these speech elements utilized the modal form of “have to” as in “you have to tape the other side” which is referring to closing up a light opening in the teddy bear microscope. Another example of Jessica’s use of modals were in the form of “we need to switch the slides” and use of the modal, “just” as in her utterance “why don’t you just tape it?” another reference to closing up a light gap in the teddy bear microscope.

Finally, for Jessica on Day 8, contributing to Dualism’s influence was the 68% of speech elements identified as declarative. Most of her statements here were short, cursory, and to the point: “Yeah, I did”, or “got it” and “the lens that goes in the box.”

On Day 10, Jessica had the greatest percentages in three of the four epistemological development categories for all members of the group. Of the 70 utterances Jessica made, there were only three were considered to belong to Multiplicity. This resulted in the other three epistemological development categories having frequencies that were elevated: Here again, the preponderance of speech elements in these categories belonged to declarative in Dualism, and interrogative in Relativism and acknowledgement in Commitment.

Examples of Jessica’s utterances in Dualism were primarily declarative such as “I can try” made in response to Kevin’s request for her to help a guest student build a model of the cell and her description of the function of the adjustments on the microscope, “the coarse adjustment knob moves the stage up and down and the fine adjustment knob focuses the image”, and “okay, then we’ll go through this with you” spoke as she was demonstrating the microscope project to the guest students on Presentation Day.
The high-ranking percentage in Relativism resulted in large part from Jessica’s interactions with the guest students. During this time, 34 utterances were labeled as belonging to Relativism, 65% of these (22) were interrogative. During these exchanges, Jessica would question the guests on their knowledge of cell structure and function. For example, to one guest Jessica asked “Which one’s a plant cell?” To the same student she posed the question “Do you know what the cytoplasm is?” Jessica continued to ask questions of the student guests about their knowledge about structure and function of the microscope.

*Table 7. Jessica’s profile.*

<table>
<thead>
<tr>
<th></th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
<th>Day 6</th>
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<th>Day 10</th>
<th>AVG</th>
<th>REF</th>
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</thead>
<tbody>
<tr>
<td>Relativism</td>
<td>27.56</td>
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<td>27.17</td>
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<td>27.78</td>
<td>48.57</td>
<td>38.02</td>
<td>45.83</td>
</tr>
</tbody>
</table>

Jessica was absent on Day 7 of the observations so the average percentages were based on 9 observations as opposed to 10. Jessica’s percentages showed wide variation in all categories. Jessica’s lowest percentages were in the category of Multiplicity, with 7 days having a percentage less than 10% and with the lowest percentage of 3.41% on Day 8.

Conversely, with the exception of the first day, all of Jessica’s highest percentages occurred in the category of Relativism. There were 5 observation days with percentages greater than 41% and the highest percentage on Day 10 at 48.75%. This trend continued with the post-PBL reflection which was 45.83%.

In Dualism, the percentages ranged from a low of 19.2% on Day 4 to a high of 35.71% on day 9 giving a range of 16.51%. The category of Commitment had the least variation in percentages with a low value of 19.61% on Day 5 to a high value of 29.55% on Day 8 resulting in a
range of 9.94%.

When Jessica’s average values were compared to the values for the post-PBL reflection, there was a slight decrease of 1.46% in Dualism from 26.46% to 25.0%. There was an increase of 6.5% in Multiplicity from an average of 10.17% to 16.67% for the post-PBL reflection. A modest increase in percentage was seen in the category of Relativism where the difference between the average percent of 38.02% and the post-PBL reflection of 48.83% yielded a 7.81% increase. In the category of Commitment, there was almost a 50% decrease from the average value of 25.35% to the post-PBL reflection value of 12.5%.

**Theresa**

Project Rollout on Day 1 found Theresa making 235 comments. With the exception of the 28 comments in the category of Multiplicity, her utterances were spread evenly among the remaining categories of Dualism, Relativism, and Commitment with 68, 69, and 70 utterances respectively. Like Kevin, Sara, and Jessica, for Theresa, only one kind of speech element accounted for the majority in each of the three categories. In Dualism, declarative statements represented almost 65% if the speech elements here, while in Relativism it was interrogatives that totaled 62%, and 44% of speech elements in Commitment were attributed to the classification, acknowledgement.

A typical example of Theresa’s declarative statements in Dualism can be seen in her comment to the group in which she relates her findings for a research question on receptors in the cell membrane, “So, the binding of the hormone to the receptors triggers a cascade of the reaction within the cell that can affect the functions.”

An interesting example of Theresa’s interrogative speech element from the Relativism category comes from when she is explaining the process of osmosis to the group and she queries
them as to their understanding. “Osmosis? So, basically this is showing how the water will…so….if…you see how there is a little bit of salt here?” This type of interrogative differs from the usual questions students ask in which they’re seeking clarification for some aspect of the project. For example, at one point when the students are researching the chemical composition of biomolecules, Theresa asks for clarification of the elements, “Hydrogen, oxygen, and carbon?” “Phosphate?” “What’s the symbol, periodic table label for phosphate?”

Theresa’s largest number of comments in Commitment were acknowledgements. These ranged from the mundane “okay” and “yup” to her stating agreement to a specific idea, “yeah, it moves the water because it’s easier too.”

On Day 2, Theresa had the least number of utterances with only 258 compared to Kevin’s 556, Sara’s 409, and Jessica’s 308. The two major speech element classifications in Dualism were declarative statements accounting for 67% and negatives, accounting for almost 28%. For instance, when the group was working on the lens activity, Theresa remarked how many images she saw, “I see 2!” and “you times it by 5” referring to the calculation needed to compute the magnification of the lens. And in response to Jessica’s question about the lens fitting in the lens tube during the magnification of a lens lab, she commented “not very easily, you have to press it.”

In an unusual turn, while Multiplicity held its usual low place with the lowest percentage of speech elements, the classification of interpretation was a relatively large 57%. Comments such as “so we basically made up our own distance here”, “hold on, it’s really blurry….like really blurry”, and “it doesn’t matter” characterized this category.

Keeping with the typical pattern, interrogatives in Relativism had the most percentage of
speech elements with 51%. Several of Theresa’s questions sought to confirm what the lens experiment was showing, “what was the distance for the first (lens) one?” and “is it clear?” and “are you sure it’s millimeters and not centimeters?” Theresa also asked questions on this day in regards to the diffusion through the membrane lab: “Is that that like a greenish color on the outside?”, “so we need to test it with…do we want to do that now?”, and “Is that the glucose solution?”

The pattern of large percentages of speech elements in Commitment being due to modals and acknowledgement continued on this day as well: modals accounted for 36% and acknowledgement, 40%. The negative statement Theresa made earlier about the lens, also contained the modal “have to”, “not very easily: you have to press it.”

For Theresa on Day 3 there were some changes from the previous observation day in terms of the relative number and type of speech elements. On this day, almost 52% of her comments in Dualism were declarative ones. Utterances like “and then of those plans, just set a specific thing in the box and it’s going to be in a specific slot” and “So the eyepiece is going to be set”, exemplify this. Interrogatives and hedges were the predominant forms in Relativism and modals and acknowledgements carried their weight in Commitment.

On Day 4, Theresa had only 281 utterances, much less than Sara’s 376 and significantly less than Kevin’s 509. Jessica had left early this day, thus her comments had a net of only 20 characterized speech elements. In Dualism, 54% of the speech elements were identified as declarative. The group was involved in creating a labeled poster of the microscope and working on their lab on measuring under a microscope.

Two of the declarative utterances Theresa made dealt with microscope design, “It’s a pro-
jector; it’s actually going to project through its head” and “to see how big we need the projection.” These comments were made in reply to the teacher inquiring about the group’s microscope design.

On Day 5, Theresa’s 71 utterances accounted for 22% of the group’s speech. Her declarative utterances in Dualism measured 70% and were exemplified by such comments as “right now we’re working on the pamphlet”, “so yeah, there’s going to be a hole”, and “that’s what I’m wondering.” The first comment was a reply to Kevin’s question about what the group was supposed to be working on then; the second utterance was to confirm Kevin’s thoughts on how the light path would travel through the teddy bear microscope; and the last comment was echoing Jessica’s question about what the team was supposed to be doing then.

On Engineering Design Day, Day 6 of the PBL, Theresa’s 87 utterances were consistent with Jessica’s comments (85), but only half of the number spoken by Kevin (173) and Sara (163). Fifty-six percent of Theresa’s Dualism comments were declarative statements such as “I still helped; I told him what to draw” and “Yes, Sara’s design; I was struggling” both uttered in response to Kevin’s query about the nature of her drawing for the design idea for the microscope. In the Relativism category, interrogatives held 44% of the classification. One of Theresa’s questions reflected her detachment or unawareness of the functioning of the group, “is this even ours?” referring to the final microscope design. Two other comments also reflect this, “Do we have to finish the lab?” and “Should we finish the lab?”

Once again, modals and acknowledgments were the most classified comments in Commitment with 44% and 33% respectively. The following two quotes reflect these types of utterances, “yeah, we should probably do that” and “okay, I think we should put these together” both
comments referring to her opinion regarding how the group should handle the making of the prepared microscope slide.

On Day 7, the group continued with their task of building their teddy bear microscope. Today, Theresa was once again the least verbal member of the group speaking only 87 utterances to Kevin’s 135 and Sara’s 124 (Jessica was present this day, but was not in the classroom during the observation). Fifty percent of her utterances in Dualism were declarative statements. As is often the case with student utterances, different types of speech elements are combined. The following example illustrates this with Theresa explaining how she could stop the light from leaking out of the microscope. This utterance contains both declarative and modal speech elements: “I could block it out with this paper” where “could” is the modal which modifies Theresa’s statement about using paper to stop the light.

Likewise, 50% of Theresa’s comments in Commitment were modal, yet unlike other observations she spoke only one utterance that was identified as acknowledgement. In addition to the above example of the occurrence of a modal, another example is “I can’t put my hand there you have to put it up” which contains the two identified modals, “can’t” and “have to.” This comment was made by Theresa to Kevin as they were trying to adjust the placement of the light source for the microscope. On Day 9, the array of data was similar to previous days: declarative statements dominated Dualism with 72% of those speech elements; interrogatives accounted for 50% of Relativisms comments; and in Commitment, modals and acknowledgements were close with 21% and 31% respectively, but were outdone by the 46% of utterances identified as justification.

On Day 10, like Jessica, a large percentage of Theresa’s utterances in Relativism (59%)}
resulted from interrogatives. This can be attributed to just as what Jessica had done, Theresa engaged student guests by asking them questions about the cell and microscope: “What do you think represents the cell membrane?”, “What are the Golgi bodies?” and “So, can someone explain to me what a vacuole is?”

The category of Dualism was next highest for Theresa on Day 10 with a phenomena similar to Relativism where one type of speech element accounted for the greatest percentage. In this instance, 38 of 53 utterances or 72% were due to declarative statements, when Theresa explained to the students the function of the organelles: “So basically this acts like a mitochondria and a mitochondria that breaks down sugar to give the cell energy and that’s what makes you bounce around.” Some of Theresa’s declarative statements were replies directed to the teachers when asked about the format of their presentation: “And when they view the cells and then they’re going to make replicas of the cell.” The following table shows the changes Theresa went through in her utterances during the observation period.

Table 8. Theresa’s profile.

<table>
<thead>
<tr>
<th></th>
<th>Day 1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>AVG</th>
<th>REF*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dualism</td>
<td>28.94</td>
<td>29.46</td>
<td>26.61</td>
<td>28.11</td>
<td>25.81</td>
<td>20.25</td>
<td>32.18</td>
<td>25.89</td>
<td>24.27</td>
<td>27.46</td>
<td>27.20</td>
<td>A</td>
</tr>
<tr>
<td>Multiplicity</td>
<td>11.91</td>
<td>14.34</td>
<td>13.76</td>
<td>9.96</td>
<td>20.97</td>
<td>20.25</td>
<td>11.49</td>
<td>11.00</td>
<td>11.43</td>
<td>11.40</td>
<td>13.65</td>
<td>A</td>
</tr>
<tr>
<td>Relativism</td>
<td>29.36</td>
<td>29.07</td>
<td>32.11</td>
<td>34.88</td>
<td>22.58</td>
<td>26.58</td>
<td>37.93</td>
<td>31.39</td>
<td>35.92</td>
<td>35.23</td>
<td>31.51</td>
<td>A</td>
</tr>
<tr>
<td>Commitment</td>
<td>29.79</td>
<td>27.13</td>
<td>27.52</td>
<td>27.04</td>
<td>30.65</td>
<td>32.91</td>
<td>18.39</td>
<td>31.71</td>
<td>27.18</td>
<td>25.91</td>
<td>27.82</td>
<td>A</td>
</tr>
</tbody>
</table>

*REF – Post-PBL reflection; A = Absent

Like the others, Theresa’s lowest percentages occurred in Multiplicity. This category had an average of 13.65% which was the lowest and at least half of the averages of the other categories. And like Jessica, Theresa’s Relativism also had the greatest average percentage of the four
categories of 31.51% although for Theresa, the difference from the other categories was on average, a modest 4%.

**Sara**

Sara was quite verbose during the project rollout speaking a total of 368 utterances. With the exception of Multiplicity with only 37 comments, Sara made fairly even numbers of comments in Dualism, Relativism, and Commitment with 103, 121, and 107 statements respectively. Seventy percent of comment in Dualism were due to declarative statements. Sara made such comments as “the closer you are to the center, the more magnified it gets”, “and he’s using a ratio to determine the magnification” both comments refer to determining the magnification of a lens lab. Some of Sara’s comments were organizational in nature, “Oh, let me put the document in there” and “and everything is already in our team folder; I did that last period.” Other declarative statements made by Sara relate to the groups research work on biological macromolecules, “and there are four different types of macromolecules”, “okay, so macromolecule; it’s basically a large molecule mad out of things called monomers and if you need help spelling anything I can just…”

Sara’s speech elements in the category of Multiplicity were primarily incomplete sentences accounting for 62% in that category. Some of these statements dealt with the groups responsibilities of handing in homework by a specific date, “we could check in on the 12th because there’s…, then we can change it to the 15th because we already have a set of research notes due on the 20th for Global, so…” and “I’ve got us saying…yeah, we are…”

Sixty percent of Sara’s speech elements in Relativism were from interrogatives. Some of these questions had to do with helping the group understand and complete the research questions
on biological macromolecules. For example, Sara asked the group “And the last is nucleic acids…want me to spell it for you?” Sara also asked the group is they needed clarification about these chemicals, “Ah, carbohydrates are a form of macromolecules, um…wait, do you guys want me to explain this to you?” But more frequently, Sara’s questions dealt with seeking confirmation from the group regarding whatever she had just said: “I know…so question one…okay?” In some cases, she was looking for what someone else to repeat what they had just said because she missed it: “what?” or “for the what?”, and some questions were for seeking agreement on the group’s responsibilities, “Equal understanding; okay, so everyone’s all good with that?” Several of Sara’s questions functioned in focusing the group, “what do you guys think”, “Do you guys have any ideas?”, and “okay, so what are we going to do for our summary?” As on previous days, Sara’s utterances in the category of Commitment were well represented by modals and acknowledgements, both contributing 36% to the total of comments in this group.

Day 5 found Sara having a majority of declarative comments in Dualism, a few incomplete statements and interpretations in Multiplicity, many interrogatives in Relativism, and several modal utterances and acknowledgements in Commitment. Sara’s declarative comments included such statements as “I have a teddy bear we could use” and “we’re going to be doing a projection microscope.” Her first statement was to tell the group that she would be able to contribute the stuffed animal with which to build the microscope and the latter comment was in response to a question from the teacher regarding the type of microscope the group planned on building.

Sara’s utterances in Multiplicity related the style of presentation that the group was striving for on Presentation Day, “and ours will be like a carnival them so it will help us with the dark
room because we were thinking of having like string lights coming up and stuff.” Sara also commented on the group’s failed attempt at making a prepared microscope slide to use with their microscope, “We have to redo it.” Sara’s interrogatives in Relativism frequently sought to clarify the status of their progress which, in this instance was in reference to the previously mentioned prepared slide, “Do we have to redo?” Other interrogative comments were to clarify lab procedures in the diffusion through a membrane lab, “wait, was that the salt water?”, “is this the fresh water or the salt water?” and “Can you plug the microscope in?”

The modal comments Sara made on Day 6 frequently indicated obligation, as in only one action is possible. In these examples, Sara is indicating and acknowledging a mandatory step in the diffusion through a membrane lab, “yeah, we have to do it with distilled water” and two similar comments regarding the prepared slides of cells that the group needs to make, “we have to be able to see at least one” and her response to Kevin about the types of cells that the group was required to make, “no, we have to use one of each; it’s required; we can use the onion.”

Day 7 when the students were constructing the teddy bear microscope, Relativism accounted for the majority of Sara’s utterances with 43%. Of these, again there were many interrogatives and several hedges. In Dualism, declarative statements had 56% of the share of utterances. In Commitment, the largest contributor were modals with 53%.

Day 9 was for “teamwork time” and the group was making its final push to complete project for the Presentation Day in four days. During this time, Sara made 97 comments; 22 in Dualism, 11 in Multiplicity, and 32 each in Relativism and Commitment. In Dualism, 16 of the 22 comments were declarative. There were 8 utterances in Multiplicity identified as generalizations. For Relativism, the trend continued with interrogatives have the most statements, 62.5%.

In Commitment, modals accounted for 53% of utterances followed by 31% justification.
Sara’s modal comments reflect the chaos the group is experiencing, “we have a lot of things going on, it’s not just this.” Sara’s suggestions about how to complete construction of the teddy bear microscope contain multiple modals, “we could put like dowels in it”, “like in the back over here to hold it”, and “like build external structure in the back.”

Sara’s justification utterances served to establish her suggestions regarding the microscope light source as being valid, “and it doesn’t matter anyway, cause mine is just brighter so it shines directly into both of them at the same time” and “and it should help with the stabilization a little bit because it’s right there now.” The following table presents Sara’s progression during the project.

*Table 9. Sara’s profile.*

<table>
<thead>
<tr>
<th>Day</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>AVG</th>
<th>REF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dualism</td>
<td>27.99</td>
<td>19.32</td>
<td>27.52</td>
<td>22.87</td>
<td>30.38</td>
<td>33.87</td>
<td>21.77</td>
<td>A</td>
<td>22.68</td>
<td>A</td>
<td>25.8</td>
<td>35.84</td>
</tr>
<tr>
<td>Multiplicity</td>
<td>10.05</td>
<td>11.73</td>
<td>12.39</td>
<td>12.23</td>
<td>4.14</td>
<td>12.9</td>
<td>10.48</td>
<td>A</td>
<td>11.34</td>
<td>A</td>
<td>10.66</td>
<td>5.67</td>
</tr>
<tr>
<td>Relativism</td>
<td>32.88</td>
<td>37.41</td>
<td>36.7</td>
<td>30.32</td>
<td>39.29</td>
<td>25.81</td>
<td>42.74</td>
<td>A</td>
<td>32.99</td>
<td>A</td>
<td>34.77</td>
<td>28.3</td>
</tr>
<tr>
<td>Commitment</td>
<td>29.07</td>
<td>31.54</td>
<td>23.39</td>
<td>34.57</td>
<td>23.21</td>
<td>27.41</td>
<td>25.0</td>
<td>A</td>
<td>32.99</td>
<td>A</td>
<td>28.40</td>
<td>30.19</td>
</tr>
</tbody>
</table>

Overall, when comparing Sara’s beginning percentages on Day 1 to her final percentage on Day 9 (She was absent on Day 10), Dualism decreased by 5.3%; there was an increase in Multiplicity of 1.29%; Relativism barely increased by 0.11%; and Commitment increased by almost 4%.

In the epistemological development category of Dualism, Sara’s average for 8 observations was 25.8% which increased by 10% in her post-PBL reflection. This was the largest increase for her in all four categories. Multiplicity saw a decrease of almost 5% from average to post-PBL reflection. Sara decreased in Multiplicity and Relativism by 5% and 6.47% respec-
tively also between her average and post-PBL reflection. Her highest percentage, 42% in Relativism occurred on the 7th observation day. Sara’s lowest value of 4.14% was in Multiplicity on Day 5.

Sara’s ranges in each epistemological developmental category were as follows: In the category of Dualism, the low value of 19.32% occurred on Day 2 and a high value of 33.87% occurred on Day 6 and yielded a range of 14.55%. For the category of Multiplicity, a range of 8.76% was derived from a high value of 12.9% on Day 6 and a low value of 4.14% on Day 5. In the category Relativism, a low value of 25.81% on Day 6 and a high value of 42.74% on Day 7 produced a range of 16.93%. The category of Commitment saw a range of 11.26% that resulted from a high value of 34.57% on Day 4 and a low value of 23.31% on Day 5.

Along with the increase in Commitment was an increase in one of the speech elements from that category, modal. The incidence of modals in Sara’s utterances began with 36.4% on the first day, climbed to 63.5% on the 6th day before settling in the mid-50’s (54.8% and 53.1%) on days 7 and 9. During this time there was a concomitant decrease in two speech element classifications from Multiplicity, interpretation and incomplete sentences, which allowed Commitment to have the increase that it did.

**Group trends**

For the group, Relativism had the highest average percentage of speech elements over the course of the project at 32.46%. This was followed by Dualism at 28.47%, Commitment at 27.40%, and Multiplicity a distant fourth at 11.74%.

Interestingly, the group’s highest percentage for Relativism, 39.48% occurred on Day 7 of the observations. Dualism’s highest percentage was on Day 6, Commitment’s highest percentage of 28.45 occurred on the first day, and Multiplicity’s highest of 13.8 happened on the fifth
Within each epistemological development stage, there were one to three speech element classifications that occurred more frequently than others. For the category of Dualism, it was the classification of declarative that was highest for all four students. In Multiplicity, the utterance classifications that had the highest percentage were interpretation, false start, and incomplete sentence.

As the group moved through the project, a lot of their conversations were focused on bringing them closer and closer to being able to present their project to guest students on the final day. As we have seen, the interrogatives usually sought to clarify the status of some aspect of the overall project, for instance when they discussed due dates for the lab components or to clarify the procedure when they were doing one of the lab activities like the determining the magnification of a lens, or the diffusion through a membrane, or constructing the teddy bear microscope.

**Individual trends**

Individually, Jessica, Theresa, and Sara all had the highest average percentages in Relativism. Jessica had the highest value at 45.83%, Theresa had 31.15%, and Sara had a high percentage of 38.02%. Kevin’s greatest percentage occurred in Dualism which was 34.62%.

For some epistemological development categories, the presence of certain speech elements varied with the category and with the students. For instance, the category of Relativism found hedge and interrogative with the highest percentages where the latter was between two and ten times as great as the percentage for hedge. For Commitment, it was the classification groups of modal and acknowledgement with the highest percentages. This pattern of greatest percentages was consistent for each of the observation days.
Occasionally, other classification categories had high percentages, but they were not consistent each day or for each student. For example, the classification of justification in Commitment had a high percentage for Kevin on Days 8 and 9, and for Theresa on Days 8, 9, and 10 but not at all for Sara and only on Day 10 for Jessica.

The more complex or lengthy the comment, the more modals it contained. Consider the following comment from Sara regarding the construction of the microscope: “Kevin, so we were talking while you were grabbing the lenses and um maybe we could do what like they did in the video and show, like how it shows they used the magnifying glasses, um and then we could also use like a flashlight as a light source with a piece of black paper with like a hole in it so that it could um…” which contains 7 modals, compared to a short statement containing only one, like “yeah, we’ll print like 30” referring to the number of user guides the group will need for the guests on presentation day.

Perry’s idea of multiplicity, which is characterized by the pluralism of answers, opinions, ideas, and perspectives is frequently observed as the students engaged in the microscope design process. The speech elements that were assigned to this epistemological development category were omissions, false starts, generalizations, interpretations, incorrect statements, additions, and incomplete statements. The following excerpt reflects this position. In this exchange, Kevin, Sara and Jessica are attempting to solve a problem with their microscope construction. All of their utterances contain speech elements classified as generalization:

*Sara:* to keep that in place, we could just like tape it this way

*Kevin:* I know, this is the part that keeps moving

*Sara:* I know, we could…

*Jessica:* because you could just move that…
Sara: I could take out the stitches here and then we could build a structure.

The dialogue on Day 4 when the students were beginning to design their microscope serves to capture Perry’s notion of Relativism. It is understood that Relativism relates to a stance that is based on context and relevance. Here students start to engage in meta-cognition.

The speech elements assigned to relativism are hedges, inexact statement, inferences, evaluations, interrogatives, and instructive. The following excerpt with their corresponding epistemological development categories reflects this position.

Jessica: Now what?  Relativism
Kevin: What are we doing next?  Relativism
Sara: Ah…next we have the materials list  Dualism
Kevin: Aren’t we working on the microscope?  Relativism
Sara: Now we have to do the materials list  Dualism
Kevin: The materials list?  Relativism
Sara: Yeah….  Commitment
So what’ll we need?  Relativism
What are we going to makes ours out of?  Relativism
Kevin: Well…  Commitment
We’re making ours out of a teddy bear and cardboard would be perfectly fine;  Relativism
they’re not  Dualism
actually touching  Relativism
Sara: and that would be  Relativism
the easiest thing to like….  Commitment
Kevin: to get a hold of….  Relativism
Sara: and cut  Relativism
Kevin: and cut and…  Relativism
it’ll be cheap  Multiplicity
Sara: for like….  Commitment
Kevin: uh huh  Relativism
Sara: wait….  Relativism
is it going to be stationary? What did we decide on making it?  Relativism
Kevin: did we decide on making the microscope….  Relativism
Jessica: a projector?  Relativism
Kevin: yeah….  Commitment
but….  Dualism
adjustable or stationary?  Relativism
Sara: It’s going to move stationary?  
Kevin: I thought we said adjustable?  
Yeah…  
we said adjustable…  
because of the different size of lenses

In this segment, Jessica initiates engagement of the group with a general prompt, “Now what?” Kevin utters a similar query, “what are we doing next?” affirming the indecisiveness of the group. As the conversation develops, the group make suggestions about their materials list. Their talk takes on a metacognitive tone as they question their decisions regarding the type of microscope to build: adjustable, stationary, or projector.

Based on the classification of the students’ speech elements, 7 were placed in Dualism, 3 in Multiplicity, 17 were assigned to Relativism, and 9 were placed in Commitment. This is a brief example that shows how utterances in this selection place it squarely in the category of Relativism.

**Student artifacts**

Figures 2.1 and 2.2 below shows the artifact created by the students on Day 5 for the Microscope Project PBL. This “user manual” was a required element of the PBL and which all four students contributed to its preparation. Evaluation of the text was done in the same manner as with the observations and post-PBL reflection. Since the statements and directions included in the manual are not identified by author, then are treated as belonging to the group. The speech elements represented in the text of the manual were pretty much evenly divided among Dualism, Relativism, and Commitment with 13, 13, and 15 elements respectively. Only two speech elements were identified as belonging to Multiplicity.
The relative “strength” of the epistemological development categories present in the manual is attributed to the presence of one kind of speech element. For Dualism, it was declarative statements that predominated. Examples of speech elements here were explanations of the structure and function of the Teddy Bear microscope. For example, one section of the manual described the path that light would take from its source to the viewers eye, “The light will then flow threw the Teddy Bear to the slide and all the way to the eyepiece, which you will be looking threw.” There were a series of declarative statements in the manual that dealt with the function of
lenses: “Our microscope uses two lenses, an objective lens and an eyepiece lens.” “Both lenses have a magnification of 10X.” Subsequent statements in the manual continued to explain how the lenses worked to magnify objects under the microscope.

A similar trend of having one type of speech element carry the weight of the category is seen in Commitment. In this group of comments, the majority (11 out of 15) were coded as justification. This type of code is seen in the manual’s explanation of the change in the appearance of object as seen through the eyepiece compared to its actual orientation on the slide: "This is when an object under a microscope is viewed upside down and backwards. In other words, the image seems to have been rotated 180 degrees.” Several statements under the justification category began with the conditional tense, “then.” For example, the manual was providing stepwise directions for the scope’s use, “Then you put the slide on the cardboard…” and “Then put a phone and/or flashlight…” and an explanation on measuring objects under the microscope, “We can then find the size of the original cell…”
Conclusions

A significant conclusion is that at the end of the microscope project PBL, as a group, Relativism had the highest average percentage of the four epistemological developmental groups. Individually, three of the four students had Relativism as their highest average percentage of the four epistemological developmental groups. Additionally, along with Multiplicity, Relativism had the largest percentage in the post-PBL reflection.

Examination of the conversations among Kevin, Sara, Theresa, and Jessica revealed some interesting features in regards to the number and type of utterances made by each student in each epistemological development category.
All four students had average percentages greater than 61 % for declarative speech elements in Dualism. The speech element classification interrogative under the Relativism category was another case where all four students had high average percentages. Ranging from Kevin’s “modest” 39% to Jessica’s lofty 73.62%.

In each developmental category, certain speech elements were found more commonly than others. This was true regardless of the observation day, speaker, or activity. For example, in Dualism, the speech element declarative was most prominent. Kevin for instance, had declarative speech elements that averaged almost 67% for the duration of the PBL, but yet had hardly any speech elements classified as evaluation which came under Multiplicity. Or, in the case of Sara, who had 8 days that included speech elements classified as interpretation under the category of Multiplicity, yet she had only 2 instances of speech elements classified as generalization, which is also in Multiplicity.

The category of Multiplicity, while it was the developmental group that consistently contained the least number of speech elements, it too had an identified utterance that was more commonly represented than others and that was interpretation. In the case of interpretation, the percentages ranged from Sara’s high of 33.19% to Jessica’s low of 26.40%.

In the category of Relativism, it was the speech element interrogative that far and away exceeded all other speech elements uttered by the students. It was right behind declarative as the most frequently uttered speech element with percentages that ranged from Jessica’s high of 73.62% to Kevin’s low of 39.39%.

For the category of Commitment, modal and acknowledgement utterances occurred most frequently. Interestingly enough, while also under the heading of Commitment, the speech element justification had a sporadic presence. For Kevin, its use did not appear until observation
Day 5 and then continued for the remaining days. While Sara never uttered it once and for Theresa it occurred on two days and Jessica only once.

In Chapter 5, I will discuss the results and will propose possible explanations for the findings. I will also attempt to answer the research questions regarding students’ epistemological development as they participate in a Project-Based Learning activity and explore implications for future research.

**CHAPTER 5: DISCUSSION**

**Introduction**

In this chapter, I discuss the findings of Chapter 4 and articulate their importance. The present study focused on investigating the epistemological development of high school students. This study differs from previous research in various ways including duration of the study, age and gender of the participants, and grade level. The present study involved 10 days of observations over one month with male and female high school sophomores as participants. Other studies examined epistemological development of male college students over four years (Perry, 1968); women college students (Belenky et al. 1986); 18-34 year olds of both sexes over 16 years (Baxter Magolda, 1992); and male and female junior college and college freshmen and sophomores (Schommer, 1990).

The following sections will address the two research questions, the effect of grade level, the notion of a linear epistemological development trajectory, and the robustness of epistemological development stages. I will then examine the role of hedges and interrogatives and their effect on epistemological development. Finally, I will discuss the limitations of the study and end with my conclusions for the study.
The research questions

This study sought to answer two basic questions regarding epistemological development: how do students advance through Perry’s epistemological development stages as they engage in a Project-Based Learning activity? And, if there is a change in epistemological development during a Project-Based Learning activity, how does students’ language during this exercise serve as an indicator of their progress?

In response to the first question, only one student demonstrated any advancement in epistemological development. Jessica began the study in the Dualism stage based on its highest percentage on Day 1 and ended the study on Day 10 at a “higher” stage, Relativism based on its highest percentage. The other students did not have as straight a trajectory as Jessica. Sara began and ended the study in Relativism; Theresa did basically the same thing, while Kevin was the only one who appeared to regress in his development going from Relativism with the highest percentage on Day 1 to Dualism having the highest average on Day 10.

Regarding the second research question we can use one of the students to help answer. A comparison of Jessica’s speech elements on Days 1 and 10 indicates that indeed, a change in epistemological development did occur. On the first day of the study, Jessica had a high percentage of declarative utterances placing her firmly in Dualism. By Day 10, Jessica’s placement was in Relativism due to the high percentage of its interrogative utterances.

Grade level and trajectory

In terms of the effect of grade level on epistemological development, it seems that grade level does matter. At the eighth grade level, students exhibited an epistemological development position more aligned with Dualism than older students, like college freshman (Mason et al, 2006). Citing the work of Kuhn et al, (2000), Schommer (1993), King and Kitchener (1994),
Perry (1970), and Jehng, Johnson, & Anderson (1993), Mason et al. (2006) propose that with advanced education comes enhanced epistemological reasoning (p. 47). Thus differences in epistemological development can be seen across middle school grade levels, throughout college, and between college and graduate school (Mason, 2006).

The assumption that epistemological development in students follows a linear, forward-moving path is supported by the literature. For example, an essential step in epistemological development occurs in the transition from Dualism of elementary school to Multiplicity of middle school (Mason et al. p. 53, 2006). In addition, it is shown that epistemic beliefs in older students have the characteristics of Perry’s epistemological development category of Relativism: individuals start to broaden their views about what knowledge could possibly be, “scientific knowledge is complex, tentative, and evolving, does not reside in omniscient authorities and can be validated in light of corroborative evidence” (Mason et al., p. 51, 2013). This is a view also shared by Schommer (2004), who in agreeing with Perry, argued that the more mature students become, relativistic thinking becomes dominant.

In referring to Perry’s study, Belenky et al. (1986) note that the homogeneous study group Perry utilized produced predictable results, indicating that a linear sequence of development is prevalent given a consistent context (p. 15). In the same manner, the present study also takes place in a consistent context and also shows evidence indicating a linear sequence of development. By consistent context I am referring to the learning environment of the classroom which is always Project-Based Learning. There are seven PBL activities that anchor the students’ Biology course. Just as the microscope project led the students with a prescribed set of steps to follow, the entire course was designed the same way. The students knew what to expect with each new project.
However, there is evidence in the literature to indicate that epistemological development may not always favor a forward progression (Perry, 1968). This evidence suggests that a kind of regression or backwards movement in one’s epistemological development trajectory is possible. One student, Kevin did appear to revert to an earlier epistemological development category by the end of the study.

Perry (1968) recognized that smooth transitions from one stage to the next do not always occur: “a person may suspend, nullify, or even reverse the process of growth” (p. 44). Perry referred to these alterations as “temporizing” which could involve a person pausing for a year or more, usually aware of what lies in wait for them. This would be a time for the person to regroup and gather their resources. In an effort to avoid responsibility, a person may separate themselves from the process and settle for an intermediate position on the scale. Perry referred to this as “escape” (p. 44). "Retreat" is the third possible reason for a person's trajectory to be altered. Identified by “prejudice” and “hatred”, Retreat is an individual’s response to stress brought about by fear, anger, moral challenges, or simply be being overburdened. The consequence of this state is for the person to take refuge in the all-or-none position of Dualism, which is where Kevin turned out to be.

**Epistemological development stability**

In Chapter 4, Table 3 presents the percentages for the group’s epistemological development over the observation period. What is noticeable in the table is that Relativism was the category with the greatest percentage for 8 out of the 10 days and also had the greatest average percentage. The table also shows that the category of Multiplicity had the least percentage throughout the study.
Tables 4 through 7 reflect similar trends of relative consistency of epistemological development as seen in Table 3. The data from these tables shows that the percentages for each students’ epistemological development categories remained relatively consistent over the duration of the study. In light of these results, it appears that two possibilities exist for the students’ epistemological development position. One, that the students do not progress through Perry’s stages of epistemological development possibly because they do not possess the cognitive skills to do so, or two, the students are progressing through the stages of epistemological development, but the students have either not been followed long enough to detect their progress or that the measuring instrument is not sensitive enough to detect the change. This is a possibility because as I indicated elsewhere, previous studies lasted anywhere from four years (Perry, 1968) to as long as 16 years (Baxter Magolda, 1992).

In terms of the comparison of percentages of speech elements for each student between the first observation day and the last, there is for the most part, little variability. What appears as surprising is the difference in percentages for Jessica in the epistemological development category of Relativism. Jessica has a 21% increase in her utterances in this category from Day 1 to Day 10. According to Perry, Relativism is where knowledge and learning are something to be analyzed and evaluated based on its context. An explanation for this may be that Jessica is in the midst of coming to grips with the content she is attempting to master and for which she will be held accountable for when she has to present it to the visiting students. Her increase in percentages in Relativism may signal her efforts to do just that.

**On hedges**

From a sociological perspective, it was proposed that gender affects communication (Lakoff, 1973). According to this notion, males communicate in an assertive fashion because of
their assumed position of dominance in the social structure. Whereas females’ communication tends to be submissive by being more tentative and polite, a behavior attributed to their social standing (Leaper & Robnett, 2011). It was proposed that females’ use of hedges sought to soften their influence (Leaper & Robnett, 2011), and to represent their uncertainty, self-doubt, and internalization of negative interactions (Hancock and Rubin, 2015, p. 47).

Mondorf (2002) argues that what the practices of politeness, tentativeness, and hedging, some of the same speech elements classified in this study, have in common is that their use can indicate epistemic meaning and are related to gender differences. In combination with the use of modals, interrogatives, and “intensive adverbs”, according to a student’s gender, females used twice as many ‘tag questions’, modals, and intensive adverbs than males during problem-solving activities (p. 47). With the exception of Jessica and Sara, this phenomenon does not hold true. In terms of the use of hedges, Kevin had an average of 18.5%, Sara – 17.69%, Theresa – 19.20% and Jessica 7.28%.

Leaper and Robnett (2011) report findings that reveal gender differences exist based on the type of activity the individuals are engaged in. They report that the nature of the conversation can affect what is spoken. Accordingly, males tend to prefer discussion over impersonal topics and task-oriented activities whereas the preference for females is for more personal topics and socioemotional activities (p.132). It has also been reported that gender influences how one’s experiences are related to others. Hancock and Rubin (2015) proposed that in terms of personal pronouns, negations, references to emotion, and intensive adverbs the use of these elements is greater in females than in males. Again, a finer grain approach to the data would be needed in order to validate the presence of these elements in the present study. This would entail reviewing
the transcripts to find incidences where Kevin tended to speak about impersonal and task-oriented topics and the girls spoke of personal and socioemotional activities. In addition, a finer grain approach would mean examining the transcripts to see if there was any gender preference for the speech elements referred to by Hancock and Rubin (2015).

Holtgraves and Perdew (2015) reported that the motivation to use one form of speech over another is mediated by the type of message one wants to communicate: does the person wish to communicate uncertainty and/or politeness? They found that speakers tend to hedge when it comes to “severe” events and thus those events tend to be judged as less likely (p. 1). ‘Severe’ in the case of this study could imply that some aspect of the PBL is not working properly, i.e. the microscope is not focusing, or there is light escaping from the scope, or the microscope slides will not stay in position. Holtgraves and Perdew (2015) argue that the interpretation of probability speech elements is mediated by the degree to which the speaker wishes to be accepted or to put it in other terms, “to save face” (p. 3). So by a student using a hedge they would be sending the message that he or she wanted the other students in the group to accept what they were saying, thus “saving face.”

It has been shown that in scientific writing, authors employ different writing forms which can communicate various levels of doubt or uncertainty and everything in between (Oliveira, et al., 2012). Specifically, the use of hedges in scientific writing provides authors some latitude in presenting their claims as they attempt to have those claims accepted by the scientific community (Oliveira et al., 2012) and the same can be said for scientific discourse. Through the use of hedges by the students in this study, it is their intention to have their comments accepted by the group; it is their way to also obtain latitude in their arguments in the same fashion as authors in their scientific writing are striving to do ultimately leading to acceptance of the argument by the
In another example of how language can affect the process of science inquiry, Oliveira et al. (2012) point out that speech used in the process of inquiry in science has several applications, one of which is to establish the status of the inquiry and another is to achieve a mixture of “socially constituted ends” (p. 655). In the PBL in this study, the speech element classification declarative is one such utterance that the students use to identify the state of the project at a given moment. All of the students made declarative utterances that established where they were in the activity, be it conducting a lab exercise like finding the magnification of a lens or assembling the teddy bear microscope.

In specific regard to the use of hedges, students employ them in order to safeguard their forays of engaging in scientific inquiry during face-to-face, classroom activities (Oliveira et al., 2012). The four categories of oral hedging reported by Oliveira et al., plausibility shields, rounders, adaptors, and maximum hedges were seen in the students’ conversations. While Oliveira et al. advocate for the selective use by teachers of hedges in order to avoid undue influence over students’ ideas, this study inevitably captured an unfettered array of student-only conversation. What this means is that the utterances spoken by the students were not influenced by what the teachers were saying. The conversations that were recorded and analyzed were unique to the students themselves providing an authentic look at their ensuing epistemological development.

Oliveira et al. report on the pedagogical function of classroom discourse that has two sometimes opposing functions. The first function of communicating standard acceptable vocabulary is not applicable here. But the second function of allowing the students the chance to express their ideas and opinions and to speak meaningfully about their refined understandings of science bears our interest. It is this second function which is of most interest here and which raises the
question, “how can monitoring student discourse during PBL ensure progression through personal epistemological stages?”

On interrogative

In terms of the speech elements classified as interrogative, I pointed out that some questions the students posed were generic, meaning they sometimes questions simply asked for someone to repeat what they had just said. Other times, the questions were in direct efforts to further the groups’ progress in the PBL. This brings up the notion of how important are these questions to the students’ epistemological development.

Often times, the interrogative form was used by one of the students merely to ask another student to repeat what they had just said. This as opposed to making an inquiry that had legitimate bearing on the PBL process and outcome of the project. This makes senses in light of the context in which the PBL was occurring: there were four students working together in a large classroom with 30 other students engaged in the activity. There was a lot of cross-talk and overtalk among this group and with members of other groups. In other studies like those of Belenky (1986), Baxter Magolda (1992), and Perry (1968), data was collected through the use of interviews, surveys, and questionnaires; instruments which were not confounded by conversations among participants.

Henderson et al., (2015) argue that interpersonal and intrapersonal reflections are necessary in order to establish the validity of scientific ideas. This kind of “epistemic work” is at the heart of need for “critical questions.” The nature of these interrogative statements is such that they compel students to defend their own rationale and formulate a response. Since the interrogative classification played a significant role in establishing Relativism as the leading epistemolog-
ical development category it would be worthwhile to closely examine the kinds of questions included in this category and establish a finer grain distinction as to determine if the students’ questions indeed can be considered as “critical.” This would require sifting through all questions in the study and separating them further based on the type of question they are, including “critical questions.” This would provide evidence to support the idea that “epistemic work” was being done thus serving as a basis for epistemological development. Critiquing one’s ideas or the ideas of the group involves activities which have corresponding speech element classifications: questioning, explaining, justifying, and evaluating. These actions breed cognitive conflict (Henderson et al., 2015) or dissonance, the prerequisite for another epistemological development category, Commitment.

Much research has been done on whole-class interactions in terms of question-answer sequences (Solem, 2015). The present study differs in that it is focused on student-student interactions in a group setting and specifically with student use of interrogatives to begin communication. Solem (2015) argues that when the initial utterance is interrogative, students present themselves as “being in the know” and that they display “epistemic stance” in various ways. This supports my rationale of placing interrogative-identified speech elements in the epistemological development category of Relativism. In addition, student-led interrogative progressions add to how subject-area discussions and interactions develop within the group (Solem, 2015). Solem (2015) proposes that by studying student-initiated interrogative sequences, it contributes to students’ understanding of the opportunities available to them to engage in. Solem argues that through student-initiated question-answer sequences, students display “epistemic stance” and place themselves based on their knowledge claim. It might be worthwhile to explicate the student-led question-answer sequences to see if they reveal anything in regards to the students’ epistemological
stance. In this study, interrogative was one of the highest percentage categories: Kevin had 39.39%, Sara had 47.46%, Theresa had 47.21%, and Jessica had the highest interrogative average of 73.62%. These high averages support the importance of the role that questioning plays in epistemological development.

**Implications for future research**

According to Perry, when a student is at the Multiplicity level of epistemological development, he or she is on the fence about allowing themselves to consider the existence of other possible answers, opinions, ideas, and points of view. However, they still remain loyal to the authority figure, be it a person or a text. Is this what Multiplicity’s low percentage is indicating, that the students are maintaining some residual level of loyalty to some authority figure? What could cause this in these students? Are they that unsure of themselves and their ability to learn, comprehend, and absorb the content of the microscope unit that their lack of utterances in this category reveal this fear? If they are steadfast in their loyalty, is it to their teachers or their textbook(s), or both? Is this low percentage in Multiplicity indicative of these student’s epistemological development status all the time or just for this particular PBL?

According to Perry’s scheme, Commitment is the fourth position. In this position, students feel the need to define their personal choices, thereby establishing themselves in terms of their identity and their position in the community. If this is true, then why did this measure decrease on the final day of the PBL? If the students were developing along Perry’s epistemological path, it would be expected that this measure be higher. Was this decrease in the student’s sense of Commitment related to the culminating activity and their anxiety over having to present their microscope project to visiting students or their level of confidence in having to do so? Would it have made a difference in the students’ epistemological development if the final step
was in a different format? Would it have made a difference in the percentages for this step on the final observation day if Student 2 was not absent? Other questions that this position bring up are, is this a new baseline in the epistemological development for these students? Does this measure represent the position where they begin their next PBL? How does this position compare to the next and/or previous and/or final PBL? The PBL that was observed for this study occurred mid-year. Does this data represent a midyear state of epistemological development?

In order to thoroughly examine high school students’ epistemological development in high school biology PBLs, it would be necessary to follow the students over the course of the entire school year. But, this time frame of one school year is somewhat arbitrary. I say one school year because of the assumption that students do progress in their knowledge, abilities, and skills from the beginning of the school year to the end. The literature does not offer nor recommend a time frame in which to study epistemological development. For instance, as previously mentioned, Perry studied his subjects for their four years in college. Belenky gathered her data from intensive interviews from 135 women over an unspecified period of time and Baxter Magolda’s study took 16 years. Therefore, I think I is reasonable to offer one school year as a period of time for an initial study. Then, following Perry’s format, extend that to cover a student’s entire high school career. This procedure would help provide a coherent account of their epistemological development. Following the students during this period would eliminate or at least diminish the concerns regarding whether or not the topic of the PBL had any effect on the students’ epistemological development.

**Limitations**

There are certain details that constrain the discoveries reported here. These items include the size of the sample, the context of the study, and its duration, the student demographics, and
the epistemic climate. First, the findings of this study are limited by the small sample size. This means that any conclusions are limited to the particular contexts involved. This applies to both the number of individuals and the setting itself. This results and conclusion of this study are based on the utterances of four students during one Project-Based Learning activity and ten days of observations. The validity and reliability of the study area also affected by these limitations. In order to improve these study characteristics, it would be beneficial to enact some procedural changes. For instance, following students throughout the year as opposed to just one month, would reduce the effect student absences might have on data collection. Conducting the study throughout the year would also include the production of different artifacts, thereby eliminating the possible effect that the production of only one type of artifact might have on students’ epistemological development. Conducting the investigation over the entire school year would further allow the researcher to capture students in different groupings, such that their epistemological development would not be hindered or accelerated by being connected to any one group.

The next item for consideration is student demographics. The students were chosen by lottery for the school where this study took place. This fact distinguishes this subject pool because students here wanted to go to this school. Compare this situation to the students in my school which serves as the default school for attendance. Anecdotally, the previous PBL school principal told me that my district will not pay the ‘tuition’ for students to go to the PBL school, even though they have the right to do so. So, right away, there is bias in terms of the subject pool.

Secondly, in the PBL school, the students that I observed were selected by their teachers. Their selection was in part due to the fact that they had submitted completed student assent and parent consent forms. In addition, this group had not worked together on previous PBL activities;
a condition that the teachers manipulated to ensure equity among the groups. In addition, I am not aware of their educational background such as their aptitude, class rank, and strength in science or any other metric upon which to evaluate them. In the future, knowing the academic background of the subjects is advisable. Anecdotally, they all seemed to be bright students which is supported to some extent by Kevin being part of a select group of students who was preparing to take the SAT II for Biology.

The question raised by the comparison of scores on the state exam between my school and the PBL school, raises the question of why were the scores for the PBL school greater than both the state average and my school? According to Muis and Murphy (2013) students in constructivist classrooms like those in the PBL school, have higher achievement scores when compared to students in traditional classrooms like those in my school. One possible explanation for this difference may rest in the epistemic climate of the schools.

Epistemic climate can be thought of as the foundations for knowledge development. This would include the form and function of each: the “instruction, activities, discourse, curriculum, and materials” (Muis and Duffy, 2013). As previously stated, the Biology class these students are in conduct seven PBL projects throughout the year. In addition, the entire school embraces Project-Based Learning as its preferred learning and teaching method. Therefore, it would be prudent to consider the disparities in epistemic climate between the school where I teach and the study school when searching for factors contributing to differences in performance between the two schools. This stance is supported by Muis and Duffy (2013) who argue that an essential context that nurtures the development of epistemic beliefs is the instructional milieu within the school setting and that constructivist and traditional learning settings may reveal learners’ epis-
temic growth in decidedly different ways. I would argue therefore, that the epistemic climate differs significantly between the two schools and as such deserves consideration as a mediating factor when considering the results.

**Conclusion**

Epistemological development is characterized by an individual’s progression through a series of four stages or phases. These stages reflect the individual’s changing view of their knowledge and the world. What can be concluded from this study is that epistemological development over the course of a one month-long PBL project, is relatively stable. The data demonstrates that over the course of the PBL, there is some degree of vacillation for each student within the epistemological developmental categories but for the most part, students remained in the same epistemological category in which they began. The data also suggests that it may be possible for a student to regress or return to a previous stage. I can also conclude that certain speech elements within each epistemological development category attain the greatest percentages and in essence “drive” that particular category. One final conclusion to be made is that the context of this study, the school and classroom learning environment, are a necessary component for epistemological development to occur. It is the sense of community that the students feel in this class and in this school that nourishes their epistemological development. It is also the mode of instruction in the form of PBL, student-student, and student-teacher interactions that support the students in their knowledge advancement.

**References**


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### APPENDIX A. Linguistic Evidence Checklist of Sample Data

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