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ABSTRACT

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The National Academy of Engineers' Engineer of 2020 initiative recommended changing the way engineering students are educated in order to produce engineers that can contribute to a rapidly changing world. In response, the Engineering Education Research Colloquies with support from the National Science Foundation released a research agenda to frame the direction of addressing challenges stated in the Engineering of 2020 initiative. One of the research areas described in this agenda that has received little attention in recent publications is engineering epistemology, defined as the views and beliefs an individual has about the nature of engineering knowledge in different contexts. This is particularly troubling since advanced epistemological views have been shown to have a positive effect on academic performance and an individual's ability to solve the kinds of ill-structured problems engineers frequently encounter in industry.

While previous research has established the epistemological development patterns for engineering students, there has been little focus on what factors influence this development. Because of the importance of understanding a student's epistemological development, this research proposes to identify such factors through a cross-sectional research design that focuses on the epistemological development of electrical and computer engineering students. The proposed framework of this cross-sectional design is a modified version of Muis et al. 'sTheory of Integrated Domains in Epistemology (TIDE), which encapsulates epistemological beliefs and their development. In addition to the sociocultural, academic, and instructional contexts from the original version of the

TIDE framework, an industrial context was also included in order to account for potential influences from internships and cooperative education rotations.

Electrical and computer engineering students at a large Midwestern university generated epistemological profiles by completing a set of inventories to represent the various components of the TIDE framework. A background survey asked various questions that corresponded to the different contexts. Participants also completed Felder and Silverman's Index of Learning Styles in order to determine type and degree of their learning preferences. The complexity of the participants' epistemological beliefs was measured by Moore's Learning Environment Preference inventory.

The analysis found evidence that individual differences from the sociocultural (gender, whether or not a participant was a U.S. citizen or permanent resident, and neighborhood in which they grew up), academic (major, GPA), and instructional (active/reflexive learning preference and sensing/intuitive learning preference) contexts may have some form of influence of ECE student's epistemological beliefs.

This research contributes to the literature by providing insight into the epistemological development of two specific engineering majors. The study also introduced a new context for the TIDE framework in which epistemological beliefs can develop. Additionally, the study found evidence that the individual differences with respect to learning preferences and U.S. citizenship may affect epistemological development.

1. INTRODUCTION

1.1. Background

Everyday, people encounter multiple problems in their job that they must deal with. These problems can range in nature from trivial to highly complex. While most occupations do put some emphasis on problem solving, it is particularly important for engineers. Many reports have identified problem solving to be one of the primary skills that an engineer needs to possess [1], [2]. For instance, the Accreditation Board for Engineering and Technology (ABET) lists "the ability to identify, analyze, and solve technical problems" as one of the primary learning outcomes for undergraduate engineering students [3].

Yet, the necessary conditions for something to be considered a problem are inexact. Several definitions have emerged from prior research studies [4]. One popular definition within the realm of scientific problems was proposed by Jonassen [5] who suggested that problems have two critical attributes: 1) they involve an unknown entity in some situation and 2) finding a solution has some social, cultural, or intellectual impact.

The process by which the solution is found is defined as problem solving. Jonassen [5] described problem solving in terms of three aspects. The first aspect is the problem type. Researchers have proposed several categorizations of problems based on characteristics such as context, dynamicity [6], complexity [7] and representation [8]. This has also lead to some uncertainty within problem solving research with respect to which categorization schemes best describes the various types of problems that exist. One way researchers have addressed this issue is by expressing problems as a continuum between "decontextualized problems with convergent solutions to very contextualized problems with multiple solutions" [8, p. 67] and describing the different clusters that arise along this spectrum. The clusters are commonly divided into three groupings: puzzle problems, well-structured problems, and ill-structured problems [8]–[10].

Puzzle problems have been the primary focus of much problem solving research. These problems have only one correct solution and all the elements required for the solver to reach it are known. In order to reach the solution, individuals must use algorithmic processes [11]. The problems are domain-independent and designed to demonstrate reasoning and thinking processes [8]. Examples of these types of problems include anagrams and the Tower of Hanoi game [12]. Most problem-solving research has used these types of problems because "they are not complicated by requiring background knowledge, and because they reveal the strategies that people employ in searching for a solution" [13, p. 228].

The most common type of problem that students encounter in school is the well-structured problem [14]. Like puzzle problems, well-structured problems present all aspects of a problem and have a correct solution [8]. In order to solve such problems, individuals use a finite set of concepts and techniques to reach the solutions that are typically only applicable to similar problems. Unlike puzzle problems, well-structured problems do depend on the context in which the problem is presented [5].

The last cluster of problems is referred to as ill-structured problems. These problems usually depend on knowledge from multiple domains in order to solve the problem. Unlike puzzle and well-structured problems, ill-structured problems possess unknown aspects [15] and can have multiple solutions, multiple paths to a solution, or even no solution at all [11]. These problems also possess unknown aspects that individuals must discover themselves while solving the problems. Since ill-structured problems have uncertainty, individuals often need to make decisions and express opinions about the problem.

The second attribute of problem solving is the representation of the problem that is being solved. Problems are typically written within the contexts of the environment in which they are situated. This forces individuals to discern what is pertinent when creating the problem space, defined by Newell as "the fundamental organizational unit of all goal-oriented activity" [16, p. 696]. The problem space normally consists of three components: 1) an understanding of the problem type, 2) the recognition of an initial problem state and solution, and 3) the operators used to move across states to create the problem solution [15]. The amount of this related information, as well as the ease with which individuals can discover it, help dictate how difficult the problem will be to solve, especially for novices.

The last attribute of problem solving is the various individual differences that exist between problem solvers. For instance, researchers have identified several personal traits that showed evidence of influencing the ability to solve problems. One factor that is believed to have a strong correlation to problem solving is the amount of knowledge one has in the domain(s) in which the problem is situated. The more concepts an individual understands with respect to a domain, the more likely they can solve problems in that domain. In addition, individuals need to understand how these concepts are interrelated, which is also known as structural knowledge [17]. Another important attribute is the amount of experience an individual has with respect to solving the type of problem being evaluated. One would expect individuals to develop schemas relating to a particular problem type as they encounter more instances of that problem [18].

Thinking and reasoning skills are another individual difference that may influence one's ability to solve problems [6]. These skills operate under the influences of cognitive controls, which include field independence, cognitive complexity, cognitive flexibility, and category width. As these controls become more advanced, so should the problem-solving skills of individuals. The last factor is epistemological beliefs, defined as the views on knowledge [19] that an individual possesses. There are several models of epistemological beliefs [20]–[24] and a majority of them operate under the assumption that beliefs go from having a dualistic belief of right and wrong to a more relative view where knowledge is context-driven and individuals are the makers of meaning. A relativistic view can be useful for ill-structured problems as they require justifications for the different decisions made while problem-solving [6], [21].

Many researchers across multiple disciplines have tried to measure the effect of individual differences on problem-solving skills for STEM students [25]. For example, there have been multiple studies looking at the effect of prior experiences on problem solving skills and techniques [26], [27]. Litzinger et al. found evidence that engineering students with stronger problem solving skills relied more on reason than memory when solving statics problems [28]. Research looking at cognitive controls and problem solving has also found that individuals who are more field independent [29] as well as have more cognitive complexity and flexibility tend to be better problem-solvers. Most of the previous work on epistemological beliefs has looked at the epistemological development of students during the academic career in various STEM disciplines [30]–[33], or compared the epistemological beliefs of STEM students to those in the humanities [34]–[37].

Yet despite both this growing body of research the importance of problem solving capabilities for practicing engineers, there is growing concern from both educators and industry that engineering students are graduating without the ability to solve problems that they will encounter in the workplace [2]. One potential reason for this gap is that educators have long assumed that the problem-solving skills that students develop in school will be applicable to the problems they will encounter in industry. However, most problems that students encounter in a formal education environment are well-structured, while the problems in the workplace tend to be ill-structured in nature [14], [38]. This can be problematic for students as each type of problem requires its own set of problem-solving skills in order to solve them [39].

1.2. Statement of the Problem

If educators want to improve the ability of engineering students to solve ill-structured problems, one potential approach would be to focus on developing the internal attributes of individuals that have been found to have an influence on problem-solving abilities. In order to accomplish this, it is important to understand how these attributes develop and what factors play a part in that development. Of these attributes, one that has not received a lot of focus is the epistemological beliefs of engineering students and its development. This is surprising given that one of the most prominent research agendas for the field of engineering education includes the epistemology of engineers as one of five strands of research that could have a transformational impact in how we recruit and educate engineering students [40].

When researchers have examined the epistemological beliefs of engineers, they normally have been part of studies that look to compare "hard" (i.e. mathematics, engineering) and "soft" (i.e. psychology) majors according to Biglan [41]. Even when researchers focused only on engineers, they looked at engineering as a whole instead of looking at specific engineering disciplines [34], [42], [43]. This approach leaves an incomplete picture, as there may be subtle differences within the different engineering majors that may cause variations in epistemological development. In addition, researchers have really only begun to focus on how different environments and contexts may impact on epistemological development, particularly with respect to engineering epistemology research. Exploring these effects could give educators a better understanding of how student differences influence engineering epistemological beliefs and potentially improve engineering courses, pedagogy, and curricula by including different aspects of epistemological development.

1.3. Purpose of the Study

To fill this research gap, a cross-sectional, quantitative research study with a quasi-experimental design was developed to evaluate the epistemological beliefs of electrical and computer engineering (ECE) students. The beliefs were measured using the Learning Environment Preferences (LEP) Inventory [44], which measures epistemological beliefs with respect to Perry's Scheme of Intellectual and Ethical Development [20]. The LEP results were used as part of a modified version of the Theory of Integrated Domains in Epistemology (TIDE) framework [45], which describes epistemological development within various contexts (sociocultural, academic, and instructional). This study expanded the TIDE framework to include an industrial context to account for the environments in which engineering students are immersed when completing internships, co-ops, and other relevant employment opportunities. Potential influences from the TIDE contexts were captured using a background survey and used with the LEP results to examine the potential impacts of these contexts. In addition, the study investigated the relationship between the students and the engineering learning environment by examining the learning preferences of electrical and computer engineering students with respect to Felder and Silverman's model of learning styles [46] using the Index of Learning Styles (ILS) [47].

1.4. Definition of Terms

The following definitions were used for this study:

Domain is a body of knowledge relating to a subject consisting of conditional, procedural, and declarative knowledge [45].

Domain-general is an epistemological concept where an individual's beliefs and justifications of knowledge are consistent across subjects [24].

Domain-specific is an epistemological concept where an individual's beliefs and justifications of knowledge differ in terms of their complexity across domains [24].

Dualism is an epistemological position where all knowledge is considered to be known and concrete. Any views that contradict knowledge the be are considered to incorrect [20].

Engineering epistemology is the nature of the technical, social, and ethical aspects of engineering thinking and work within social contexts [40]. It centers on questions of what counts as engineering knowledge

Epistemology is the study of how people view and justify knowledge [19].

Intellectual Development is the evolution of an individual's epistemological beliefs with respect to their complexity over time [20].

Learning Preferences are the preferred methods of individuals to obtain and interact with knowledge [48]. For example, an individual may prefer to new information to be presented as images and charts instead of words

Multiplicity is an epistemological position where knowledge is no longer believed to be concrete. In the cases where knowledge is unknown, different views may be acceptable [20].

Relativism is a position where knowledge is considered to be context-based and relative. Individuals see themselves as sources of knowledge and create views based on evidence [20].

1.5. Thesis Overview

Chapter 1 has provided some background on this research and presents the research objectives. Chapter 2 discusses the background literature with respect to this subject matter. Chapter 3 presents the methodology and methods of the study. Included are the justifications for the methodology as well as descriptions of the various inventories used in the study. Chapter 4 presents the results of the study and discusses some of their potential implications. Chapter 5 summarizes the study, its implications, and suggests some ideas for future research.

2. LITERATURE REVIEW

In 1970, William Perry released his model of intellectual and ethical development based on a 15-year study that examined the educational experiences of university students [20]. This model was the beginning of a series of investigations into the nature of epistemological beliefs and how they develop. In subsequent decades, several more models have been developed to describe epistemological development. This literature review will discuss some of the frequently cited epistemological belief and development models.

In addition, the review will explore some of the prominent models with respect to learning preferences. Researchers have long believed in a link between epistemological development and learning[49], and some have even included aspects of learning in their models[22], [23]. Since this study also looked to expand the understanding of the relationship between epistemological beliefs and learning through learning preferences, a review of learning preference models commonly used in engineering are also included in this chapter.

2.1. Epistemological Development Models

The first category of literature to be discussed in this chapter centers on models of epistemological development. These models normally consist of well-defined sequential stages and have been especially influenced by the pioneering work of William Perry [20]. Over the past fifty years, researchers have developed several domain-general models, which are normally grouped into three categories: 1) those that infer beliefs through educational experiences [20], [22], [50]; 2) those that focus on how epistemological beliefs influence thinking and reasoning processes with respect to problem solving [21],

[51]; and 3) those that view epistemological beliefs as a multidimensional construct [23], [24]. This chapter will discuss different models from each of these three categories.

2.1.1. Educational experience-based epistemological models

Perry's Scheme of Intellectual and Ethical Development

A group of researchers at Harvard University led by William Perry set out to document student experiences within the relativistic environment that exists within intellectual and social atmospheres of college through a two-step experiment [20]. The first step consisted of the development and the implementation the Checklist of Educational Views (CLEV) instrument. This inventory, based on the Adorno's et al. [52] research on the authoritarian personality, consisted of a series of statements where an individual expressed how much they agreed with each statement and were assigned a score based on their responses. 313 freshmen students attending either Harvard University or Radcliffe University completed the CLEV in the fall of 1953 and the spring of 1954. The second step consisted of Perry selecting a subset of students to take part in a series of interviews where they would discuss their educational experiences. These interviews were conducted in an open-ended manner in order to limit the researcher's influence on participants' responses. Participants were interviewed at the end of every academic year until they graduated. Of the 55 students that were chosen to participate in this part of the experiment, 31 (27 men, 4 women) agreed.

During the evaluation of the interviews, Perry and his team noticed a natural progression with respect to participants' views on knowledge and the role their professors have in shaping these views. This progression led Perry and his team to translate these responses into a scheme to represent this progression. Perry then repeated the procedure in 1958 and 1959 with another 109 students in order to validate his initial findings. The final result was a nine-stage model that also described the transitional process between stages. The first five positions described the intellectual development of students with respect to how they view knowledge and its sources. The last four stages shifted to ethical development with respect to classical Greek views on existence in a relativistic world [53]. Over time, the nine positions have been clustered into four groupings:

Dualism (Positions 1-2), Multiplicity (Positions 3-4), Relativism (Position 5-7), and Commitment within Relativism (Positions 7-9) [53]. Descriptions of the positions are given below:

Position 1: Basic Dualism

In this position, all knowledge and truth is considered to be either right or wrong. Authority figures and absolutes are the infallible sources of knowledge and every problem has a concrete solution. In an academic setting, the objective of the individual student is to extract knowledge and meaning from the authority figure. This position was a hypothetical extension of the model as Perry never measured an individual at this position [20], [49].

Position 2: Multiplicity Pre-Legitimate

In the position, views of knowledge and the roles of authority figures do not change. Individuals at this position start to perceive the concept of multiplicity, defined as multiple perspectives with respect to knowledge and truth that are considered to be valid [20], but its implications are not comprehended. Instead, multiplicity is perceived as what Perry referred to as either Alien or Opposition [20]. When viewed as Alien, multiplicity is either assimilated into the individual's dualistic perception or to their perception of authorities. Individuals who view multiplicity as Opposition see it as an obstacle that authorities place in front of the truth.

Position 3: Multiplicity Subordinate

Multiplicity views expand in this stage of development as some of its implications are incorporated into knowledge frameworks. Some knowledge is now viewed as unknown, but it is because authorities have yet to find the answer. Individuals in an academic setting operate under the directive of determining what authorities want.

Position 4: Multiplicity Correlate/Relativism Subordinate

At this position, individuals begin to create rationales for multiplicity. In his study, Perry [20] found two paths that one may take when transitioning from multiplicity to relativism. In the multiplicity correlate path, individuals reorganize their dualistic perspective to consist of their original right/wrong perspective vs. multiplicity. Knowledge falling in the multiplicity category may not have an absolute explanation; therefore, all possible opinions and explanations are feasible [53]. All aspects of multiplicity are now viewed as relevant.

Those that take a relativism subordinate path, on the other hand, begin to recognize relativism through the multiplicity of authorities. They see that authorities can make decisions within multiplicity through comparison of different opinions or methods. Relativism is viewed as the way authorities want them to think instead of as an effect of the nature of all knowledge [20].

Position 5: Relativism Correlate/Competing/Diffuse

At this position, individuals move from viewing all knowledge within various dualistic structures to a relativistic structure. They take on the role of being active makers of meaning and knowledge. Authorities lose their place as unquestioned sources of knowledge. There are also three sub-categories of individuals at position 5: relativism correlate, relativism competing, and relativism diffuse [20]. The relativism correlate form divides knowledge into two worlds: one where knowledge is known and can be gained from authorities and one where a relativistic approach must be used to create knowledge. A relativistic view of knowledge is applied to all knowledge in the relativism competing form but it alternates with a previous view of knowledge. The relativism diffuse form just uses the relativistic view of knowledge but there is no implication of commitment.

Position 6: Commitment Foreseen

With this view comes an understanding that an individual will constantly contend with uncertainty. In order to deal with the possible disorientation of uncertainty, one begins to see that they may need to make commitments to certain aspects of knowledge within the relativistic world.

Positions 7-9: Initial Commitment, Orientation in Implications of Commitment, and Developing Commitments

When individuals reach these positions in the scheme, there are no more structural changes with respect to how individual view knowledge and the focus shifts on the development of one's commitments to relativism. In the initial commitment position, the first commitments are usually made with respect to some important area of their life like their career. As one gains experience with commitments, they begin to realize the implications that come with the commitments. The individual begins to sense an identity in their commitments and their style of how to address commitment. They also begin to view themselves as authorities in the areas where they have made commitments. This marks a transition to the eighth position, called orientation in implications of commitment.

Eventually, the individual gains enough experience to feel a level of comfort with their commitments and their style of developing them to reach the ninth and final position, developing commitments. There is a balance between acting and reflecting on commitments. The experience also shows that commitments will constantly need to be altered as one continues to grow.

Perry assumed that growth along the scheme happens in surges in a wavelike pattern. Yet for some individuals, development with respect to the scheme does not always occur in a positive direction. Students could show no growth or even revert with respect to the complexity of the beliefs. To account for this, Perry included three concepts to account for this behavior: temporization, retreat, and escape [20]. Description of each are given below:

Temporization – Perry [20] defined temporization as occurring when epistemological development stagnates for longer than a full academic year. It can occur at any stage within the scheme and may happen for several reasons. For example, sometimes the individual is undergoing a period of what Perry [20] called lateral growth, where they examine the implications of their current position. Other times the person is not prepared to take the next step in the scheme.

Retreat - When moving along the early positions of the scheme, individuals are exposed to increasingly complex views and their implications. This exposure can lead one to reject growth and regress to a previous position. This is known as retreat. Retreat from a relativistic position back to multiplicity is justified because "there is no one to argue with; everyone has a right to their own opinion" [20, p. 183]. Retreat to dualism requires there to be an entity that is the focus of the rejection. Perry [20] suggested that in the early stages of the scheme, individuals keep a distance from those who provide false knowledge. Progression into higher positions brings these others into the view of the individual. When retreat occurs, the individual either adheres to authority and rejects complexity or opposes authority and opposes all that it stands for.

Escape - In positions 4-6, the realization of relativism allows individuals to detach from a context in order to observe it objectively. Sometimes individuals take advantage of the detachment and completely avoid the responsibility that is required in a relativistic world. This concept is known as escape. Escape is usually a progression from temporizing, with two paths that one can take: dissociation or encapsulation [20]. On the dissociation path, the individual abandons their responsibility of being an active maker of knowledge. In encapsulation, a person seals him or herself from growth by losing themselves in the doing of assignments. By doing this, authorities retain their responsibility with respect to being makers of knowledge. Though possible at any of the three stages, dissociation usually occurs within multiplicity where encapsulation occurs in relativism [49].

Women's Ways of Knowing

Though Perry's study was groundbreaking with respect to the epistemological beliefs of individuals, it received a fair share of criticism. One of the biggest complaints was the lack of female responses used for the justification of the model [24]. Perry only included two female participants despite his assertion that all of the female participants responses mapped to the model. In order to investigate whether there was a gender difference for epistemological beliefs, researchers began to repeat the study in order to better include the epistemological perspectives of women. Belenky et al. [50] conducted one of the more prominent of these studies in the 1980s. In addition to trying to repeat the results reported by Perry [20], the goal of the study was to gain insight into the how women develop the idea of "self". This led the researchers to only include women as participants in the study.

The group interviewed 135 women from two "collegiate" settings. Ninety of the participants were either currently in or had recently graduated from six educational settings that ranged from an inner-city high school to a prestigious women's college. The other 45 participants were from family agencies that supported women with raising their children, referred to by Belenky et al. as "invisible colleges" [50]. As in Perry's study [20] , the individuals were asked a series of questions about their experiences. In addition, the researchers also included sections on gender, relationships, education and ways of knowing based on the framework of Gilligan [54] and Kohlberg [55]. Unlike Perry, the study had a cross-sectional design, meaning that the participants were interviewed once at a specific point in time with respect to the educational level.

Analysis of the interviews suggested that Perry's scheme did not fully explain some of the differences they found in the participants' responses [22]. This led Belenky et al. to develop a new model of epistemological development known as the Women's Way of Knowing [50]. The model consists of five perspectives and seemed to suggest that individuals would progress through the perspectives in a linear fashion [24]. The five perspectives are: 1) Silence, 2) Received Knowledge, 3) Subjective Knowledge, 4) Procedural Knowledge, and 5) Constructed Knowledge. Descriptions of the stages are discussed below:

Silence

Individuals at this stage are usually the most socially, educationally, and economically deprived. They are disconnected from the outside world and listen only to external authority [56].

Received Knowledge

Women in this stage believe that knowledge is either completely true or it is believed to be completely false. All knowledge is derived from outside sources. They believe that they have the same perspectives as their friends and may subconsciously adapt their thinking to that of their friends. Authorities have the role of providing the right answers.

Subjective Knowledge

Women in this stage take ownership of knowledge with respect to its origination, though it is still viewed as true or false. Like the individuals in Perry's scheme who are in the multiplicity stages, differing opinions are allowed in situations where knowledge is unknown [56]. Authorities may have the right answer, but are questioned and sometimes rejected. Women with a subjective perspective tend to rely more on personal experiences and intuitive reasoning for justification instead of logic, analysis, and other perceived methodologies typically used by men.

Procedural Knowledge

At this stage, knowledge is no longer seen as black and white. Instead of relying on intuition, knowledge is formed through an objective analytical process where multiple positions are considered. The positions are ranked with respect to the evidence supporting them. Individuals are split into two groups at this stage: separate knowing and connected knowing. Those in the separate knowing category took an impersonal approach in their thinking to match the authorities they interacted with in college. Connected knowing relies more on understanding other opinions through empathy.

Constructed Knowledge

In this stage, knowledge is contextual and is constructed by the individual by integrating subjective and objective knowing. The individual's own assumptions about knowledge are now important and are constantly being evaluated and reevaluated. The expertise of authorities is now evaluated and those who "reveal an appreciation for complexity and a sense of humility about their knowledge" [50, p. 139] are included when constructing knowledge.

While these findings have proven noteworthy and influential, there were some serious criticisms of the interviewing methods used in the study. The women in the academic settings were asked questions with respect to conceptions of knowledge while those in the invisible college were asked about expertise[50]. This made it difficult to draw conclusions about any differences that may have arisen from this difference in questioning. Also, the ordering of the different sections of the interview may have affected their finding on women having a "relational, connected approach to knowing" [24, p. 96]. Despite this, The Women's Way of Knowing gave new insights into the epistemological view of women, especially with respect to how they view the sources of knowledge.

Model of Epistemological Reflection

Another focus of researchers following the publication of Perry's work centered on the method of evaluating intellectual development among students and other individuals. Researchers began developing pen-and-paper inventories to serve as an alternative to interviews to assess an individual's epistemological position. Among this group was Baxter Magolda, who developed the Measure of Epistemological Reflection (MER) [57], [58]. The MER had individuals complete short essays on the role of the instructor, learner, peers, and evaluation in learning, as well as the nature of knowledge and educational decision-making. Also around this time, Belenky et al. [50] introduced the Women's Ways of Knowing model. Baxter Magolda noticed that their study had run into the same issue, namely of responses not relating to the stages of Perry's scheme.

In order to account for this discrepancy, Baxter Magolda designed a two-phase longitudinal study looking at the student's experiences. The first phase focused on the progression of epistemological views during college. Baxter Magolda started with 101 students (50 males, 51 female) from a large, Midwestern liberal arts university. The epistemological beliefs of the participants were obtained in two ways. The first was through semi-structured interviews that focused on six areas: 1) their own roles as learners, 2) role of instructors in learning, 3) role of peers in learning, 4) nature of knowledge, 5) perception of the evaluation of their work, and 6) educational decision-making. The second was an inventory that Baxter Magolda developed called the Measure of Epistemological Reflection (MER). The participants completed both methods yearly until they graduated. In Phase II, Baxter Magolda wanted to examine epistemological beliefs outside of the university setting. Seventy of the participants from Phase I agreed to also participate in Phase II. Participation continued to consist of the completion of a yearly interview and the MER. The interviews were more conversational in tone and focused on what participants deemed to be significant learning experiences and ways to assess their thinking. The MER was also modified to account for participants no longer being in the undergraduate educational context.

Responses were analyzed using a grounded theory methodology, which is a generalized method of comparative analysis that allows researchers to extract theory from that data collected in social research [59]. The results led to the creation of the Model of Epistemological Reflection (MER), which was comprised of four stages: 1) Absolute Knowing, 2) Transitional Knowing, 3) Independent Knowing, and 4) Contextual Knowing. Like other epistemological development models before it, MER consisted of a series of stages that individuals progressed through. Unlike Perry [20], Baxter Magolda also looked to see if there were any patterns that occurred inside the stages. The patterns that were found were not necessarily restricted to, but tended to fall along gender lines [60]. Descriptions of the stages and these patterns are given below:

Absolute Knowing

Individuals at this mindset operate under the assumption that all knowledge exists is some absolute form and uncertainty happens only when the answer is not known to them [22]. The role of authority figures is to express knowledge to individuals in ways they can understand. Peers are not sources of knowledge but can express that which they have learned from other authorities. Women at this stage tend to prefer the receiving pattern where individuals resorted to listening and recording information to acquire knowledge and preferred to operate in a relaxing environment where peers were supportive while asking questions. Men usually used the mastering pattern where they wanted to be actively involved during knowledge acquisition and liked to debate and quiz their peers in order to achieve mastery[60].

Transitional Knowing

In the transitional knowing phase, individuals became aware that knowledge in some fields was not certain. Due to the uncertainty, there is a shift from acquiring knowledge to understanding it. Authorities should help with this understanding usually through application knowledge to life. Peers take a more active role in this process since understanding needs more exploration.

Women at this stage usually operate with what Baxter Magolda called the interpersonal pattern [22]. Interpersonal pattern knowers tend to diverge from authority figures and focus on relationships while they try to understand knowledge. They connect with the subject matter and others to understand knowledge, want to share their views of knowledge with others, and lean on their own personal judgment to decide on their own opinions. Men on the other hand preferred the impersonal pattern. Impersonal pattern knowers remain close to authority figures and prefer individual learning. They prefer to keep the subject matter and others at a distance while trying to understand, focus on defending their views, and using logic to justify opinions. Peer opinions are only considered if the peer has been elevated to the status of an authority.

Independent Knowing

At the stage of independent knowing, uncertainty plays a larger role in how knowledge is viewed. Differing views of authority figures correlate to a variety of possible views in an uncertain world. Individuals now see themselves as authority figures and their opinions of knowledge have merit. The purpose of authority figures is to provide context for individuals to explore knowledge instead of knowledge itself. Peers now serve as sources of knowledge and share their own opinions of knowledge.

The patterns in this stage are the interindividual pattern which women favored and the individual pattern which men favored. These patterns are extensions of those from previous stages (receiving and interpersonal for interindividual; mastery and impersonal for individual). The major change for interindividual pattern knowers is that they finally find their voice among their peers and authority figures. In contrast, individual pattern knowers adjust to accept the voices of their peers on the same level as their own.

Contextual Knowing

Knowledge is now created and viewed by judging varying perspectives inside a context. Judgments of existing knowledge are now weighed and ranked in order to construct one's point of view. Peer opinions and views have more weight, but only those that the individual views to be credible. Authority figures and students now critique each other with respect to their views in order to continue to fine-tune them. Gender-related patterns from previous stages now merge into one in the contextual knowing stage [22].

Baxter Magolda's work on the model of Epistemological Development expanded upon the work on Perry [20] and Belenky et al. [50] by evaluating gender differences in epistemological development within a gender-balanced population. Yet as in Perry's research, the population of the study lacked diversity with respect to race, culture, and the academic fields of the participants [24].

2.1.2. Thinking and reasoning epistemological development models

Reflective Judgment Model (RJM)

Instead of looking at educational experiences, King and Kitchener chose to incorporate Dewey's [61] work on reflective thinking in order to explore the link between epistemological beliefs and justification. They eventually expanded their research to include epistemological beliefs as a part of the cognitive process used to solve everyday, ill-structured problems [62]. Using Perry as a basis, King and Kitchener looked to model the progression of reflective judgment with respect to epistemological beliefs and how they justify knowledge. They reviewed and incorporated findings from other previous work on reflective judgment and epistemological development [63]–[66].

The result was a seven-stage model which King and Kitchener called the Reflective Judgment Model (RJM). While each stage was not given a specific name, the stages have been grouped into three categories of reasoning: 1) Pre-reflective, 2) Quasi-reflective, and 3) Reflective. Descriptions of the stages with respect to individuals' beliefs of knowledge and their justification of knowledge are given below:

Pre-Reflective Thinking Stages

Stage 1: Knowledge is viewed to be concrete and unchanging. Anything that can be seen or perceived is believed to be true. Knowledge does not need to be justified because what is believed to be true must be true. This is a theoretical stage, as King and Kitchener never evaluated anyone at stage 1 in their studies.

Stage 2: Knowledge is still considered to be absolute, but it just might not be immediately available. Individuals at this stage begin to recognize differing views of knowledge, but they are justified by categorizing them as incorrect. Knowledge is justified by comparing them to the views of those considered to be authority figures.

Stage 3: Individuals in this stage recognize that there are some areas where knowledge is uncertain even for authorities. Knowledge is justified by authorities or from the accumulation of evidence. Individuals choose what they want to believe in order to justify unknown knowledge until evidence becomes available.

Quasi-Reflective Thinking Stages

Stage 4: Knowledge is no longer viewed as absolute and there are several possible explanations for all knowledge. Differing views cannot be compared with respect to which is correct due to uncertainty. Individuals justify one's views with evidence, but the process of choosing what evidence is used is individualized.

Stage 5: Knowledge is viewed to be contextual and subjective in this stage. The perspective and the "rules of inquiry" relating to the perspective of the individual shapes how knowledge is justified.

Reflective Thinking Stages

Stage 6: Objective knowledge is no longer seen as attainable because all knowledge is influenced by the individual's own interpretations and perceptions. Individuals take an active role in the construction of any claims about knowledge. Knowledge is constructed through a generalized process of comparing evidence and differing opinions the individual views as credible.

Stage 7: Knowledge is the by-product on an ongoing process of "reasonable" inquiry. The process may lead in incorrect claims about knowledge since the process is imperfect. Justification of knowledge comes from a general methodology of evaluation, but the criterion may change from subject to subject.

A common critique of models that have used these kinds of stages or positions is that participants are viewed with respect to a simple stage model where they are associated with one position. Yet a review of data from King and Kitchener's [62] original study showed that individuals could hold assumptions across multiple positions at the same time. Rather than a simple lock-step progression, epistemological beliefs may progress in a wavelike manner that can include multiple stages.

In addition to the RJM, King and Kitchener developed a semi-structured interview format known as the Reflective Judgment Interview (RJI) to assess one's reflective judgment [21]. The interview consists of a set of ill-structured question, usually corresponding to one of four domains: science, current event, religion and history. After each problem is presented, a trained interviewer asks a series of follow-up questions designed to explore how the participant is justifying their positions. The responses for each dilemma are then evaluated and assigned a position within the model. The positions are then averaged to represent an individual's overall position.

There have been several cross-sectional and longitudinal studies conducted by King and Kitchener and others over the past 30 years to justify and enhance the RJM[21]. The results show that on average, individuals progress less than half of stage from their first year (3.6) to graduation (4.0). This progression is slightly larger for graduate students (4.6 to 5.3).

A critique of the RJM is the inconsistency with respect to gender differences. A little more than half of the studies conducted by King and Kitchener found no gender differences, while others suggests that males may more advanced beliefs according to the RJM [21]. Also, most of studies have been conducted on Caucasian college students in the U.S., so it is not known how much this model is applicable in other contexts.

Argumentative Thinking

Many of the earlier studies conducted in epistemological development focused on the beliefs and thinking of students in a college setting. Interested in how people think on an everyday basis, Kuhn focused on a theory of argumentative thinking that was based on philosophical theories and concepts drawn from Plato, Socrates, and Aristotle [51]. Kuhn also believed that epistemological beliefs played an underlying role in an individual's argumentative thinking, even if the individual was unaware of such beliefs.

To further explore argumentative thinking and the associated role of epistemological beliefs, Kuhn conducted a study with 160 participants. Like Belenky et al. [50], Kuhn was interested in the development of epistemological beliefs over an individual's lifetime. To do this, Kuhn evenly split the individuals interviewed across four age groups: 1) teens, 2) twenties, 3) forties, and 4) sixties. Each participant underwent two sessions of interviews. The first session had participants look at three social issues: 1) unemployment, 2) children failing in school, and 3) individuals returning to crime after being released from prison [51]. The interview consisted of five segments for each topic: 1) explain the causes of three issues of varying degrees of expected knowledge, 2) justify their positions, 3) develop a counterargument to their position, 4) suggest a solution to the issue, and 5) answer questions about their epistemological beliefs and perceived amount of knowledge they held on the given subject [51]. The second session had individuals evaluating evidence from scenarios based on the crime and school topics.

The results of the study suggested that individuals fell into three categories based on their epistemological beliefs: 1) Absolutists, 2) Multiplists, and 3) Evaluativists. The structures and characteristics of individuals in these categories are similar to previous models and studies of epistemological belief [20], [21]. Absolutists believe that experts have and can possess with enough effort all knowledge and that their views are irrefutable. A majority of absolutists see themselves at or below the knowledge levels of experts and can possess contradictory views on divergent beliefs. For multiplists, expert certainty is dismissed and devalued, and individuals now view their own certainty either on the same level as or greater than experts. Knowledge goes from being facts to ideas, which do not need to be proved and feel like personal possessions. Multiplists allow for the existence of multiple viewpoints that can be viewed as legitimate. Like muliplists, evaluativists reject the concept of certain knowledge. Evaluativists have less certain beliefs than experts, allowing them to compare multiple viewpoints and rank them based on their merits. Because of their openness to viewpoints that may differ from their own, evaluativists may change their own perceptions based on differing view if evidence supports it.

2.1.3. Multidimensional epistemic belief models

Schommer's Dimensions of Epistemic Beliefs

By the mid 1980's, researchers investigating personal epistemology began to explore its impact on other constructs. One of the topics investigated during this time was the effect of personal epistemology on student comprehension. Previous research looking into the relationship using Perry's model produced mixed results [67], [68]. The lack of consistency led Schommer to believe that the one-dimensional views of Perry's scheme on the nature of knowledge were incomplete. Several independent dimensions would be needed in order to fully encapsulate the complexity of one's epistemic beliefs [23].

For her model, Schommer [23] settled on five dimensions based on previous research. The dimensions of Omniscient Authority ("Knowledge is handed down by authority instead of derived by reason"), Certain Knowledge ("Knowledge is certain instead of tentative”), and Simple Knowledge (“Knowledge is simple rather than complex”) are derived from Perry’s [20] original study. Quick Learning (“Learning is quick or it does not happen at all”) comes from Schoenfeld’s [69] work with high school students. The Fixed Ability (“The ability to learn is innate rather than acquired”) dimension came from the work of Dweck and Leggett [70] on the nature of intelligence.

In order to validate her proposed model, Schommer conducted two experiments. The first experiment looked at the epistemic beliefs of 117 junior college and 149 undergraduate students. Unlike a majority of the epistemological belief research of the past, Schommer took a more quantitative approach in measuring beliefs. Participants completed an epistemological questionnaire that Schommer developed. The questionnaire consisted of 63 items that participants rated on a scale of one to five based on the degree of their agreement. The items were split across 12 subsets used to assess the five proposed dimensions. The results were evaluated using factor analysis across twelve subsets of the items. The second experiment had 85 of the junior-college students read passages at home dealing with two domains: psychology and nutrition. The following day, students completed four tasks for each passage: 1) written conclusions, 2) a mastery test, 3) survey of prior knowledge, and 4) a confidence rating. Results were examined using a regression analysis with respect to demographic information obtained during experiment one. Four of the five dimensions (Quick Learning, Certain Knowledge, Innate Ability, and Simple Knowledge) were found to have some type of impact of comprehension.

While Schommer’s work has been very influential in the area of epistemological beliefs, it also has been subject to several points of criticism. Researchers have questioned the inclusion of the Fixed Ability and Quick Learning dimensions as they describe the nature of intelligence and learning respectively. Also, there have only been a few studies that have had items load onto the Omniscient Authority dimension [34], [71]–[73]. As for the measurement tool and its analysis, critics have suggested that several of the items used in the assessment tool may not have any relevance with respect to epistemological beliefs [24]. In addition, the items have only been analyzed with respect to the subsets so it is unknown if all 63 items would load onto the proposed dimensions.

Hofer's Model of Epistemological Beliefs

Interested in the commonality of dimensions expressed in different epistemological development models, Hofer [24] performed a detailed analysis of the epistemological models of Perry [20], Belenky et al. [50], Baxter Magolda [22], King and Kitchener [21], Kuhn [51], and Schommer [23]. She found several points of convergence in the models with respect to the dimensions of personal epistemology, which prompted her to propose a new model of epistemological beliefs [74]. Since Hofer was only concerned with personal epistemology, she ignored the dimensions relating to learning, college experiences, and intelligence. This left four dimensions to serve as the basis for a new model: 1) Certainty of Knowledge, 2) Simplicity of Knowledge, 3) Source of Knowledge, and 4) Justification of Knowledge became the basis for Hofer's Model of Epistemological Beliefs [24]. Hofer grouped the dimensions into two categories: Nature of Knowledge (Certainty of Knowledge and Simplicity of Knowledge) and Nature of Knowing (Source of Knowledge and Justification of Knowledge). Descriptions of the dimensions are given below:

Nature of Knowledge

Certainty of Knowledge describes how individuals view knowledge. Individuals in the lower levels of this dimension believe knowledge is fixed and exists with certainty and those in the higher levels believe knowledge is fluid and ever-evolving [24].

Simplicity of Knowledge describes the structure of knowledge. At lower levels, knowledge is viewed as an accumulation of facts that are discrete, concrete and knowable. Those at the higher end of the spectrum view knowledge as a web of related concepts that should be viewed as relative, contingent, and context-bound [74].

Nature of Knowing

Source of Knowledge describes derivation of knowledge and its meaning. Individuals in the lower levels believe that the origin of knowledge exists outside of oneself and resides with authority figures that transmit the knowledge to them. In higher levels, individuals take responsibility for the creation of knowledge and view themselves as sources of knowledge [24].

In the *Justification for Knowing* dimension, Hofer discusses how individuals evaluate knowledge claims. In lower levels, individuals use observation or authority figures to justify knowledge. If the individual believes that the answer is uncertain, then any explanation could work. At the higher end of the dimension, individuals perform their own inquiries and evaluate the opinions of experts to create their own justifications of knowledge [74].

To test the validity of the model, Hofer conducted a study with 326 1st year psychology students who completed two inventories. The first was Qian and Alvermann's [72] General Epistemological Beliefs Questionnaire (GEBQ). The GEBQ is a shortened version of Schommer's Epistemological Beliefs Questionnaire that included items that loaded well to the various dimensions of epistemological beliefs. The second questionnaire was the Discipline-Focused Epistemological Beliefs Questionnaire which Hofer devised [74]. Both questionnaires had participants rank a series of statements on a Likert-scale from one to five based on how much they agreed or disagreed with the statement.

The responses to the questionnaires were analyzed using factor analysis. The Certainty of Knowledge and Simplicity of Knowledge dimensions seemed to merge into a singular dimension. There was also evidence of a new dimension that corresponded with an individual's ability to eventually find the answer to unknown problems, which Hofer labeled Attainability of Truth [74]. While Hofer [74] found some evidence of an underlying dimensionality across domains, individuals appeared to possess domain-specific beliefs.

2.2. Assessment of Epistemological Beliefs

As suggested by the preceding review of literature, one of the biggest pitfalls in epistemology research is the process of assessing participants' beliefs [24]. Many epistemological beliefs are not readily available because they are not regularly discussed or are entangled with beliefs of other constructs such as learning [75]. The extant literature reveals two primary ways that researchers have gone about assessing epistemological beliefs: interviews or pen-and-paper assessment tools [76].

Most studies that use interviews to obtain an individual's epistemological beliefs typically mimic Perry's study. The interviews are typically loosely structured and consist of open-ended questions that are designed to identify an individual's beliefs and their reasoning for having them. The questions are either about the experiences of the individuals [20], [22], [50] or involve a series of ill-structured problems [21], [77]. The individuals conducting the interviews and evaluating the responses to assign a position normally have been trained to do their task.

The pen-and-paper assessment tools usually come in one of two formats. The first has individuals write out responses in the form of essays. The topics of the questions can range from their ideal learning environment to how they make decisions [76]. The length is up to the participants and they can provide as much detail as they wish. An example of this type of inventory is the Measure of Intellectual Development (MID) [78], [79]. The other type of pen-and-paper assessment tool has individuals rate their agreement with a series of statements designed to represents different levels of epistemological beliefs with respect to a Likert-scale. Examples of this type of assessment tool include the Learning Environment Preferences Inventory (LEP) [80], the Schommer Epistemological Questionnaire (SEQ) [23], and the Epistemic Belief Inventory (EBI) [71].

Many researchers believe that the interview format is the most effective way to measure one's epistemological beliefs [81], [82]. A major reason for this is the argument that the interview format allows for more insight into one's epistemological beliefs. However, the interview process can be difficult to implement [32] and the cost of properly training or hiring individuals to perform and evaluate the can be high in terms of both money and time [83]. Pen-and-paper instruments are easy to use to measure epistemological and are also significantly cheaper to analyze compared to interviews. This allows researchers to evaluate larger population sizes at a fraction of the cost of interviews. The pen-and-paper instruments also lend themselves to more effective quantitative analysis. The drawback of pen-and-paper measurements tools is that they tend to be conservative when used to measure the complexity of epistemological beliefs, which has led to low correlations between their results and those obtained through interviews [22], [100].

2.3. Previous Research of the Epistemological Development of Engineers

While engineering students have been included in the populations of prior studies [34], there are few instances where their epistemological development is focused on exclusively. These studies have either attempted to track development over the course a collegiate career, or to investigate development or to evaluate the impact of new programs and courses on engineers. This section will review these studies and discuss their implications.

2.3.1. Pavelich and Moore

Interested in the development of the ability of students to solve complex problems, Pavelich [30] conducted one of the first major study of epistemological development focused specifically on engineering students. The focus of the study was to examine how a highly experiential curriculum would impact epistemological growth. Pavelich chose Perry's scheme to represent the participants' epistemological beliefs because it "spoke directly to the perspective an individual uses to solve real-world, open-ended problems" [30, p. 451].

With the help of Moore, Pavelich designed a cross-sectional study that consisted of interviewing students at three points in the academic progression: the beginning of their freshman year, the end of their sophomore year, and the end of their senior year. The interview was semi-structured and asked students to express their views on different topics such as their ideal learning environment and their decision-making process in unclear situations. The interviews were then evaluated and each participant assigned a primary and secondary position based on their responses. A total of 125 students (45 freshmen, 34 sophomores, and 46 seniors) from the Colorado School of Mines agreed to participate in the study.

The results of the study showed that students progressed one position along Perry Scheme over their college career on average [42]. This was significant because it represented atypical growth as compared to participants in previous studies on epistemological development [21]. However, only 25% of the senior participants were measured at Position 5 or greater while another one-third of senior participants were found to not have progressed to at least Position 4. This was of concern for the researchers because of their belief that engineering students needed to have a relativistic view of knowledge in order to consistently real world engineering problems [42].

2.3.2. Wise, Lee, Litzinger, Marra, and Palmer

In response to suggestions that engineering students were not prepared to solve the types problems they will encounter in the workforce [84], [85], faculty at Penn State developed a first-year design course in order to expose student to more project-based learning. As part of the larger evaluation process for this course, researchers wanted to compare the epistemological development of students who did and did not complete the course [86]. Like Pavelich and Moore [42], the study used Perry's Scheme [32] to model students' epistemological beliefs at the beginning, middle, and end of their academic careers, and used a semi-structured interview to assess their beliefs. Where the study differed was that it had a longitudinal design where the same students would be interviewed throughout the study. In addition, researched obtained characteristics such as gender, GPA, and co-op experience in order to compare the participants.

Over the course of four years, 220 students split across six cohorts participated in the study. Yet due to research design and attrition, only 21 of the participants completed all three interviews. The results of the study mirrored what Pavelich and Moore [30], [42] found with respect to the amount of epistemological development the participants underwent during their academic career. The results also suggested almost all epistemological development occurred during the second half of an engineering curriculum, which the researchers attributed to more chances for team-based project learning. The first-year project course was found to have an impact on epistemological development while the students were underclassmen, but the effect did not hold over the course the four years [43]. None of the individual characteristics were found to be significant, which the researchers attributed to the small number of participants who completed the study.

2.3.3. Culver, Cox, Sharp, and Fitzgibbon

As epistemological development research became more prominent, researchers began to examine individuals outside of the U.S. One of the first studies was conducted by a group led by Culver [31]. The group wanted to examine effectiveness of innovative engineering programs in mechanical and electrical engineering geared towards non-traditional students at a university in the United Kingdom. The researchers developed a pen-and-paper inventory called the Technical Student Learning Environment Preference (TSLEP) inventory to measure students' epistemological beliefs. The TSLEP is based on Moore's Learning Environment Preferences (LEP) inventory [44], [80], which measures beliefs with respect to Perry's Scheme [20]. In addition, the researchers had participants complete the Myers-Briggs Type Indicator (MBTI) [87] in order to measure how the personal style of students with respect to learning potentially affected their epistemological development.

The study consisted of two rounds of data gathering. The first round had 229 undergraduate (142 from the U.K., 87 from the U.S.) and 18 graduate students in the U.K. complete the TSLEP and MBTI. A review of results as well as discussion with participants led the research group to remove and reorder statements in the TSLEP. The second round of the study included another 254 students (190 U.K. undergrads, 7 U.K. graduate students, 57 U.S. undergrads). In addition, a subset of participants was selected to complete epistemological interviews in order to validate the results of the TSLEP. The results of the study suggested that students who are in programs that are tailored toward their personal style have more advanced epistemological beliefs. Culver et al. [31] also found a positive correlation between individuals positions measured by the TSLEP and the semi-structured interview, however the correlation was weak (r = .44).

2.3.4. King and Magun-Jackson

King and Magun-Jackson [88], [89] wanted to assess epistemological development of engineering students throughout their collegiate career. Unlike most of early studies examining the epistemological development of engineering students [30]–[32], [42], King and Magun-Jackson assumed that epistemological beliefs consisted of multiple, independent dimensions. This led them to use Schommer's model of epistemic beliefs to model students' beliefs.

The study had 518 engineering students who ranged in academic standing from incoming freshmen to doctoral students. The students came from three universities in Tennessee that varied in size and funding. The participants' epistemological beliefs were measured by having them complete Schommer's Epistemological Questionnaire (SEQ). In addition, the students completed a background survey that had them report GPA, gender, ethnicity, education level, and number of courses completed. After scoring the questionnaires, the results were then evaluated with respect to the individual characteristics to determine correlation with epistemological development. Overall, students' beliefs with respect to quick learning became more complex as they advanced from underclassmen to upperclassmen. King and Magun-Jackson [88] also found that male participants tended to have a stronger beliefs in quick learning and fixed ability than females, which matched results from previous studies.

2.3.5. Zhu

Like most fields of study, there is little published research that focused specifically on the epistemological beliefs of engineering graduate students. This is especially true with respect to international graduate students who are studying in the U.S. In an attempt to fill this gap, Zhu [90] conducted a study looking at epistemological beliefs of Chinese doctoral students. To ensure that the study would have a sufficient population size, Zhu sent recruitment emails to over 1,200 students from five universities located in the Midwestern United States, of which 147 responded.

The study had a mixed method design that consisted of a quantitative and qualitative study. In the quantitative study, participants complete three surveys: a modified version of Zhang's Cognitive Development Inventory (ZCDI) [91], the Knowledge Construction and Modification factor of the Epistemological Belief Survey, and a background survey. The results of the study suggested almost 80% of the participants could be considered to have relativistic or commitment epistemological belief. The study also found significant difference with respect to several individual differences such as the university the participant's attended and their academic progress in their doctoral program [90].

Based on the results of the quantitative study, Zhu then conducted semi-structured interviews with 19 of the participants in order to expand and verify the results found in the quantitative study. The results suggested interactions with advisors, professors, and their peers played a major role in forming relativistic beliefs. They also highlighted dealing with obstacles and failures as a component in shaping their beliefs.

2.4. Recent Trends in Epistemological Beliefs/Development Research

Schommer's work on the dimensionality of epistemological beliefs [23] renewed interest in epistemological beliefs and their development as a research topic of interest. A majority of the work in the past twenty-five years has focused on confirming if other previously held assumptions about epistemological beliefs remain valid. One such assumption is with respect to generality of epistemological beliefs. A majority epistemological belief models assumed that epistemological beliefs were domain-general, meaning an individual's epistemological beliefs were the same across all domains of knowledge [20]–[22]. Researchers began to doubt the generality of beliefs based on research that suggested that individuals maintained domain-specific realms of knowledge for different subjects [92]–[94]. This led to a number of studies that investigated whether this was also true for epistemological beliefs.

The design of the studies usually fell within one of two categories: between-subject and within-subject studies. A between-subject study examined the differences in epistemological beliefs between participants of different majors. When selecting majors to include in the study, researchers normally considered how majors were classified based on the categorizations of Biglan [41]. At least one major came from the "soft" category (i.e. psychology, history) and one came from the "hard" category (i.e. mathematics, engineering). Most of the studies found evidence suggesting that students in the soft majors had the more advanced views [34]–[36], [95]. Since these studies assumed that epistemological beliefs were domain-general, this led researchers to believe that people often possess some level of domain-specific beliefs.

In the within-subject studies, beliefs are no longer assumed to be domain-general. Researchers instead have students of the same major complete multiple versions of the assessment tool being used in the study. For each inventory participants completed, they were asked to consider their responses within the context of a specific domain. Researchers normally chose one "soft" (psychology, history) and one "hard" (mathematics, physics) domain based on Biglan [41] to be evaluated. The responses for each domain would then be compared to see if there were any differences. The results of the in-between studies were mixed as there was evidence that supported the domain-generality [96], [97] and domain-specificity [33], [98] of epistemological beliefs. Some studies even found evidence that participants had both domain-general and domain-specific beliefs [74], [99]–[101], which supported Stenberg's theory that epistemological beliefs consisted of both domain-general and domain-specific beliefs [102] .

Reviews of these studies have also identified methodological and analytical issues that may have contributed to the lack of consensus on the specificity of epistemological beliefs. Op't Eynde et al. [103] and Límon [104] suggested that the lack of context when examining beliefs allowed for ambiguity with respect to the specificity of beliefs. Schommer [96] additionally noted that some of the conclusions drawn about domain-specificity of beliefs were dependent on the analytical methodology of the study.

The other research topic researchers have focused on has been the relationship between epistemological beliefs and the contexts in which they are developed. When

Perry [20] conducted his study, it focused primarily on how the academic environment in which the participants were immersed in affected their views on knowledge. Belenky et al. [50] and Baxter Magolda [22] expanded upon this by finding evidence that factors outside of formal education, such as gender, can also influence epistemological beliefs. This led researchers to begin to look at individuals differences in socioeconomic factors such as parent's education [23] and family structure to measure their impact on epistemological beliefs.

More recently, researchers have focused on the impact that cultural differences may have on epistemological beliefs. A majority of the research in this area examined of epistemological beliefs among students outside of the United States. Researchers have conducted studies with individuals from across Europe [31], [103], [105]–[108], the Middle East [109]–[112], and Asia [113]–[119]. Many of these studies have encountered issues due to the fact that most epistemological development models were created based on studies of individuals in Western formal education environments. This required researchers to assume that these epistemological beliefs models could be applied across cultures [120], implying that the results found for U.S. students should also been seen for student outside of the U.S.

Research examining the applicability of epistemological belief models across cultures has contradicted this assumption. In a study looking at the cross-cultural potential of Perry [20], Zhang [119] compared the epistemological beliefs of college students in China and the U.S. The results suggested that the Chinese students' became more dualistic during their academic career while the U.S. students became more relativistic. Zhang [119] attributed cultural differences with respect to freedom to choose major and peer interactions was a main reason for the difference in development. Because of these and other educational differences, Perry's model was not universal since it could not be applied to Chinese students.

Looking to see if the dimensions of epistemic beliefs that Schommer [23], [35] had identified were applicable across cultures, Chan and Elliott [114] administered a translated version of Schommer's Epistemological Questionnaire to 385 teacher education students in Hong Kong. While the factor analysis identified the same number of dimensions as Schommer [23], [35], the nature of the dimensions was different. Chan and Elliott [114] associated these differences with the traditional Confucian-heritage culture of Hong Kong students. They also suggested that "care needs to be exercised in applying Schommer's questionnaire in other cultural contexts" [114, p. 408].

Youn [118] replicated the study of Jehng et al. [34] on U.S. and Korean students to see if the five-factor model was present in both groups. The epistemological beliefs of 496 U.S. students and 487 Korean students were measured using a modified version of the epistemological belief scale Jehng et al. [34] developed. Factor analysis found evidence of a five-factor model and two-factor model for both groups. The five-factor model was the same for both groups and matched the findings of Jehng et al. [34]. However, the makeup of the two-factor model for U.S. students was different than for the Korean students. Youn [118] attributed this difference to a cultural difference in teacher-student interactions.

2.5. Integrated Models of Epistemological Beliefs

The previous section has shown that years of research have led to several new breakthroughs with respect to the structure of epistemological beliefs and their development. Many of these newer concepts were not included in previous models of epistemological beliefs. This led researchers to create new models that incorporated the newer concepts of epistemological beliefs within the previously held ideas about epistemological beliefs. This section discusses three of these models: 1) an epistemological belief model developed by Buehl and Alexander [121], 2) the Theory of Integrated Domains in Epistemology (TIDE) developed by Muis et al. [45], and 3) an integrated model of personal epistemology developed by Bendixen and Rule [122].

2.5.1. Integrative Personal Epistemological Model of Bendixen and Rule

In 2004, a special edition of the journal *Educational Psychologist* focused on epistemological beliefs and their development. It contained papers from several prominent names within the field [123]–[127]. The goals of the special edition were to present the various approaches the researchers used when conceptualizing and researching epistemological beliefs and introduce an integrated model of epistemological beliefs based on these different approaches [128]. Developed by Bendixen and Rule [122], this was one of the first attempts to unify these various methodologies. These researchers believed that an integrated model would improve the quality of future research and help clarify how epistemological beliefs could be used in applied to educational practices.

The model itself included eight topics within personal epistemology that Bendixen and Rule believed to be important issues and potentially interacting with one another. Epistemological beliefs are assumed to be multidimensional and are represented in the model by Hofer's model of epistemological beliefs [24]. When epistemological beliefs evolve, an individual must undergo some condition of change. Bendixen and Rule focused on two concepts with respect to conditions of change: dissonance and personal relevance. Dissonance occurs when the experiences do not align with one's expectations [21] and personal relevance relates to how much interest a person has in a topic, the outcome of a situation, or a strong emotional response to an experience [129]. If conditions are met, then one's epistemological beliefs may go through a mechanism of change that can lead to more advanced beliefs. Bendixen and Rule proposed that the mechanism of changes consisted of three components: 1) epistemic doubt, 2) epistemic volition, and 3) resolution strategies. Epistemic doubt was based on prior work of Chandler [130]–[132] looking at epistemic doubt for relativistic thinkers questioning absolute knowledge. They suggested that the concept could be applied to epistemological beliefs at any stage.

The second component in the mechanisms of change is epistemic volition. This concept is derived from prior work on conceptual change and is defined as "dynamic system of psychological control processes that protect concentration and direct effort in the face of personal and/or environmental distraction" [133, p. 16]. Once epistemic doubt and volition occur, an individual then performs some resolution strategies to resolve their doubt. This can include but is not limited to reflection and social interaction with peers. The results of this process can lead an individuals to more advanced beliefs, although

Bendixen and Rule [122] do suggest that regression back to current or more naïve beliefs is also a possible outcome.

The other concepts included in the model relate internal and external factors that can influence the overall structure and development of epistemological beliefs. One of these construct is metacognition, defined as an "individual's knowledge concerning their own cognitive processes" [134, p. 233]. Most of the papers in the special edition mentioned metacognition either explicitly [125], [135] or implicitly [123], [124] as an influence on epistemological beliefs and their development. Within the model, metacognition acts as an "executive control process" [122, p. 74] over epistemological beliefs and the mechanisms of change. Another internal influence of epistemological beliefs is the idea of affect, which relates to the emotions that an individual has during an experience.

As for external factors, Bendixen and Rule included the concepts of reciprocal causation as well as the environment in which a person is immersed. The idea of environmental influences stemmed from work that Fisher [136] did combining Piaget's [137] cognitive development theory with Vygotsky's [138] sociocultural approach. They believed that cognitive development was dependent on the social and cultural surroundings of the individual. Bendixen and Rule believed that this was also applicable to epistemological beliefs. They also focused on role of peers because prior research had shown that peers and not authority figures are the primary source of validation when individuals are facing and resolving epistemic doubt [139] or reforming their epistemological beliefs [135].

2.5.2. Epistemological Framework of Buehl and Alexander

In the early to mid 2000's, Buehl and Alexander conducted a multiple studies examining the specificity of epistemological beliefs [99], [100], [140]. The results of these studies provided evidence of domain-general and domain-specific beliefs. However, the epistemological models that had been developed at that time did not express this duality. This led Buehl and Alexander [121] to develop a new model, shown in Figure 2.5, which incorporated their findings with observations from other epistemological belief studies.

Buehl and Alexander based their model on the assumption that knowledge and beliefs about knowledge would have similar structures [121]. This meant that epistemological beliefs would be complex, multilayered, multidimensional, and interactive [141]. To represent the multilayered dynamic, Buehl and Alexander split the different types of epistemological beliefs into distinct layers. Originally, Buehl and Alexander believed that epistemological beliefs consisted of three layers: general beliefs, academic knowledge beliefs, and domain-specific beliefs [75]. This was eventually updated to four with the inner two layers representing epistemological beliefs. The general and academic knowledge beliefs were merged together into a single layer since they were applicable across multiple domains.

Buehl and Alexander also assumed that epistemological beliefs consisted of multiple dimensions. They included three dimensions in their model: structure of knowledge, stability of knowledge, and source of knowledge. These dimensions exist for both the general and domain-specific beliefs. The bi-directional arrows represent the ability for dimensions to interact with each other across can also interact with each other. The interactions can be positive or negative depending on the context of the interactions [121]. Buehl and Alexander also suggested that domain-specific epistemological beliefs might have other dimensions that are only applicable to that particular domain.

The layers of epistemological beliefs are enclosed within the beliefs systems layer, indicating that epistemological beliefs are one of several beliefs systems that an individual can possess. The bi-directional arrows at this layer represent interactions that can occur between other belief systems such as learning [142], [143] and problem solving [144]. To represent the notion that all belief systems including epistemological beliefs are contextual, Buehl and Alexander embedded the beliefs systems layer within the sociocultural layer. The sociocultural layer refers to the environment that determines the context in which epistemological beliefs develop. This context can influence many aspects that may influence developments such as what the importance of different experiences and the type of social interactions an individual may engage in [121]. The arrows in the sociocultural layer depict the reciprocal nature of the interactions between one's sociocultural context and belief system.

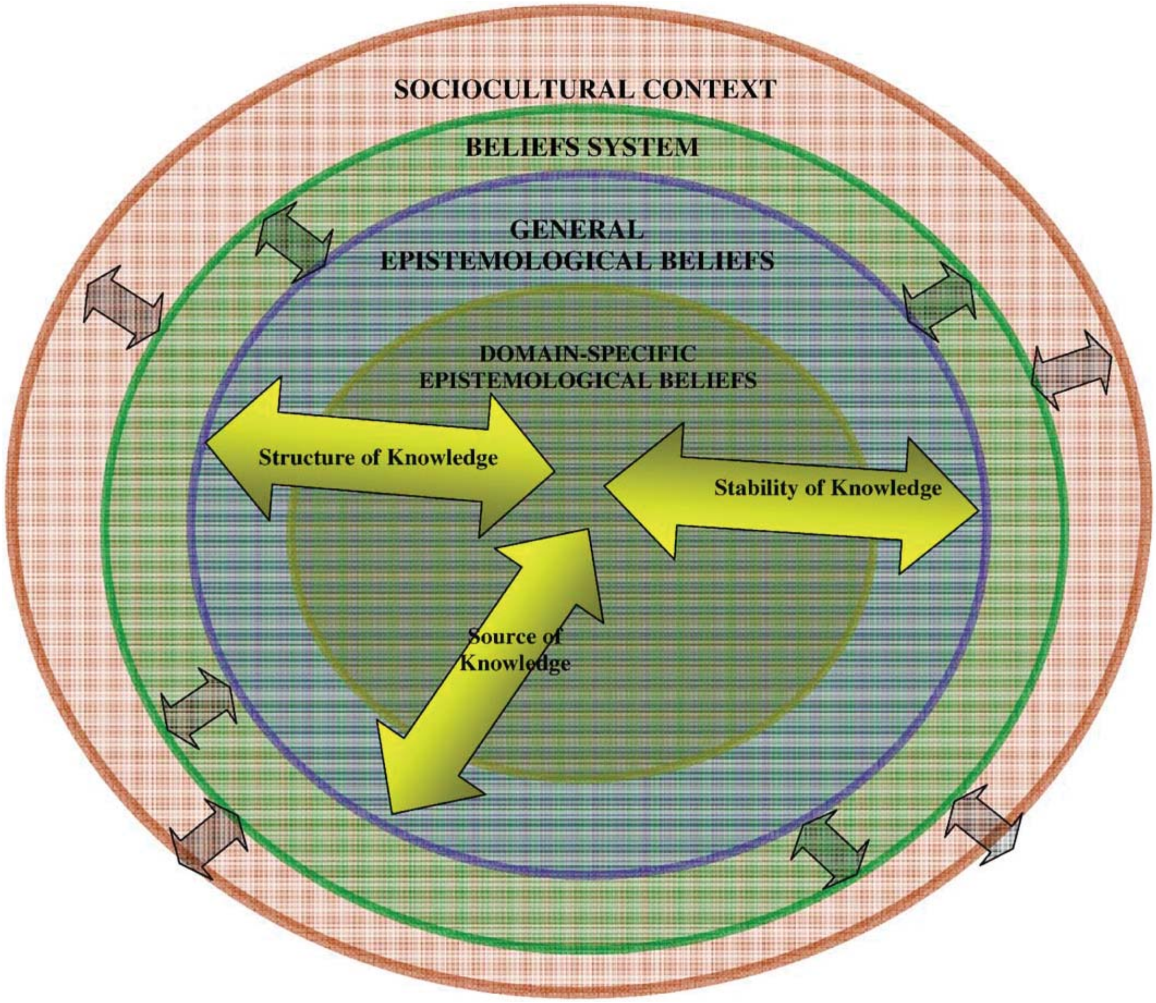

Figure 2.1: Model of Personal Epistemology suggested by Buehl and Alexander [121]. Figure used with permission of the author.

2.5.3. Theory of Integrated Domains in Epistemology (TIDE)

Like Buehl and Alexander [75], [99], [100], [121], Muis et al. [45] were looking to determine the specificity of epistemological beliefs. Instead of conducting their own study, they reviewed 19 empirical studies that had examined the domain-specificity of epistemological beliefs. The results of the studies found evidence for the existence of both types of epistemological beliefs, i.e. suggesting that there were both domain-general and domain-specific forms. Muis et al. also identified different methodological and analytical issues the studies encountered. These considerations along with epistemological tendencies found in previous studies and perspectives from different paradigms and other educational research were encapsulated into a new model, which Muis et al. named the Theory of Integrated Domains in Epistemology (TIDE) framework [45].

Like Buehl and Alexander, the TIDE framework operates under the assumption that epistemological beliefs are multidimensional and multilayered. Muis et al. suggested that Hofer's model best expressed the different dimensions of epistemological beliefs. The TIDE framework also assumes that development of epistemological beliefs is dependent on the contexts in which an individual is immersed. With respect to epistemological development, the TIDE framework assumes that individuals begin to develop beliefs at birth and the process continues until death. Muis et al. [45] suggested that epistemological beliefs develop in a spiral pattern where they may stagnate or even regress for a period of time.

All layers of epistemological beliefs are formed within the sociocultural context, which consists of all of the social and cultural influences of the environment in which an individual is immersed. Early in life, individuals develop what Muis et al. [45] referred to as general epistemic beliefs. These beliefs correspond to "the beliefs about knowledge and knowing that develop in nonacademic contexts such as the home environment, in interactions with peers, in work-related environments, and in any other nonacademic environments" [45, p. 33].

Once the individual begins their formal education, their beliefs begin to also be influenced by the academic context. This leads to the formation of a new layer of beliefs, referred to as academic epistemic beliefs. These beliefs are initially guided by the general epistemic beliefs with a reciprocal influence in the sociocultural and academic contexts. As individuals progress through school, their academic beliefs become more prevalent then the general epistemic beliefs.

In addition to the academic epistemic beliefs, individuals also begin to form domain-specific beliefs for each subject that they encounter. The main contextual influence of domain-specific beliefs is the instructional context, which relates to environments where instruction takes place. This context can include grading and school policies and practices [45]. Like academic epistemic beliefs, domain-specific beliefs have reciprocal interactions with the other layers. As individuals progress through the upper levels of grade school and into college, domain-specific beliefs become the dominant set of epistemological beliefs used to view knowledge.

While reviews of the TIDE framework have mostly been positive, there have been some criticisms. Hofer [145] found some of the terminology used by Muis et al. [45], particularly with respect to general epistemic beliefs, to be problematic. Alexander [146] suggested a disconnect between the literature review and the TIDE framework with respect to their approaches.

It is the belief of this study that researchers examining the epistemological beliefs of engineers should do so with respect to an integrated model of epistemological beliefs. Understanding the contextual nature of epistemological beliefs may provide a better understanding of the nature of epistemological development. For these reason, this study uses the TIDE framework. Further justifications for why the TIDE framework was chosen for this study to model the epistemological beliefs of engineers are provided in Chapter 3.

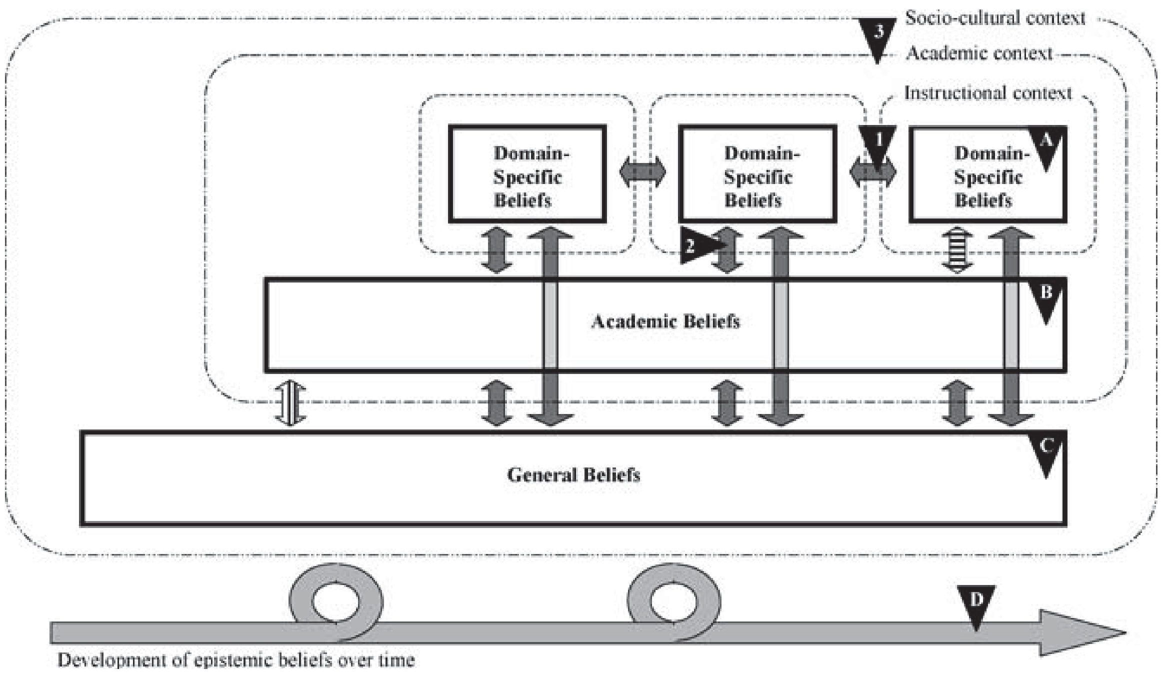

Figure 2.2: The Theory of Integrated Domains in Epistemology (TIDE) [45]. Figure used with permission of author.

2.6. Learning Preference Inventories

When looking at potential future research on epistemological development, Perry [49] suggested that the relationship between cognitive development and learning should be examined. This was based on his assumption that if an individual's beliefs about knowledge change, they would also want to adjust the methods used to obtain it [49]. In response, some models of epistemological beliefs have included this assumption into their structure. However, there is some dissent on how central the role of learning is in relation to epistemological beliefs[24]. One possible way to examine this relationship would be to examine the relationship between an individual's epistemological beliefs and their learning preferences.

There have been several models of learning preferences developed over the years [147], [148]. For research that has focused on engineering students, a popular representation of their learning preferences is Felder and Silverman's model of learning styles [46]. This model is derived from Jung's Psychological Types [149] and Kolb's

Experiential Learning Theory (ELT) [150]. This section will discuss in detail the development as well as the structure of all three models.

2.6.1. Psychological Types

Jung [149] introduced the theory of psychological types in 1921 as a way to classify individuals [151]. The theory was derived from years of observations performed by Jung examining the various differences between people. During this time, he noticed that people would interact with their environments in different ways. From these observations, he proposed the existence of two psychological types that could explain the differences: attitude types and function types [149].

For the attitude types, Jung suggested that there were two possibilites: introverted and extroverted. Extroverts tend to focus on the outside world through interactions with other people and their environments. They tend to be act instead of think and to talk out ideas due to their tendency to be sociable. Introverts on the other hand prefer the internal experience by focusing on concepts and ideas. They usually detach themselves from the environment and think about a topic or idea before speaking [149], [152].

The function types consisted of four modes: sensing, intuition, thinking and feeling. Those who use the sensing mode prefer to perceive their environment by focusing on the experiences that are immediately accessible through the five senses. They may focus on what is real, put an emphasis on the present, and have stronger powers of observation. Those who use intuition focus their perceptions on the possibilities that cannot be gathered through the senses. They like theoretical, creative, or abstract concepts and tend to focus on possibilities sometimes at the expense of actualities. Individuals who prefer the thinking mode tend to use logic to connect ideas. They usually are analytical, objective, and may come off as unemotional. Those who make judgments using feeling take a more subjective approach when weighing arguments by basing their decision on their values and the values of others. They focus on the "human" elements and how their decisions affect others around them [152], [153].

When describing people, Jung believed that people possessed all of the attitude and function types. Differences in people came from how conscious they were of the different types. For example, someone who was extroverted would be more conscious of this tendency while his or her introverted tendencies would remain regressed in the unconscious. The more an individual was conscious of a type, the more their personality reflected it. Likewise, the more a person was unconscious of a type, the less likely they would act according to the type. In addition, Jung proposed that the individuals over time become more comfortable using one of the function types. This type becomes known as the principal function [154]. In addition, a second function that "renders its service to the principal function and has no independence of its own" [154, p. 613] also comes to the forefront. This function is known as the auxiliary function. Opposing ends of a dichotomy cannot be an auxiliary function, so the sensing function cannot be the auxiliary function to the intuitive function and vice versa. Using these three categories, Jung created eight personality types that became the focus of his psychological type theory [149].

Looking to operationalize Jung's psychological types, Myers and Briggs began to develop an instrument that could find an individual's particular type [87]. During this time, they found statements by Jung that suggested an auxiliary mental function that supported the dominant mental function of individuals. This led Myers and Briggs to introduce the judging/perceiving category to describe one's attitude when interacting with one's environment. People with a judging attitude attempt to make plans and decisions as soon as it is feasible. They seem to be organized and decisive. In contrast, people with a perceiving attitude focus on gathering as much information as possible in order not to miss anything. They are seen as being open, curious, and flexible.

2.6.2. Experiential Learning Theory (ELT)

Another learning styles model that has been used to describe engineers is the Experiential Learning Theory (ELT) model developed by Kolb [150]. Kolb based the ELT on the prior work of Dewey [155], Lewin [156], and Piaget [157] who emphasized the importance of experience on learning and development. The intention of the ELT was to created to "conceptualize the learning process in such a way that differences in individual learning styles and corresponding learning environments can be identified" [158, p. 235].

Kolb defined learning with respect to the ELT as "the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience" [150, p. 41]. The grasping of experience is accomplished by one of two dialectically related modes. Active Experimentation (AE) and Reflective Observation (RO). The transforming of experience is also performed by two dialectically related modes: Concrete Experiences (CE) and Abstract Observation (AO). In an idealized situation, an individual would cycle through each of the modes in a recursive manner. The process would begin with individuals having concrete experiences that serve as a basis for reflections and observations. The individual would then incorporate these reflections into abstract concepts, which can be tested in an active manner. The results of the experiments would then lead the individual to new experiences to encounter.

Using Jung [149] as example, Kolb then looked to find individuality within the model [150]. He created the Learning Styles Inventory® (LSI) to determine the learning inclinations of individual within the four modes. A series of studies and analysis of 1,933 participants found four statistically prevalent learning styles. Each learning style had a dominant mode for grasping experiences and transforming experiences.

The *convergent* learning style had the dominant modes AC and AE. Individuals using this learning style tend to be very adept to applying ideas and theories in practical manners and thrive in situations where there is a single solution to problems [150]. They would prefer to deal with technical tasks and problems instead of people. Kolb found that people with the converging learning style preferred "to experiment with new ideas, simulations, laboratory assignments, and practical applications." [159, p. 197]

People with a *divergent* learning style have the dominant modes of CE and RO. They usually possess a strong imaginative ability and do well in situations that require the creation of ideas like brainstorming. They also like to focus on people and rely more on their emotions [160]. A divergent learning style lends itself to working in groups, listening with an open mind, and receiving personalized feedback.

The *assimilation* learning style uses AC and RO as their dominant learning modes. They excel at inductive reasoning and are well suited to generate theoretical models. Individuals with an assimilation learning style would rather deal with abstract concepts and ideas instead of people. They prefer readings, lectures, and abstract concepts in formal learning environments.

People with an *accommodating* learning style have the dominant learning modes of CE and AE. They prefer to learn through hands-on activities such as conducting experiments. They also put more emphasis on people than technical analysis when solving problems and act more on gut feelings. In formal learning settings, people with an accommodating learning style like working with others on assignments, doing field work, setting goals, and trying out different approaches while completing projects.

Later work on the ELT found that the original four learning styles did not cover all of the possible learning styles. Work by Abby et al. [161] and Hunt [162] introduced four additional learning styles: Northerner, Southerner, Easterner, and Westerner. These styles had one dominant mode while balancing the other dialectically related modes. For example, Northerners emphasize CE while balancing AE and RO. Another study conducted by Mainemelis et al. [163] found evidence of a Balancing learning styles that integrates all four modes.

2.6.3. Learning Preferences of Felder and Silverman

Concerned with poor performance and retention rates of students in engineering, Felder and Silverman began to examine ways to improve the educational experiences of engineering students [46]. They focused on misalignment of the different methods engineering students use to learn and the typical teaching styles of their professors. In order to study these mismatches, Felder and Silverman developed models of teaching and learning that expressed the dimensions of learning that were important to engineering teachers as well as accurately described the different learning preferences found in engineering students.

The premise of their model was that learning in an educational setting involves a two-stage process consisting of the reception of knowledge and how knowledge was processed [46]. Felder and Silverman looked at previous models of learning styles as well as their own experiences as educators. This led them to include five dimensions into their learning styles model: active/reflexive, sensing/intuitive, visual/verbal, sequential/global, and inductive/deductive. In addition, Felder and Silverman also developed a parallel teaching styles model to describe the preferences that professors had when teaching engineering courses.

The *sensing/intuitive* dimension was taken directly from Jung's psychological types [149] while the *active/reflexive* dimension was based on the active experimentation and reflective observation categories of Kolb's ELT [150]. The *visual/auditory* dimension described how individuals preferred to receive information. Research had split the methods into three categories: visual, auditory, or kinesthetic (tastes, smells, and touch). Felder and Silverman [46] believed that kinesthetic learning was not prevalent in learning engineering, so it was ignored. Visual learners like when knowledge is presented with pictures, maps, graphs, etc. Verbal learners prefer information in the form of words whether it is through reading or listening.

Sequential learners prefer information to be presented in a logically progressing format of complexity and difficulty. They tend to operate with linear reasoning when solving problems, do not need the whole picture to work with information, and tend to be better at convergent thinking and analysis. *Global* learners like to see the entire picture first in order to relate to prior experiences and then fill in the gaps. They may not understand something for weeks at a time and then have everything make sense in an instant. They make intuitive leaps during problem solving and tend to be better at divergent thinking and synthesis.

Another dimension that relates to the presentation of knowledge is the *inductive/deductive* dimension. Inductive learners prefer to first be shown particular instances of something like observations and measurements and then expand into more generalized concepts such as laws and theories. Deductive learners prefer the opposite. Felder and Silverman [46] noted a natural mismatch in that inductive learning is the natural learning style of humans, but the natural teaching style is deductive.

As Felder and Silverman's model became more popular within the engineering education field, they have updated the model to reflect new insights. The biggest change was the removal of the inductive/deductive dimension from the model. This was done because they believed that inductive learning was the better method of learning for engineering students, particularly undergrads [164]. However, students would say they prefer deductive learning because it would provide them what they would need in order to pass exams [164]. This would provide educators with evidence to continue to use the deductive method of teaching and help continue the status quo in engineering education.

The other change in Felder and Silverman's model was the changing the name of the visual/auditory dimension to the *visual/verbal* dimension [48]. This was done to reflect the belief that reading text was more closely related to hearing speech than looking at visual aids. This change was based on extensive research suggesting that meaning from written text can be inferred in one of two ways depending on the situation [165]. If the words are familiar or designed to make speech encoding impossible, then the direct access method is used and meaning is processed more in a visual manner. If the text is unfamiliar or difficult to understand, then the text is transformed internally into sounds before one tries to extract meaning. This is also known as the indirect method [166]. Felder believed the text that engineering students encountered (textbooks, chalkboard notes, etc.) would be complex enough to cause students to use the indirect method. This would make reading texts more of an auditory function and therefore it would be better to describe this type of learning as verbal [167].

There have been several studies that have examined the learning preferences of engineers wither respect to this model. The primary method of evaluation has been the Index of Learning Styles (ILS) developed by Felder and Soloman in the early 1990's [47]. These studies have looked at the learning preferences of students both inside and outside of the U.S. [168], [169]. The vast majority of these studies have found that engineering students have active, sensing, visual, and sequential learning preferences [48]. However, none of the published studies have tried to make any associations with epistemological beliefs.

2.7. Summary

This chapter discussed previous research with respect to epistemological beliefs and their development. Most of the research is derived from the work of Perry [20]. Over the past 40+ years, there have been several advancements in the understanding of epistemological beliefs. Many of the early epistemological belief models assumed that development occurred across stages or positions in a one-dimensional manner and were applicable across all domains. These models were derived from the educational experiences of the individuals or their justifications when solving everyday, ill-structured problems. Studies that used these models found differences across several dimensions, including gender and academic classification. However, inconsistencies in the results using the one-dimensional models caused researcher to re-examine the structure of epistemological beliefs starting with Schommer [23]. This led to models that assumed epistemological beliefs consisted of a set of dimensions that develop independently of each other.

The introduction of the multidimensional epistemological beliefs started a series of studies with respect to epistemological beliefs. These studies typically focused on determining the specificity of beliefs, validating new forms of measuring the complexity of an individuals' belief, and exploring the contextual nature of beliefs with different environments and cultures. In order to encapsulate the new findings, researchers developed new integrated models of epistemological beliefs.

During this time, a small amount of the research conducted has focused specifically on the epistemological beliefs of engineering students. These studies have found evidence of positive effect of experiential curricula on epistemological development [42], [43] and that international doctoral candidates predominantly possess relativistic epistemological beliefs [90]. Despite the progress that has been made in understanding the nature of epistemological beliefs, there is still much to investigate, especially with respect to the engineering students. There has been very little published with respect to examining engineering epistemology with respect to the newer integrated models. This suggests that our understanding of how contexts other than that of an engineering program at a university affect epistemological beliefs is limited. There have also been very few studies that have looked to see if the epistemological beliefs and their development are consistent across specific engineering majors, which may shine light on differences in within the various curricula.

Another potential area that may have some influence on epistemological beliefs and their development is learning. There has been little work that have examined the role learning plays in epistemological development of engineering students, despite some belief that learning is a central component [22], [23]. One potential way that learning could affect beliefs is through the preferences an individual has while interacting with knowledge while learning. Several different models have been developed over the years to represent these preferences. For engineers, researchers have primarily used three with Felder and Silverman's Model of Learning Styles being the model of choice for more recent studies.

This study looks to fill in some of these gaps in the literature by examining the epistemological beliefs of electrical and computer engineering students with respect to the TIDE framework. An overview of the methods of the study and the justifications for decisions with respect to the methods is provided in Chapter 3.

3. STUDY DESIGN

3.1. Background

Previous research has established that while the epistemological beliefs of engineering students do become more advanced during college [30]–[32], they do not consistently reach the levels believed to be needed to consistently solve complex, ill-structured problems [30]. One potential reason for this is Perry's hypothesis that epistemological growth is not consistent and may require encounters with situations and thinking that challenges the current views of the individual [20]. Engineering education researchers have focused on this hypothesis and have tested it through experiential courses that focus on problem based learning, which has produced some promising results [42], [43].

In the past 15 years, researchers have found several new insights into the complexity, structure, and influences of epistemological beliefs. These advancements have lead to new representations of epistemological beliefs and their development. However, many of these insights have not been examined with respect to engineering students. This led me to design a study that would begin to fill in this gap and expand the understanding of engineering epistemology.

3.2. Research Objectives

The objectives of this research study were to:

1) *Determine the complexity level of epistemological beliefs among electrical and computer engineering students,*

2) *Explore the impact of various contexts (sociocultural, academic, and instructional) of the Theory of Integrated Domains in Epistemology (TIDE) framework* [45] *on epistemological development, and*
3) *Investigate an expansion of the TIDE to explore the relationship between industrial experience and epistemological development.*

3.3. Methodology

3.3.1. Selection of epistemological belief model

As mentioned in section 2.5, there are multiple integrated models of epistemological beliefs that describe epistemological beliefs with respect to different contexts, development patterns, and interactions with other knowledge constructs, etc. Bendixen's Model of Integrated Beliefs [122], Buehl and Alexander's Integrated Model [121], and the Theory of Integrated Domains in Epistemology [45] were considered for use in this study. While all three models include sociocultural environments as an important context in which epistemological beliefs develop, only the TIDE framework includes additional contexts that describe the influence of the formal education environment. In addition, the literature review only found reviews pertaining to the TIDE framework and they were found to be mostly positive. Lastly, the only published studies found during the literature review pertaining to the application of an integrated model in a research study were with the TIDE framework[170]. For these reasons, the TIDE framework was chosen to represent the epistemological beliefs for this study.

3.3.2. Expansion of TIDE framework

When Muis et al. [45] developed the TIDE framework, they acknowledged that it did not encompass the entirety of epistemological beliefs. Their hope was for researchers to build upon the model and include other theories of beliefs and their development. For engineering students, an opportunity that was not fully described was time spent participating in internships and co-op rotations. Research has found evidence suggesting that there many be a relationship between internship and co-ops and student development. The Penn State study [32] found that participants who completed a co-op rotation were measured at a higher average Perry position than those who had not, but the population may have been to small to determine if the difference was significant. Other research found that internships and co-ops have had positive effects on GPA [171], deep learning [172], and ABET outcomes [173].

In the current version of the TIDE framework, all potential influences that occur outside of the formal learning environment are represented by the sociocultural context. However, it is my opinion that this label does not encapsulate the industrial setting. Industrial environments are similar to formal learning environments in that they complete tasks, normally ill-structured in nature, that indicate their mastery of knowledge required by their employers. These tasks are normally completed in a team format where the individuals work with and depend on their peers who may have different views on knowledge. This work is evaluated by authority figures to determine if the individual is successful completing these tasks. All of these aspects of an industrial setting may cause individuals to doubt their current views of knowledge and force them to reevaluate their own epistemological beliefs in order to succeed.

While industrial settings are influenced by the social and cultural contexts they are immersed in, it is my belief that they represent their own distinct context in which epistemological beliefs are developed. This led to the development of a modified version of the TIDE framework that included the industrial context, which is shown in Figure 3.1. While the majority of the influence of the industrial context may correspond to academic and domain-specific epistemological beliefs, there are situations that can occur in an industrial setting that can also influence general epistemological beliefs directly. Since internships, co-op rotations, and other potential industrial experiences occur outside of the formal educational environment, they would not be influencing epistemological beliefs at the same time. For this reason, all three layers of epistemological beliefs were placed inside the industrial context.

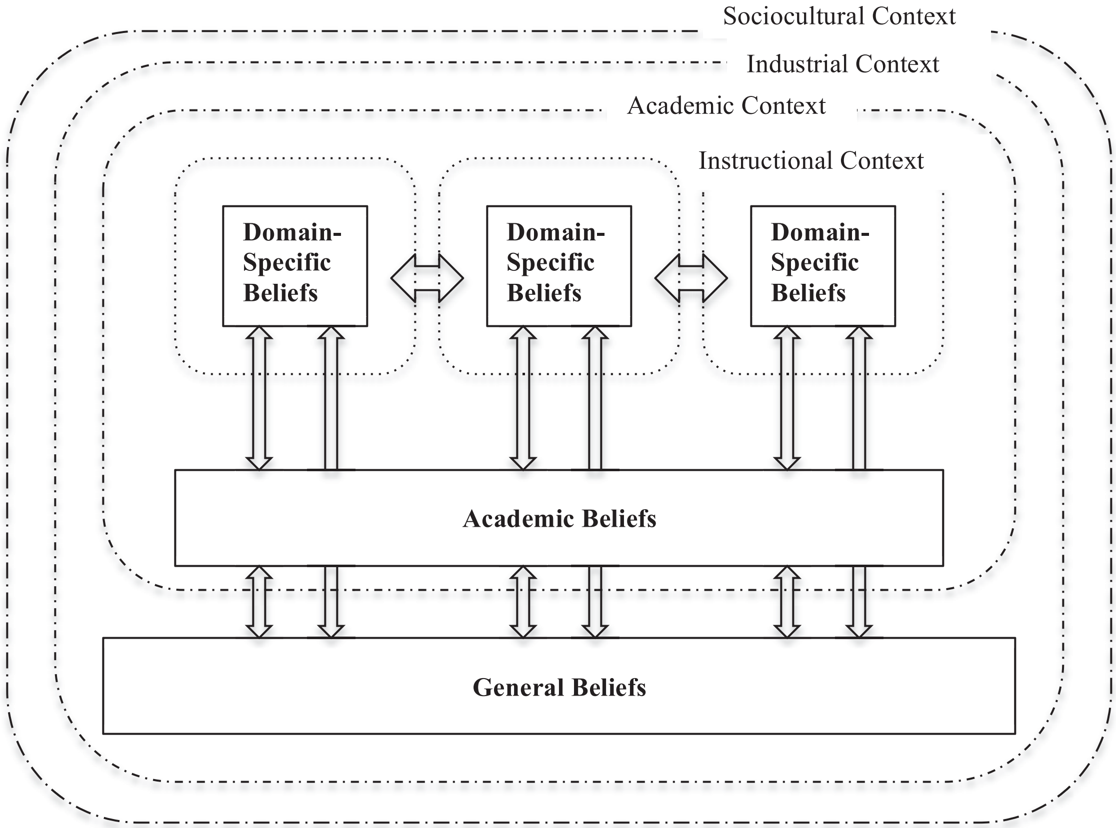

Figure 3.1: Appended TIDE framework that includes Industrial Context

3.3.3. Selection of epistemological development model

Domain-General Versus Domain-Specific

When using the TIDE framework, Muis et al. suggested that epistemological beliefs should be measured at the domain-specific level[45] and many of the recent epistemological development students have taken that approach [74], [99], [106], [73], [174]. One of the difficulties with examining beliefs at a domain-specific level is defining the domains to be examined. Most studies have compared individuals' beliefs between "hard" (i.e. math, physics) and "soft" (i.e. psychology, history) disciplines. These studies rarely examined more than a couple of domains from each grouping.

This study operated under the assumption that examining beliefs at a domain-specific level would be insufficient with respect to engineering students. In order to solve the ill-structured problems they encounter upon entering the workforce, engineering students need to apply knowledge from science, engineering science, applied engineering, the humanities, and social sciences [175]. In order to get a complete picture of an engineering student's domain-specific beliefs, one would need to examine all of these domains. However, examining domain-specific beliefs can be difficult to examine for multiple reasons. One is that researchers have found it difficult to distinguish boundaries between different domains. This can cause individuals to include aspects of other domains[24], which could affect the perceived level of epistemological beliefs. Another issue is that individuals may suffer from fatigue from having to provide responses for some any domains.

One can still gain insight regarding an individual's epistemological beliefs through a domain-general approach. Since this approach looks at epistemological beliefs at a higher level, it may provide insight into how the views and beliefs of all of the domains used in ill-structured problem solving interact. This is because domain-specific beliefs are believed to be derived from more general epistemological beliefs [45], [121]. As domain-specific beliefs evolve, the development can be incorporated into an individual's domain-general beliefs. Also, the domain-general epistemological beliefs should represent the baseline level of development for all domain-specific beliefs.

One-dimensional vs. Multidimensional Epistemological Development

When Muis et al. [45] developed the TIDE framework, they did so under the assumption that epistemological development was multidimensional [24]. However, a majority of studies focusing on engineering students have used one-dimensional development models, particularly Perry [31], [42], [43]. The primary reason for this is the belief that the perspectives described by the later stages of Perry are necessary for practicing engineers to be able to solve "real-world, open-ended problems" [30, p. 451]. In addition, the descriptions for the different positions within the one-dimensional models allow for a detailed understanding of how the different dimensions of epistemological beliefs develop. Multidimensional models on the other hand really only describe the end points of development in detail.

As mentioned earlier, several of the dimensions in multidimensional models were derived from one-dimensional models. Most of these models never discussed how individuals progressed to more advanced positions and stages. While every dimension must progress to a certain point in order to be considered, there was no indication that all of the dimensions would progress at the same time. Both Perry [20] and King and Kitchener [21] believed in a "complex stage theory" where an individual could have some dimensions that would be considered to be at a more advanced position and others that correspond to lower positions. This possibility is considered in many of the scoring methods of one-dimensional models where an individual is assigned a primary and secondary position based on the work of Knefelkamp [78] and Widick [79] or responses are correlated to multiple stages with a model to generate a "wave of positions" with respect to of epistemological beliefs [21], [44] . For these reason, this study assumed epistemological beliefs develop in a one-directional manner where individuals can possess beliefs corresponding to multiple stages at the same time.

Rationale for Utilizing the Perry Model

As discussed earlier, there are several domain-general epistemological belief models. These models derived their progressions from either an individual's interpretations of their education experiences [20], [22], [50], or from their ability to solve ill-structured problems [21], [51]. Since the TIDE framework included different contexts in which epistemological beliefs develop, the model used to measure epistemological development should take these contexts into account. Muis et al. [45] suggested that by the time individuals reach college domain-specific should be the dominant type of epistemological beliefs and that they can influence more general beliefs. These domain-specific beliefs are influenced by the academic and instructional contexts in which they were developed. The educational experience models [20], [22], [50] encompass the academic and instructional contexts.

Another consideration was any potential overlap between the different epistemological development models. In a review, Hofer [24] found that several of the dimensions of epistemological beliefs as well as the general trend of epistemological development tended to be consistent across the domain-general models. Both Belenky et al. [50] and Baxter-Magolda [22] expected to find different development paths from Perry by making gender a focus of their studies. While they did find some gender differences, they also found strong evidence of overlap between their models and Perry's scheme. This evidence of overlap is probably due to the models of epistemic beliefs [23], [24] and epistemological development [21], [22], [50], [77] that are based on Perry's scheme [74]. For these reasons, we decided to use Perry as the model of epistemological development.

3.4. Research Questions

1. What is epistemological development pattern of electrical and computer engineering students with respect to a modified version of the TIDE framework?
2. How are the individual differences that represent the influences of the different contexts of the TIDE framework related to epistemological development?
3. How do the learning preference dimensions of Felder and Silverman relate to the epistemological development of electrical and computer engineering students?
4. Does the proposed industrial context have any influence on epistemological development of electrical and computer engineering students?

3.5. Variables of Interest

3.5.1. Sociocultural context

For the sociocultural context, students were asked to provide information with respect to if they were a domestic or international student, gender, ethnicity, neighborhood, parent's education, and income level. Examining epistemological differences with respect to gender has constant focus ever since Perry [20] did not use females to develop and justify his model. The epistemological development of women has been a constant topic of discussion in epistemological development research [22], [50]. Subsequent research has shown that gender differences do exist in the early stages of epistemological development and then disappears as beliefs become more advanced

[56], [60]. Epistemological research in engineering has also shown that rates of development are consistent across gender when compared against other studies [43].

The domestic/international, ethnicity, and neighborhood factors chosen based on recent focus on the effect culture has on a person's epistemological development. Jehng et al. [34] suggested that epistemological development is a process of enculturation where students learn to view knowledge from the perspectives of those around them. These perspectives can vary across cultures and the categories for each of these factors can represent a culture or subculture that an individual can be immersed in. There have been very few published studies that have looked at these factors with respect to engineers [88]. However, the results for more general populations suggest that each should have some type of influence on epistemological development.

For the social aspect of this context, I chose to examine parent's education level and income. Schommer [23] believed that the educational level of an individual's parents can dictate the educational atmosphere an individual grew up in. It is my belief that the same assumption can also be applied to the income level of their parents. Studies have shown that students who are the first in their families to attend college tend to have poorer academic performance with respect to GPA [176], [177] as well as less advanced epistemological beliefs [23]. Prior studies that have examined epistemological beliefs with resect to parent's education has done so either by the highest level between both parent or each one individually. For this study, it was decided to examine the influence each parent's education separately because it could potentially provide a broader picture of the influence of the sociocultural context.

3.5.2. Academic context

For the academic context, the study focuses on the categories of university classification, major, transfer credits, research experience, GPA, change in major, studying abroad, and design competitions. Both academic classification and GPA represent the standing of the individuals with respect to the academic context. They have been found to have an impact on epistemological development [30], [32], [35], [42]. This lead me to believe that these factors would be found to have an influence in this study as well.

When major has been included in studies of epistemological development, it has mostly been to differences between students in "hard" (i.e. engineering, mathematics) and "soft" (i.e. psychology, history) majors according to Biglan [41]. Majors that fell in the same classification were group together because it was assumed that individuals within these majors would have the same epistemological beliefs. Though it is possible different engineering majors could have difference instructional practices and academic cultures that could lead to different rates of epistemological development, I expected a participant's major to not be a factor due to the amount of overlap between electrical and computer engineering.

The transfer credits, change of major, and studying abroad factors were chosen in to explore potential impacts of other academic contexts on engineering students. All three represent an opportunity for an individual to be immersed in another academic environment whether it is a different department at the same university or a different university all together. This can expose the individuals to different focuses that can influence development in some way.

The study also included some factors that were not directly related to the formal engineering classroom experience in order to give a more complete picture of the academic context. For this study, individuals indicated whether they had participated in any undergraduate research or engineering design competitions. Both scenarios involve attempting to solve ill-structured problems where the solutions can challenge their perceptions of knowledge and should have some influence on epistemological development.

3.5.3. Instructional context

One way this proposed research study examined the influence of the instructional context is by examining courses participation in course with different structures. The School of Electrical and Computer Engineering at Purdue has introduced directed problem-solving versions of courses where students spend the scheduled class time focused on active, team-oriented problem solving instead of lectures. Previous engineering epistemology research has shown that these types of courses positively impact epistemological development [32], [42].

Another way the study examined the instructional context is through the learning preferences of individuals. Many engineering courses are taught in a format that Felder[48] suggested did not match the learning preferences of engineering students. This mismatch can affect the academic performance of students in a negative manner. Since other studies have found links between academic performance and complex epistemological beliefs [36], [178], [179], it was expected that students whose learning preferences matched the teaching preferences of a typical engineering course should have more advanced epistemological beliefs.

3.5.4. Industrial context

Participation in undergraduate research and cooperative education programs were the factors used to represent the industrial context. As mentioned in Chapter 2, these experiences can expose students to real-world engineering problems that are ill-structured in nature. Like undergraduate research and design competition, the solving of these problems can force individuals in to a state of epistemic doubt that may lead to more advanced epistemological beliefs. Based on this, I expected these factors to be found to have an influence on epistemological development.

3.6. Setting

This study was conducted at Purdue University, a public, land-grant university located in the Midwestern United States. At the time of this study, there were 29,255 undergraduate students enrolled Purdue. Engineering was the most common major with 7,589 undergraduate students. Males made up the majority of the students with over 75% of the total engineering population. About 24% of the undergraduate population were international students (N = 1897), with the largest contingency coming from China [180]. At the time of the study, there were between 975 and 1102 undergraduate students enrolled in the department of Electrical and Computer Engineering. Seniors made up the largest portion of the students, followed by juniors and sophomores. The ECE population was more male-dominant than the college of engineering as only about 12-13% of students were female. The ECE program also had a larger percentage of international students (38%) than the overall College of Engineering population. The population was relatively distributed evenly with respect to GPA at the time of the study as 380 had a GPA at or above a 3.5, 308 had a GPA between a 3.0 and a 3.5, and 399 had a GPA below a 3.0

3.7. Study Population

3.7.1. Recruitment

All participation in the study was voluntary. The participants of the study consisted of students who were enrolled in the School of Electrical and Computer Engineering (ECE) who were working towards a bachelor's degree in electrical or computer engineering at Purdue University. The participants ranged from students completing their first semester enrolled in the ECE department, which usually occurred during the first semester of their second year, to students completing their last semester before graduating. There were two rounds of data collection in the study and each had its own method of recruitment. The first round used of a series of callouts to participate in the study. The callouts consisted of flyers posted on announcement boards in the electrical engineering building, posts on the ECE message board that appeared every time an individual logged into a university machine connected to the department's network, or a short presentation given by me at the end of required courses since they typically had larger class sizes. Instead of trying to recruit participants in the second round of data collection, students enrolled in an introductory digital design course were given the option to participate in the study by completing the inventories as a class assignment. The method of compensation also differed in each round of the study as first round participants received $15 while the second round participants received bonus points toward their course grade. Students were allowed to participate multiple times in the study as long as they waited at least one semester before trying to participate again.

3.7.2. Protection of research participant rights

The Institutional Review Board (IRB) approved this study on November 15, 2011 (Protocol Number: 1109011261). An amendment to the study was approved on February 10, 2014. Since this study collected data via surveys and the data collected could not directly identify the participants in the study, participants were not required to sign an informed consent form.

A total of 212 electrical and computer engineering students participated in this study. Eighty-two of the participants completed epistemological profiles that included version I of the background questionnaire with three students participating twice. Another 127 students participated in the study after the background survey was amended.

3.8. Data Collection

Participants generated an epistemological profile that represented individuals with respect to the TIDE framework. The profile consisted of three surveys: a background survey, the Index of Learning Styles (ILS), and the Learning Environment Preferences (LEP) inventory. The background survey and the ILS were used to establish the contexts where epistemological beliefs are formed while the LEP was used measure the complexity of their beliefs. Descriptions of the surveys are provided in the flowing sections.

3.8.1. Background survey

The questions of included in the background survey were designed based on the various individual differences examined in previous epistemological belief studies. Questions ranged from identifying what type of neighborhood participants grew up to military experience. The survey also had students describe their ideal learning environment in essay format as a way to get more insight into their beliefs.

After the first round of, the background survey was examined to see if any changes were needed. Some questions were reworded in order to improve clarity. In addition, questions relating to family income and parent's education were included to better encapsulate the sociocultural context. Version II of the background survey is attached in Appendix A.

3.8.2. Index of Learning Styles (ILS)

In order to measure where students fell on their model of learning preferences, Felder and Solomon developed the Index of Learning Styles (ILS) [48]. The inventory consists of 44 items split evenly across the four dimensions of Felder and Silverman's Model of Learning Styles (active/reflexive, sensing/intuitive, visual/verbal, and sequential/global) [46]. Each item is a forced-choice statement where the two responses correspond to each category of the dimension. Preferences are scored based on the number of the items corresponding to both categories within a dimension on a scale from one to eleven. Felder and Silverman decided to use a forced-choice inventory in order to eliminate the possibility of not having a preference and to allow for better statistical analysis [181]. The scale and number of items corresponding to each dimension was also chosen to meet these conditions [168].

The initial version of the ILS with 28 items was created in 1991 [181]. In 1994, several hundred responses were collected with the purpose of performing a factor analysis. Those that did not load significantly were replaced and led to the current version of the ILS, which was posted online in 1997.

There have been several studies looking at the reliability and validity of the ILS. For reliability, researchers examined reliability in two ways: test-retest reliability using Pearson correlation coefficient, designated by r, and internal consistency reliability using Cronbach's Alpha Coefficient, designated by α. When doing test-retest reliability analysis, the interval between test dispensations allow for subjects to forget previous responses, but exclude significant change to the population [181]. If $r > 0.5$, then the inventory is considered to have high reliability. Results of the test-retest reliability analysis for several studies are shown in Table 3.2. Studies that had either moderate (4-5 weeks) or long (7-8 months) durations between the first and second administrations of the ILS found $r > 0.5$ for all dimensions. These results suggest that the ILS is reliable with respect to test-retest.

Table 3.1: Test-Retest Correlation Coefficients of the ILS

Interval	Act/Ref	Sen/Int	Vis/Ver	Seq/Glo	N	Source
4 weeks	0.804**	0.787**	0.870**	0.725**	46	Seery et al. [182]
5 weeks	0.667**	0.640**	0.799**	0.617**	143-157	Livesay, Dee [183]
7 months	0.73*	0.78*	0.68*	0.60*	24	Livesay et al. [184]
8 months	0.683**	0.678**	0.511**	0.505**	124	Zywno [169]

* $p < 0.05$, ** $p < 0.01$

For the internal consistency reliability, there are usually two types that are being evaluated: a univariate or an attitude/preference. The ILS has been examined with respect to the latter of the two types. Under this type, a high Cronbach coefficient ($\alpha >$ 0.8) would mean that items are not looking at independent aspects of a dimension but are different versions of the same question. Because of this, Tuckman [185] suggests that an $\alpha > 0.5$ is sufficient for inventories of learning styles. Table 3.3 shows the internal consistency results for the four dimensions of the ILS for different studies. The Cronbach alpha are greater than 0.5 for all dimensions of the except for the sequential-global dimension in the Van Zwanenberg study [186]. These results suggest that the ILS is a reliable instrument with respect to measuring learning preferences.

Table 3.2: Internal Consistency Reliability for the ILS

Act/Ref	Sen/Int	Vis/Ver	Seq/Glo	N	Source
0.56	0.72	0.60	0.54	242	Livesay et al. [184]
0.61	0.76	0.69	0.55	584	Felder, Spurlin [181]
0.51	0.65	0.56	0.41	284	Van Zwanenberg et al. [186]
0.60	0.70	0.63	0.53	557	Zywno [169]
0.61	0.77	0.76	0.55	448	Litzinger et al. [168]

3.8.3. Learning Environment Preferences (LEP)

The LEP instrument was designed Moore to be an objective measure of epistemological development with respect to Perry scheme of intellectual and ethical development. The instrument is copyrighted, and permission to use it for this studied was obtained from Moore.

The LEP instrument is derived from the various studies conducted with Measure of Intellectual Development (MID), an essay-based pen-and-paper assessment tool derived from the work of Knefelkamp [78] and Widick [79]. The items of the LEP correspond to five domains of the classroom environment: 1) Course Content, 2) Role of Instructor, 3) Role of Students/Peers, 4) Classroom Activities/Atmosphere, and 5) Evaluation Procedures. These domains reflect the major position ranking criteria of the MID and research that suggested a relationship between aspects of classroom learning and epistemological development [44]. The LEP also focused on the learning environment like the MID because it was the primary focus of Perry's original study [80] and excluding the context in which development occurred would "miss crucial aspects of what makes the Perry scheme particularly relevant to a higher education context" [53, p. 30].

For each item in the LEP instrument, participants rate the importance of the statement to their ideal learning environment on a 4-point Likert scale. Each domain consists of 12 items associated to a position in Perry's scheme and one item used to account for participants making decisions based on an item sounding complex. Moore [44] chose to map the items between positions 2 (Multiplicity Pre-legitimate) and 5 (Relativism Correlate, Competing, or Diffuse) because there was no empirical evidence of position 1 [80] and studies at the time suggested that epistemological development stopped in position 5 [187]. For each domain, the participants rank the three most significant statements. The items are then scored two different ways. The first scoring approach involves calculating the percentage of responses to items that corresponded to each of the four positions being measured. The second methods has individuals select the three most important items within each domain in order to calculate what Moore called the Cognitive Complexity Index (CCI) [80]. This method of scoring is based on Rest's

DIT [188] and is meant to give a more complex evaluation of one's epistemological development. The CCI is a continuous score that ranges from 200 to 500 and relates to positions 2 through 5 of Perry's scheme. A breakdown of how many items correlate to each of the four positions is also done.

The original pilot study of the LEP was conducted with 51 liberal arts sophomores. The CCI scores were compared with MID, GPA, and ACT scores to see if there were any correlations. The CCI did correlate with the MID (r = .38) and GPA (r = .36) which was consistent with other pen-and-paper instruments correlations to variables like GPA. A second pilot study with 34 freshmen and sophomores had a stronger Pearson correlation factor (r = .57) with the MID.

Moore [44] has also conducted reliability and validity studies on the LEP. The validity study was conducted with 725 students from several types if universities. The populations were recruited from classroom samples instead of random selection. Moore focused on the Nunelly's process of validity in two ways: internal consistency of items to their expected positions and an item factor analysis. For the internal consistency, Moore calculated Cronbach's coefficient alpha for all position-keyed items and found it to be in the above 0.8 for 3 of the positions and .72 for the fourth. In addition to Nunelly's process, Moore used a subsection of the population (N = 470) to see if there were any variances between gender and academic classification. The results showed a steady progression across academic classification and the differences to be significant. The variance analysis also showed that the CCI scores showed no significant difference across gender. A concurrent study looking at the correlation of CCI with the MID and GPA with 215 students had similar results of correlation with the MID (r = .36), but less correlation with GPA (r = .18).

To test the reliability of the LEP, Moore conducted a one-week test-retest experiment with a small population (N = 30). The CCI scores had a correlation of .89, which suggests that the instrument is potentially reliable, but Moore was weary of the results because of the small sample size.

3.9. Data Analysis

Statistical analysis was performed on the percentage of response correlating with each of the four Perry positions examined by LEP and the overall CCI with respect to the different contextual factors. One-way analysis of variance (ANOVA) was used to evaluate the mean differences between groups. A factor was considered to be significant if the *p*-value was found to be less than 0.05. The effect size was also calculated in order to show the size of the impact these factors had on epistemological development. The following formula was used to calculate effect size

$$\eta 2 = \frac{Treatment\ Sum\ of\ Squares}{Total\ Sum\ of\ Squares}$$

Cohen's [189] guidelines were used to determine the magnitude of an effect size. An effect size was consider to be insignificant if less than 0.01, small if it was between 0.010 and 0.058, moderate if between 0.059 and 0.137, and large if equal to or greater than 0.138. In order for factors that had two categories to be considered for analysis, both categories had to account for at least 10% of the total population. This was done because calculating significance through ANOVA is dependent on population size. Having one group much larger than the other would skew the results to the point where it would be difficult to determine significance.

3.10. Limitations of the Proposed Research Study

The study design and results presented here have six major limitations. First, the participants of this proposed research study were undergraduate electrical and computer engineering students from the same university, therefore the results of the study may not be applicable to other universities. Secondly, the population of the study was over 80% male, therefore limiting the impact of gender differences. The third limitation was that only a limited number of students with senior standing who participated. The fourth limitation was that the evaluation of the participants' epistemological beliefs was limited to the pen-and-paper version of the Learning Environment Preferences (LEP) inventory instrument [44]. The fifth limitation of the study was that the results of the study may be subjected to self-selection bias. A potential example of this was with the participants in the second round who received extra credit as compensation. It is possible that the population was made up of lower achieving students who were looking to improve the course score. It is also possible that a significant portion of students were high achieving students whose desire to overachieve led them to participate in the student. Sixth and finally, the categories representing the domains of Theory of Integrated Domains in Epistemology (TIDE) [45] framework were chosen by the researcher and may be subjected research bias.

4. RESULTS

In this chapter I discuss the results of study and its analysis. First, I look at the study population as a whole and look at the individual factors with respect to each of the four contexts of the modified TIDE framework. Finally, I discuss the potential implications of the study results.

4.1. Overall

Overall, participants in the study had a mean CCI of 329.3 ± 45.9. The CCI values of participants ranged from a low of 247 to a high of 436. Figure 4.1 shows the distribution of responses with respect to the percentage of response corresponding to the subcategories of the LEP. Over half of students' responses correlated to Position 3 and Position 4 of Perry's framework [20]. These positions are typically associated with a person having mulitplistic epistemological beliefs. These results suggest that the engineering students tend to operate with a multiplicity epistemological view since positions three and four make up over half of the responses and are least likely to approach knowledge with a relativistic epistemological belief.

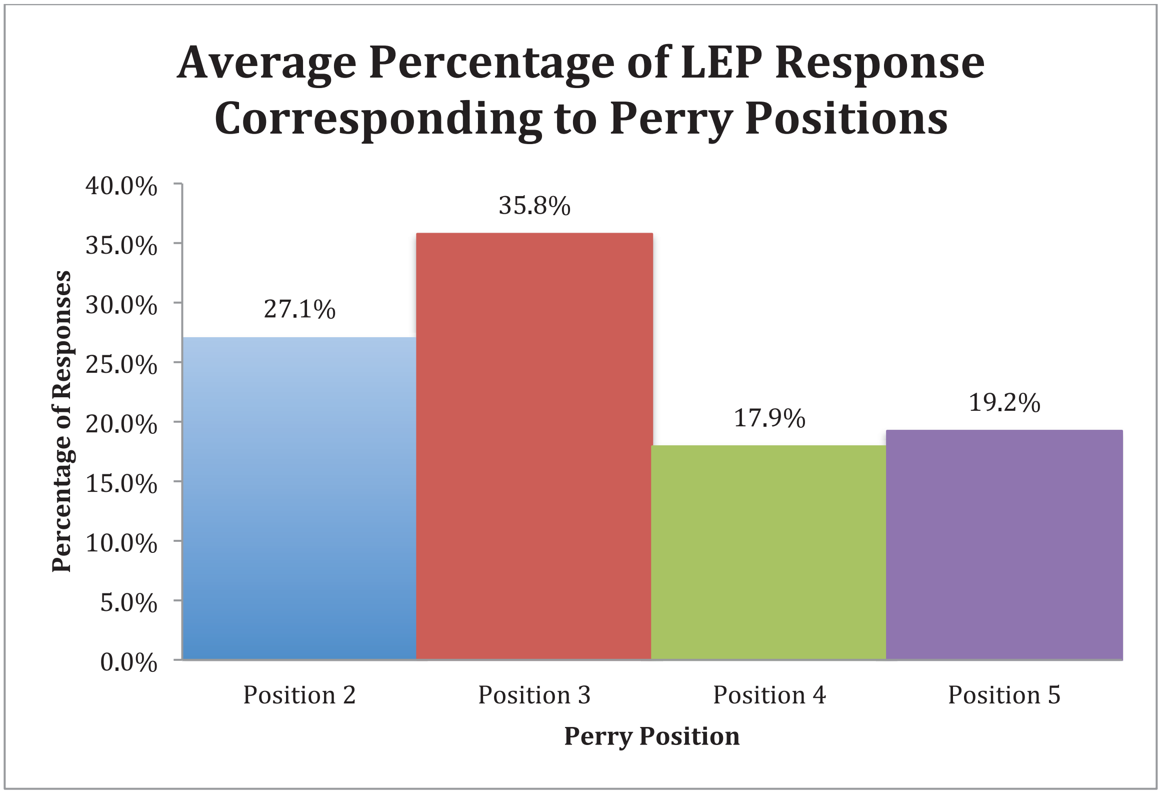

Figure 4.1: Average percentage of responses that corresponded to the Perry positions examined by the LEP

4.2. Sociocultural Context

4.2.1. Gender

Figure 4.2 shows how the participants were distributed based on gender. There were five times as many male participants (N= 176) in the study as female participants (N = 35). One participant in the study chose not to identify their gender.

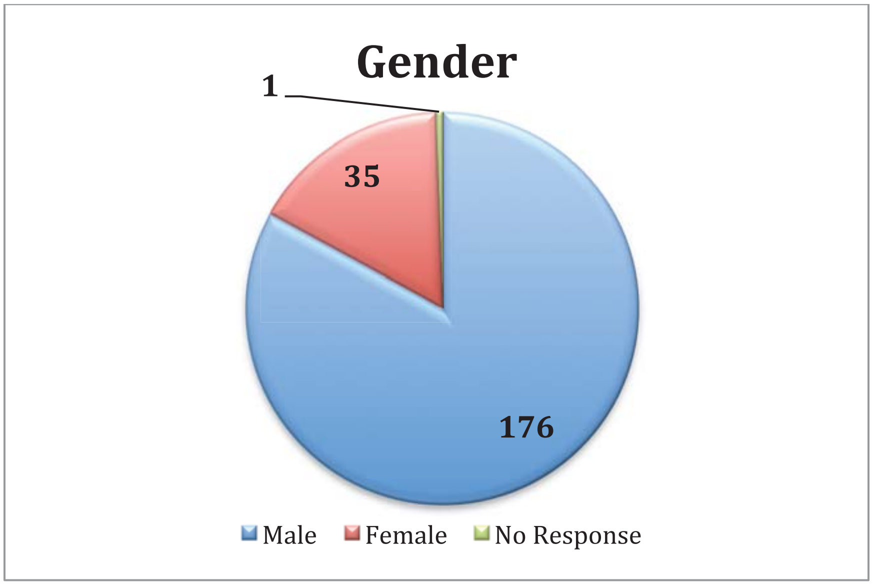

Figure 4.2: Participant distribution with respect to gender

The average CCI for participants based on gender is show in Table 4.1. The male participants in the study had an average CCI of 332.2 ± 46.1 while female participants averaged a CCI of 314.5 ± 42.9. This suggests that male electrical and computer engineering students self-identified themselves to having more advanced epistemological beliefs than their female counterparts. The subcategory distributions in Figure 4.3 show that 33.4% of female participants' responses corresponded to Position 2. Male participants had a higher percentage of responses that corresponded to the other positions with the biggest mean difference occurring for Position 4.

Table 4.1: Average CCI based on gender

Gender	Mean	Std. Dev.
Male	332.2	46.1
Female	314.5	42.9

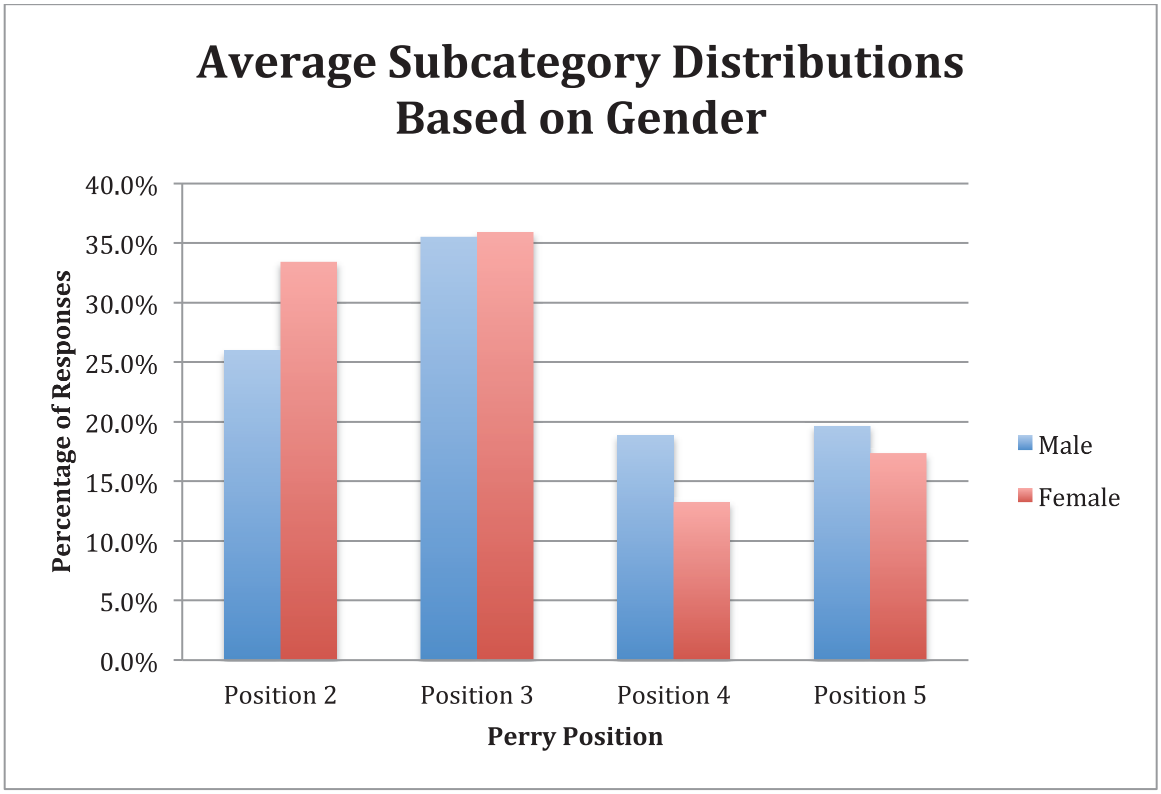

Figure 4.3: Average subcategory percentages when participants are grouped based on gender

The ANOVA results in Table 4.2 found that the difference between the average CCI for male and females to be significant [$F(1, 209) = 4.418$, $p = .037$, $\eta^2 = .021$]. This suggests that the epistemological beliefs reported by male ECE students are more complex than their female counterparts. The effect size suggests that this difference is small in nature. Male participants were also found that have to have a significantly higher number of responses correlations to Position 4 [$F(1, 209) = 4.757$, $p = .030$, $\eta^2 = .022$]. Female participants had a significantly higher percentage of LEP responses that correlated to position 2 [$F(1, 209) = 4.789$, $p = .030$, $\eta^2 = .022$]. This result suggests that female ECE students possess more dualistic beliefs.

Table 4.2: ANOVA results when results are compared based on gender

Category	SS	df	MS	*F*	*Sig*	η^2
Position 2	1625.9	1	1625.9	4.789	.030	.022
Position 3	4.476	1	4.476	.027	.871	-
Position 4	921.4	1	921.4	4.757	.030	.022
Position 5	155.9	1	155.9	1.089	.298	.005
CCI	9189.5	1	9189.5	4.418	.037	.021

4.2.2. Ethnicity

For the ethnicity factor, participants could voluntarily identify themselves with respect to one of six ethnicities. Due to this factor only being included in the second version of the background survey and some participants not providing a response, only 121of the participants responded. The participant distribution is shown in Figure 4.3. Caucasian and Asian/Pacific Islander participants made up 85% (N = 103) of the population. Only seven of the participants identified themselves as either Black/African-American (N = 4) or Hispanic/Latino (N = 3).

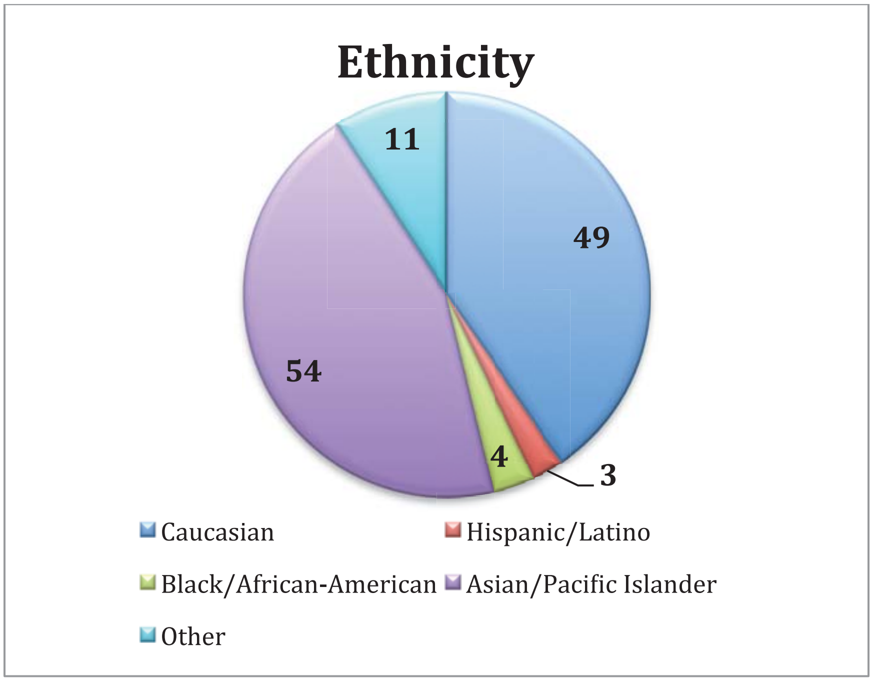

Figure 4.4: Participation breakdown with respect to ethnicity

Table 4.3 shows the average CCI with respect to ethnicity. Asian/Pacific Islander participants had the highest CCI average at 335.1 ± 43.8. This was followed by participants who identified themselves as Hispanic/Latino (334.0 ± 56.3). Both averages were at least 20 points higher than that of the Caucasian (314.0 ± 44.6), Black/African-American (309.5 ± 66.3), and participants who identified themselves as Other (300.4 ± 33.2). The subcategory distributions in Figure 4.5 show that both the Black/African-American and Other participants have the highest percentages of responses that correlated to Position 2. Asian/Pacific Islanders had the highest percentage of responses that correlate to Position 4 and Hispanic participants.

Table 4.3: Average CCI based on ethnicity

Ethnicity	Mean	Std. Dev.
Asian/Pacific Islander	335.1	43.8
Hispanic	334.0	56.3
Caucasian	314.0	44.6
Black/African-American	309.5	66.3
Other	300.4	33.2

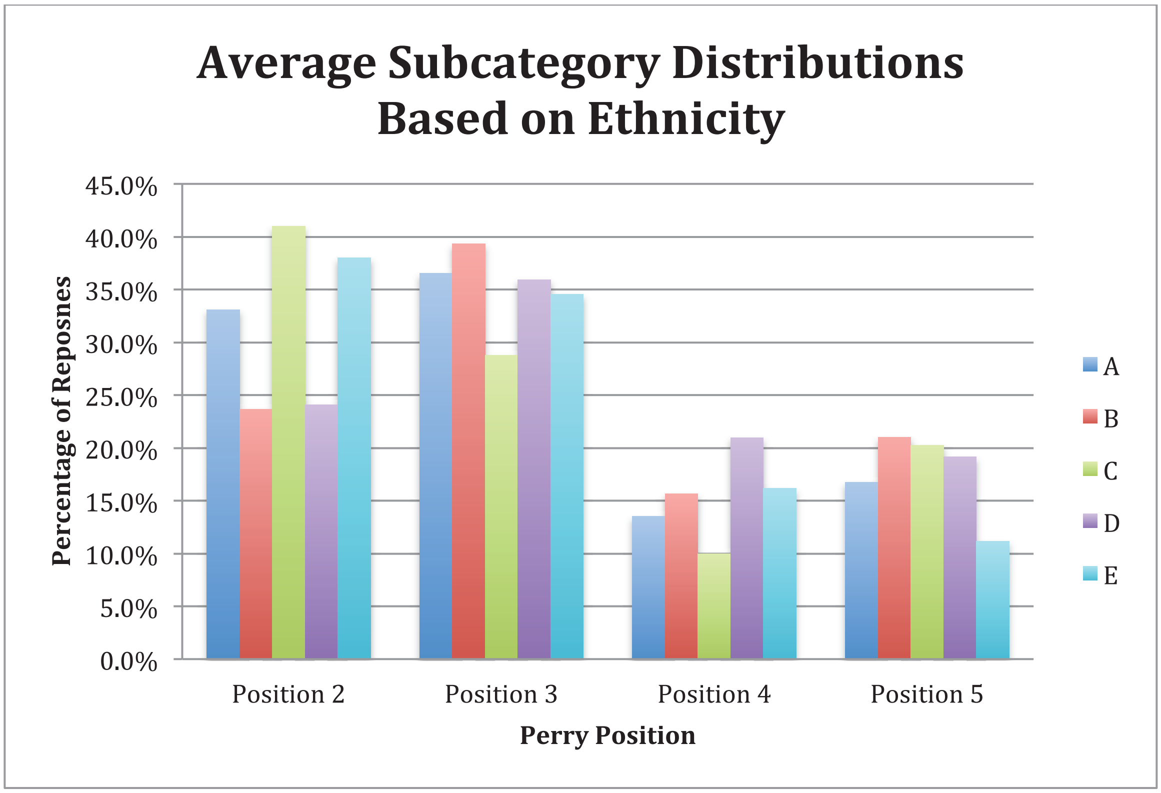

Figure 4.5: Average subcategory percentages when participants are grouped based on ethnicity

Note: A – Caucasian; B – Hispanic/Latino; C – Black/African-American; D – Asian/Pacific Islander; E – Other

When the results were analyzed using ANOVA, the mean differences for the CCI were not found to be significant [$F(4, 120) = 2.378$, $p = .056$, $\eta^2 = .073$], however the effect size suggests that there was a moderate effect. It is possible that the lack of Hispanic/Latino and Black/African-American participants contributed to this result. This could also explain the results for the Position 4 subcategory which had similar results [$F(4, 120) = 2.247$, $p = .069$, $\eta^2 = .071$]. The subcategory results in Figure 4.5 also show that the Position 2 mean differences were significant with a moderate effect size [$F(4, 120) = 2.752$, $p = .031$, $\eta^2 = .086$].

Table 4.4: ANOVA results when results are compared based on ethnicity

Category	SS	df	MS	*F*	*Sig*	η^2
Position 2	3644	4	911.0	2.752	.031	.086
Position 3	279.6	4	69.9	.505	.732	.017
Position 4	1661	4	415.3	2.247	.068	.071
Position 5	679.8	4	170.0	1.298	.275	.042
CCI	15870	4	4646	2.378	.056	.073

4.2.3. Domestic/International

The background survey also asked whether or not a participant was a U.S. citizen or permanent resident, or not. Participants who identified themselves as an international student could also provide their home country. The distributions based on responses to this question are shown in Figure 4.6. There were 114 participants who identified themselves as a U.S. citizen or permanent resident compared to 98 having citizenship outside of the U.S. China and India were the most common countries of origin for international student respondents, making up two-thirds of the international population who indicated their home country.

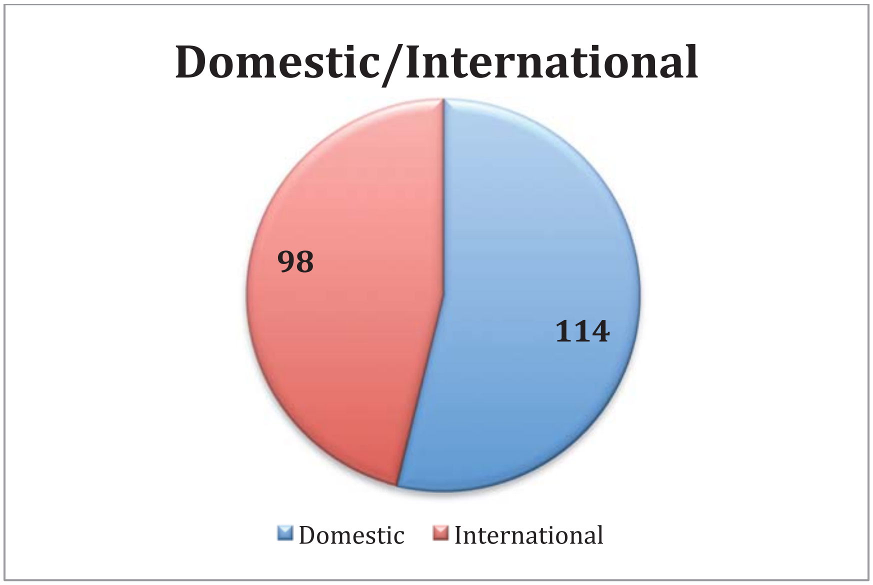

Figure 4.6: Participation breakdown with respect to if a participant is a U.S. citizen or permanent resident

The CCI results for the domestic/international category are shown in Table 4.5. Domestic participants had a lower average CCI (322.3 ± 47.3) than international students (337.5 ± 43.0). When compared with respect to the positional subcategories, shown in Figure 4.7, domestic participants had a higher percentage of response that corresponded to Position 2 and Position 3. International participants were found to have a higher percentage of responses relating to positions 4 and 5.

Table 4.5: Average CCI based on if a participant is a U.S. citizen/permanent resident

Type of Student	Mean	Std. Dev.
International	337.5	43.0
Domestic	322.2	47.3

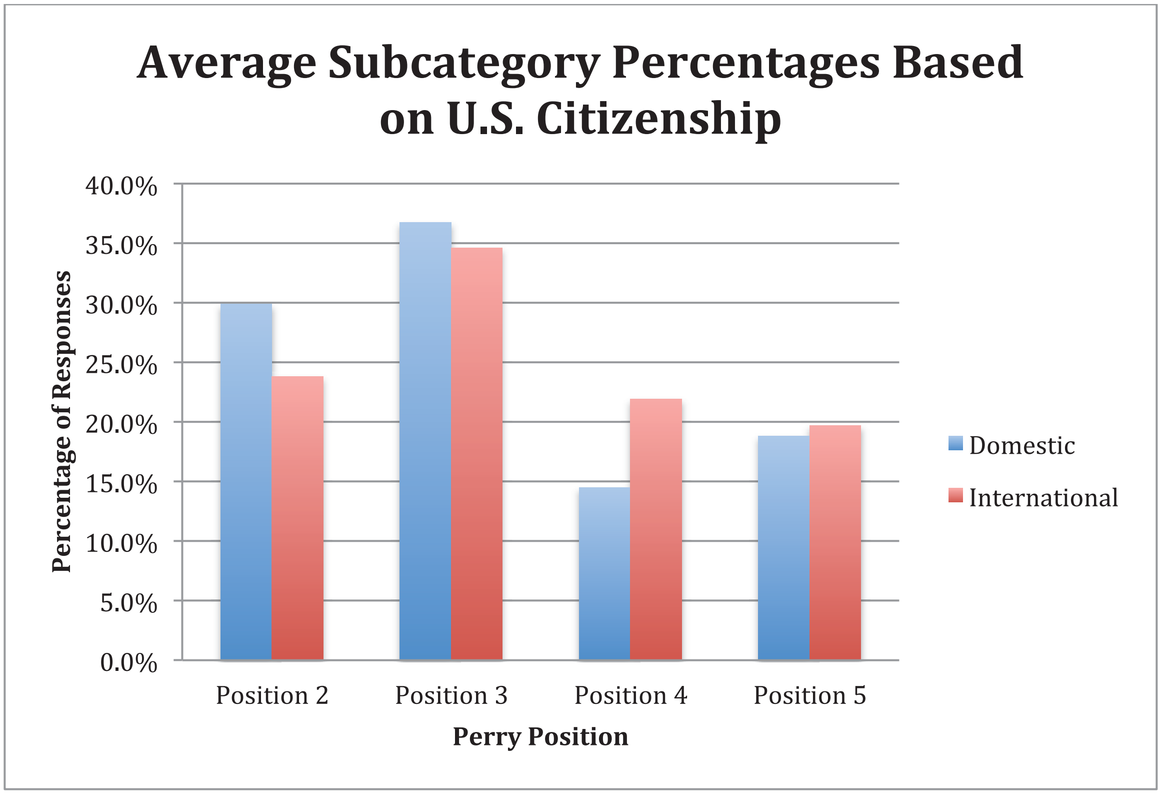

Figure 4.7: Average subcategory percentages when participants are grouped based on whether they are an U.S. citizen or permanent resident

The ANOVA results comparing the CCI and subcategories when participants were grouped based on their citizenship are shown in Table 4.6. The mean difference between the domestic and international participants for the CCI was significant [$F(1, 210) = 5.942$, $p = .016$, $\eta^2 = .028$]. The difference according to the effect size was small in nature. The analysis of the subcategories show that there were significant differences in the percentage of response correlating to Position 2 [$F(1, 210) = 5.732$, $p = .018$. $\eta^2 = .027$] and Position 4 [$F(1, 210) = 15.81$, $p < .001$, $\eta^2 = .070$]. The effect size for the Position 2 difference suggested that the difference was small in nature. The Position 4 effect size suggests that the difference between the domestic and international participants for this subcategory was moderate in size.

Table 4.6: ANOVA results when results are compared based on whether or not participants are U.S. citizens or permanent residents

Category	SS	df	MS	*F*	*Sig*	η^2
Position 2	1948.0	1	1948.0	5.732	.018	.027
Position 3	243.8	1	243.8	1.402	.238	.007
Position 4	2900.0	1	2900.0	15.81	< .001	.070
Position 5	42.5	1	42.5	.297	.586	-
CCI	12215.8	1	12215.8	5.942	.016	.028

When looking at the participants with respect to whether they were domestic or international students, I noticed that the domestic students seemed to consist of certain ethnicities while the international students were made up of other ethnicities. Table 4.7 shows the ethnic distribution for both categories. All but one of the Caucasian participants were domestic students, while just under 80% of the Asian/Pacific Islander participants were international students. This led me to evaluate a regression analysis on the CCI and subpositions scores with respect to the domestic/international and ethnicity dimensions. The results show that the domestic/international dimension was significant predictor for the Position 2 mean difference [$\beta_{dom\_int} = 25.394$, $p = .037$], but ethnicity was not [$\beta_{ethnicity} = -1.751$, $p = .554$].

Table 4.7: Ethnic distribution for domestic and international participants

Ethnicity	Domestic	International
Asian/Pacific Islander	11	43
Hispanic	1	2
Caucasian	48	1
Black/African-American	4	-
Other	2	9

4.2.4. Neighborhood

As mentioned earlier, students who participated in the second round of the study provided responses to questions about the neighborhood environment in which participants grew up, their parents' levels of education, and their family's income level. The results with respect to the neighborhood are shown in Figure 4.8. There were just as many students from urban communities as suburban communities. A small number or participants (N = 9) identified a rural community.

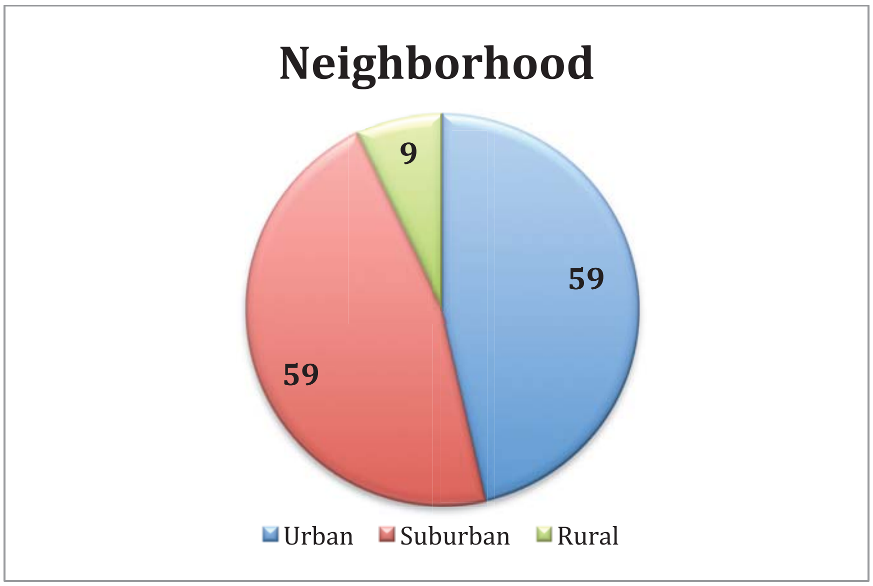

Figure 4.8: Participant distribution with respect to childhood neighborhood

The average CCI results in Table 4.8 show that students from an urban community had the highest average CCI at 329.6 ± 47.6. Figure 4.9 shows that the urban participant also averaged the most responses with respect to Position 4 and averaged the fewest with respect to Position 2. The suburban participants had the highest percentage of responses in relation to Position 3 and fell in the middle for the other position. While the participants from rural communities had the lowest average CCI (310.6 ± 41.2), they also had the highest percentage of response correspond to Position 5.

Table 4.8: Average CCI based on the neighborhood the participants grew up in

Neighborhood	Mean	Std. Dev.
Urban	329.6	47.6
Suburban	322.2	46.5
Rural	310.6	41.2

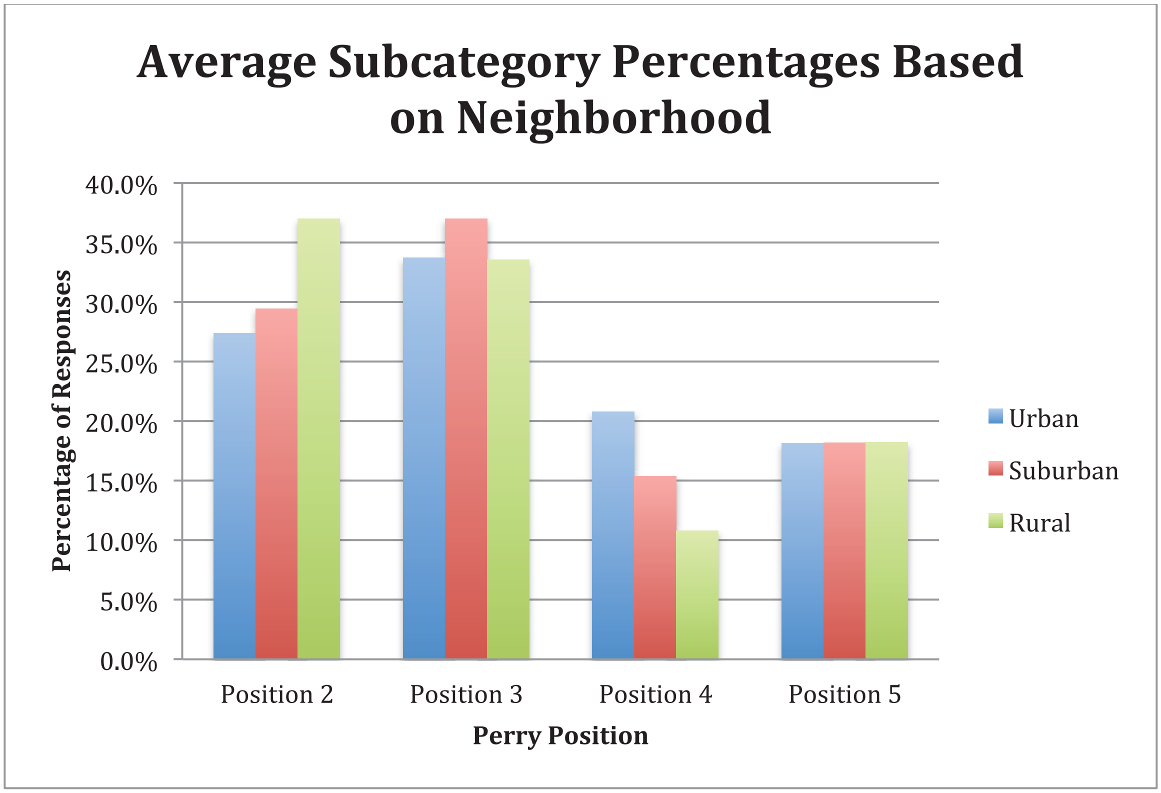

Figure 4.9: Average subcategory percentages when participants are grouped based on neighborhood

When analyzing the significance of the mean differences with respect to community, the results, shown in Table 4.9, the CCI differences were not found to be significant as well as three of the subcategories. The only mean difference that was found to be significant was the subcategory position that was significant was Position 4 [F(210) = 3.550, p = .032, η^2 = .054]. The effect size suggests that the neighborhood an individual comes from may play a role in how the epistemological beliefs develop.

Table 4.9: ANOVA results when results are compared based on the environment students grew up in.

Category	**SS**	**df**	**MS**	***F***	***Sig***	**η^2**
Position 2	741.2	2	370.6	1.069	.346	.017
Position 3	349.6	2	174.8	1.210	.302	.014
Position 4	1314.3	2	657.1	3.550	.032	.054
Position 5	.074	2	.037	0.000	1.000	-
CCI	3599.5	2	1799.8	0.837	.435	.013

4.2.5. Parents' education

Participants selected from 11 different educational outcomes ranging from no formal education to earning a Ph.D. These were combined into six categories for analysis, which are shown in Table 4.10. Groups will be referred to by the alternate representation for the remainder of this section.

Table 4.10: Education levels examined

Education Level	**Pseudonym**
Did Not Complete High School	A
High School Diploma/GED	B
Trade/Associate's Degree	C
Bachelor's Degree	D
Master's Degree	E
Terminal Degree	F

The distributions of participants based on the educational levels of their fathers are displayed in Figure 4.10. Over 80% of the participants who responded had a father who had at least obtained a bachelor's degree and almost half (N = 49) had earned at least a master's degree. This suggests that the participants in the study come from families where the father is well educated.

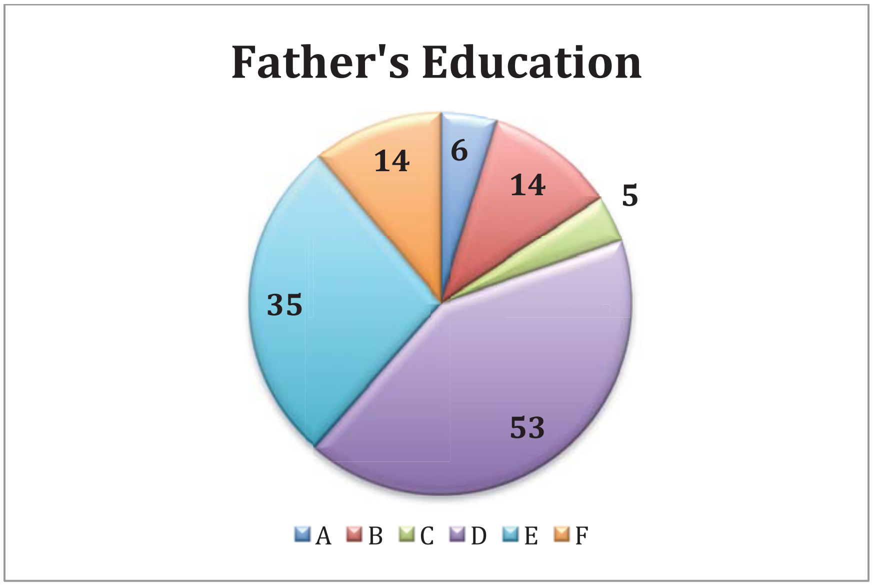

Figure 4.10: Participant breakdown with respect to father's education level

Table 4.11 shows that group C had the highest average CCI (333.6 ± 58.3) followed by groups D (330.9 ± 51.0) and A (323.7 ± 53.0). The lack of participants in groups A and C likely played a role in the results. Having a father with more formal education seemed to be a disadvantage as two of the three lowest scoring groups had fathers who earned at least master's degree. When the CCI results were analyzed using ANOVA, the mean difference was not found to be significant.

Table 4.11: Average CCI based on the education level of the participant's father

Educational Level	Mean	Std. Dev.
C	333.6	58.3
D	330.9	51.0
A	323.7	53.0
E	320.2	35.8
B	318.1	48.5
F	317.1	46.7

The response distributions with respect to the positional subcategories are shown in Figure 4.11. Group B had the highest percentage of responses correlating to Position 2 while Group D had the lowest. Group C had the most responses relating to Position 5, but this may have been due to a small sample size. Groups E and F had the lowest percentages for Position 5, which was surprising considering they represented having fathers with more formal education. However, groups F and E had the most responses for Position 3 and Position 4 respectfully. Like the CCI, none of the subcategory differences were found to be significant.

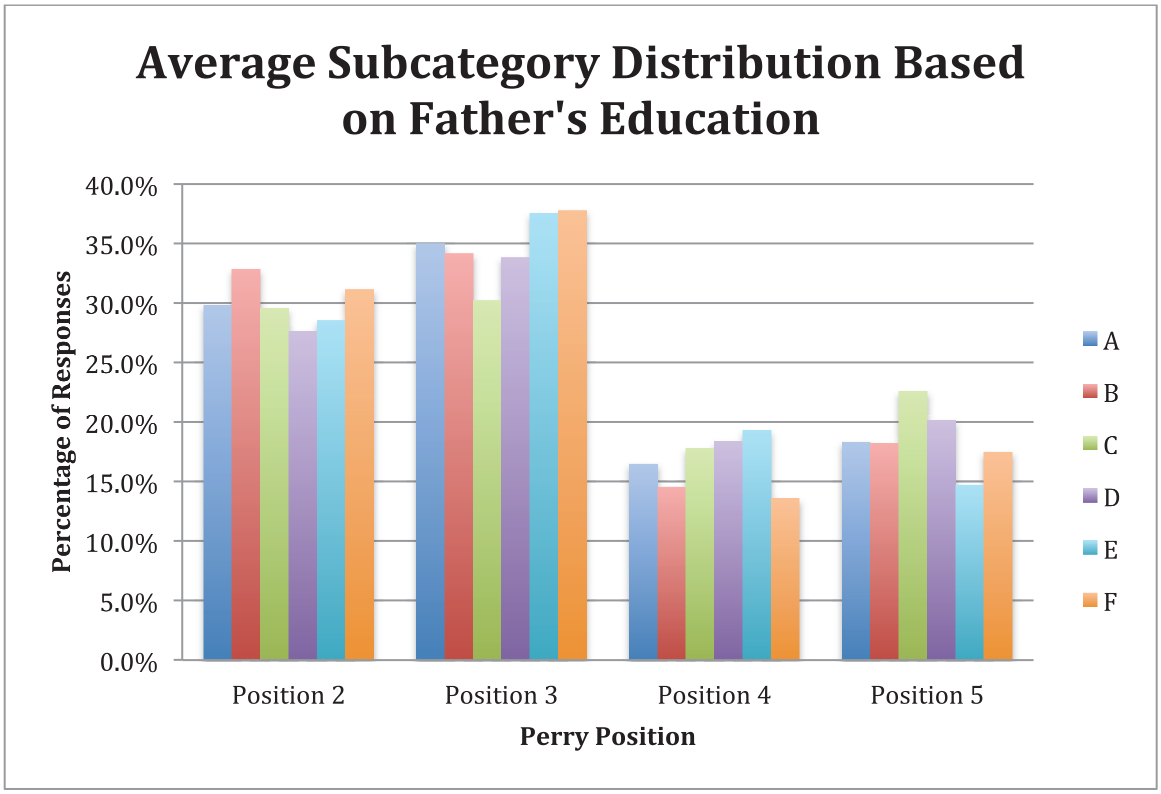

Figure 4.11: Average subcategory percentages when participants are grouped based on father's education level

Table 4.12: ANOVA results when results are compared based on the education level of participants' father

Category	SS	df	MS	*F*	*Sig*	η^2
Position 2	381.8	5	76.36	.213	.956	.009
Position 3	525.9	5	105.2	.718	.611	.029
Position 4	494.4	5	98.89	.503	.773	.020
Position 5	730.5	5	146.1	.998	.422	.040
CCI	4586.3	5	917.3	.418	.836	.017

Figure 4.12 shows how the participants were grouped with respect to their mother's educational level. The distribution was similar to that of the educational level of the participant's father. Almost 80% (N = 101) of the participants in the study had a mother who had earned at least a bachelor's degree. Only four participants had a mother who did not complete high school.

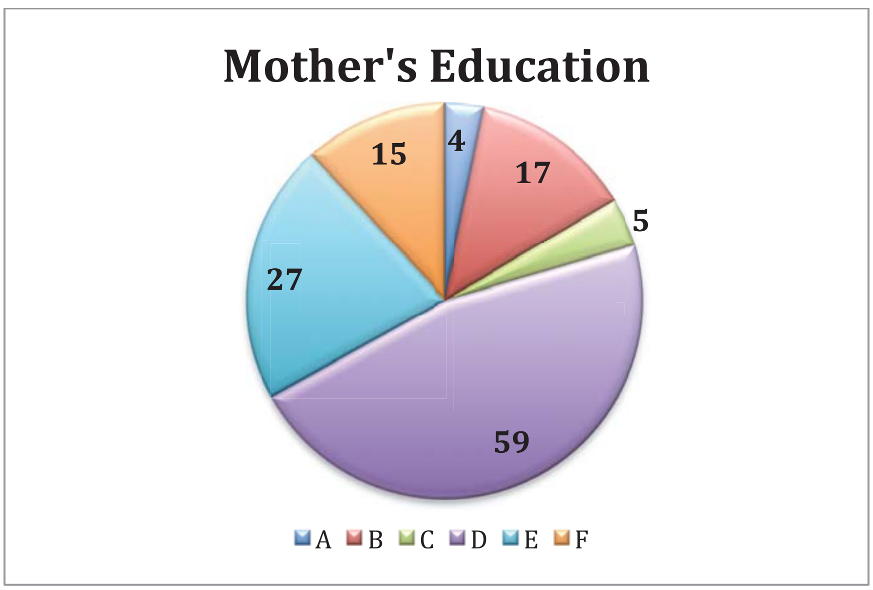

Figure 4.12: Participant distribution with respect to mother's education level

Table 4.13 shows the average CCI for the participants when group by their mother's education level. The results were somewhat reversed as Group F had the highest average CCI at 336.7 ± 36.4 while Group C had the lowest average CCI at 305.2

± 37.1. The top three CCI averages were scored by all of the groups whose mother completed at least a bachelor's degree. When the subcategory results were examined, participants in group A had the highest percentage of response for both Position 2 and Position 5. This was probably due to there being only four participants in the group. Figure 4.13 shows that group F had the highest percentage of responses correlating position 3 and group E had the most responses relating to position 4. None of the subcategory mean differences were found to be significant by ANOVA, suggesting that the mother's education level did not impact the response distributions.

Table 4.13: Average CCI based on the education level of the participant's mother

Education Level	Mean	Std. Dev.
F	336.7	36.4
E	330.6	50.0
D	323.0	48.3
B	318.9	46.7
A	316.8	40.1
C	305.2	37.1

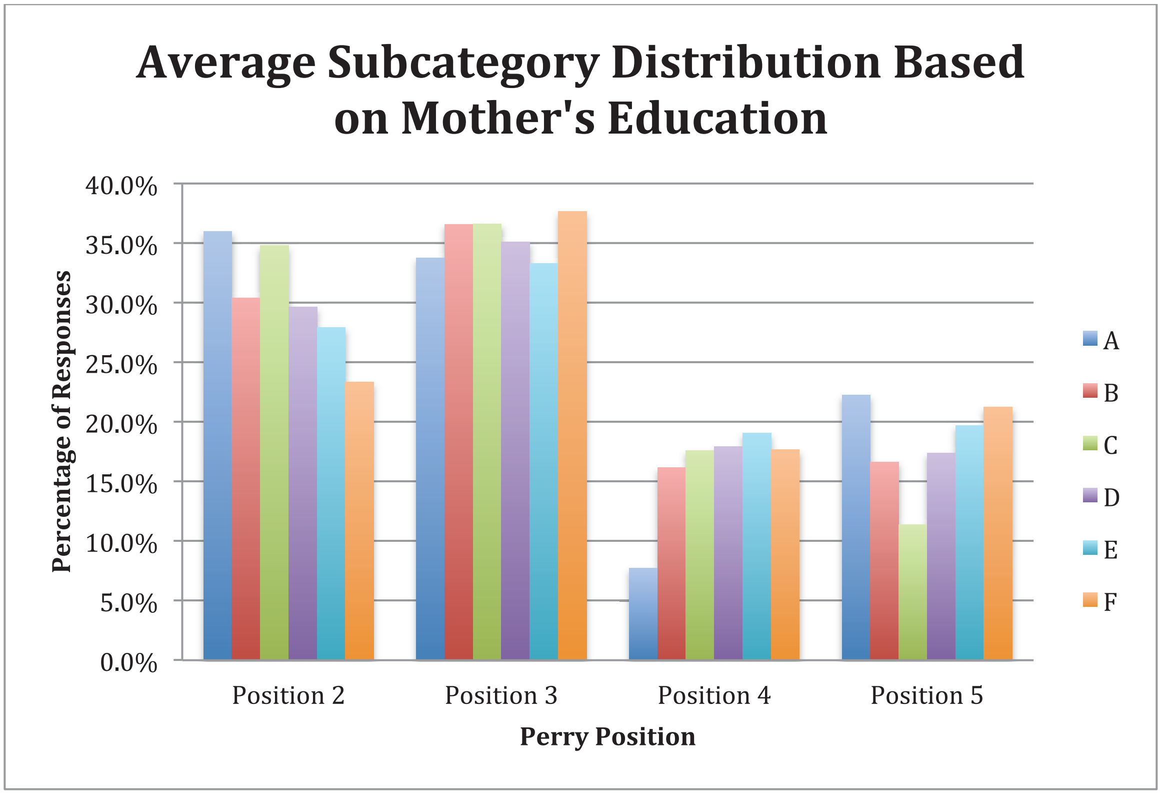

Figure 4.13: Average subcategory percentages when participants are grouped based on mother's education level

Table 4.14: ANOVA results when results are compared based on the education level of participants' mother

Category	SS	df	MS	*F*	*Sig*	η^2
Position 2	994.0	5	186.8	.528	.754	.021
Position 3	240.5	5	48.10	.323	.898	.013
Position 4	487.0	5	97.40	.496	.779	.020
Position 5	578.4	5	155.7	.783	.564	.031
CCI	6008.4	5	1201.7	.550	.738	.022

4.2.6. Income

The second version of the background survey also asked to voluntarily report their family income level with respect to eight different salary ranges. These were then grouped into four income brackets based on groupings of Gilbert [190]: low income (<$40,000), lower middle income ($40,000 - $99,000), upper middle income ($100,000 - $149,999) and high income (>$150,000). The participant breakdown with respect to income is shown in Figure 4.14. A total of 81 participants reported their family income. The most common family income level was the upper middle class (N = 26) followed by the lower middle income (N = 25) and high income (N = 21) levels. Only nine participants reported that they came from a low-income household.

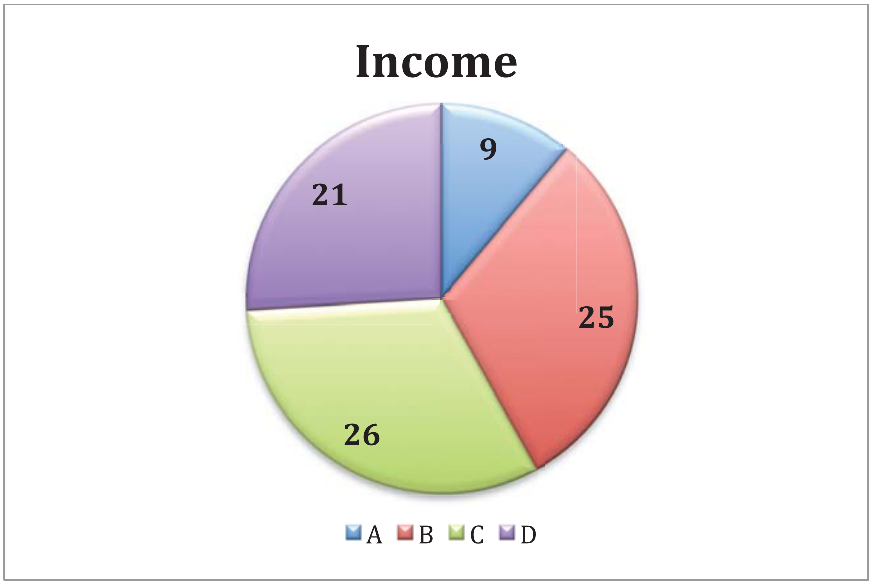

Figure 4.14: Participant distribution with respect to family income
Note: A – Low Income; B – Lower Middle Income; C – Upper Middle Income; D – High Income

The results in Table 4.15 show that the average CCI mostly increased as the family income level increased. Participants from low-income families had the lowest average CCI of the three groups (317.3 ± 58.9), while those from high-income families had the highest average CCI (327.7 ± 430). While the lower middle-income participants had a higher average CCI (325.0 ± 56.2) than those from a upper middle income family (324.6 ± 42.7), the difference was less than half a point.

The participant distribution across CCI ranges is shown in Figure 4.15. Every group had one position where it had highest percentage of responses. Low income and upper middle-income participants had the most response relating to the lower positions while the lower middle income and high-income participants were more likely to have responses correlating to the higher positions. Analysis using ANOVA did not find any of the subcategories or the CCI mean differences to be significant suggesting that family income level does not affect learning preferences.

Table 4.15: Average CCI based on family income

Income Level	Mean	Std. Dev.
D	327.7	43.0
B	325.0	56.2
C	324.6	42.7
A	317.3	58.9

Note: A – Low Income; B – Lower Middle Income; C – Upper Middle Income; D – High Income

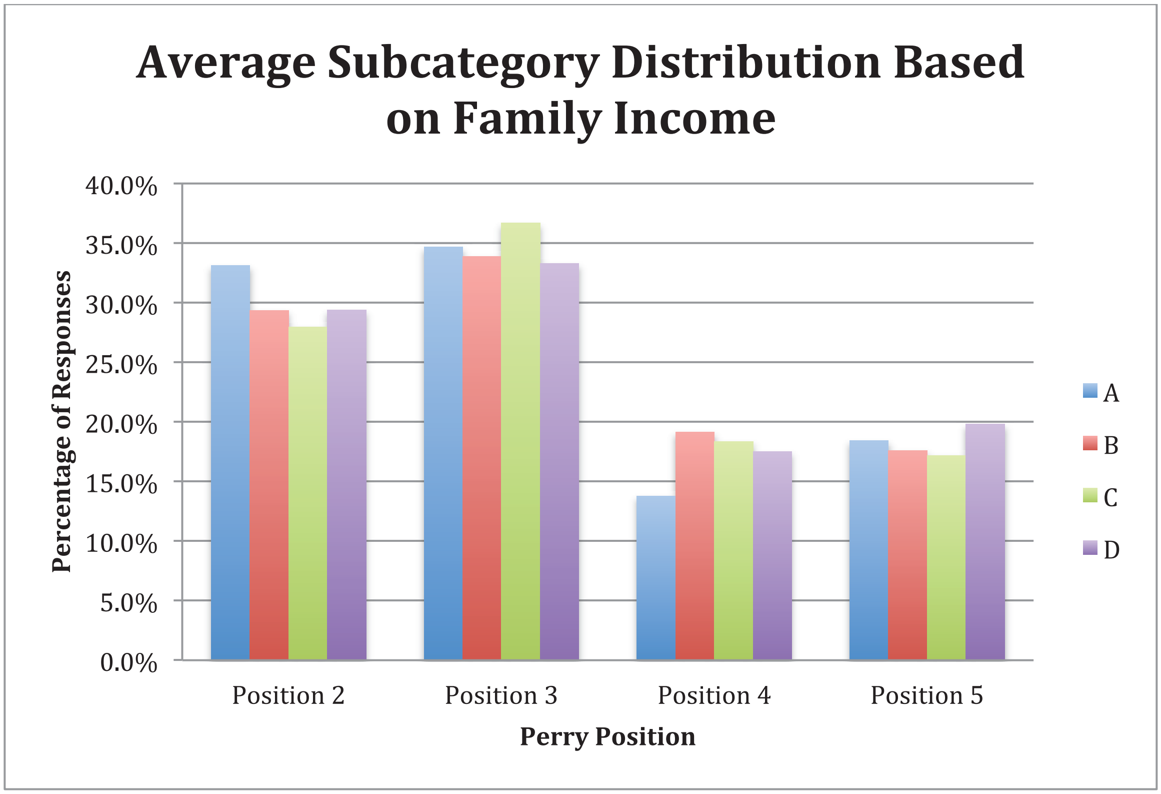

Figure 4.15: Average subcategory percentages when participants are grouped based on family income

Note: A – Low Income; B – Lower Middle Income; C – Upper Middle Income; D – High Income

Table 4.16: ANOVA results when results are compared based on income level

Category	**SS**	**df**	**MS**	***F***	***Sig***	**η^2**
Position 2	241.7	3	120.9	.332	.718	.001
Position 3	642.5	3	321.3	2.011	.141	.049
Position 4	253.8	3	126.9	.579	.563	.015
Position 5	630.0	3	315.0	2.003	.142	.049
CCI	6360.9	3	3180.4	1.375	.259	.034

4.3. Academic Context

4.3.1. Academic classification

For this study, participants self reported their academic classification with respect to the university as well as the ECE department. Figure 4.16 shows the distributions of the participants with respect to the university classification. Sophomores made up the largest grouping of participants (N = 89) followed by juniors (N = 85). Only 38 of the participants in the study identified themselves as seniors.

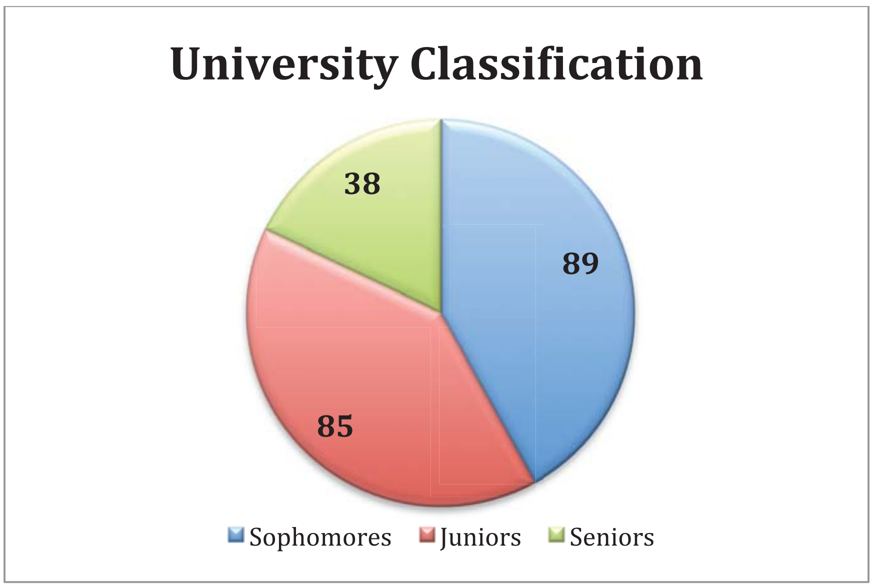

Figure 4.16: Participant distribution with respect to university classification

The CCI results for each academic classification are shown in Table 4.17. Seniors had the highest average CCI at 331.7± 44.1. However, this is only a couple of points greater than the averages for both sophomores (328.2 ± 48.4) and juniors (329.4 ± 44.3). The subcategory results in Figure 4.17 show that sophomores had the highest percentage of responses relate to positions two and four, juniors had the highest percentage relating to Position 3, and seniors had the highest percentage correlating with Position 5.

Table 4.17: Average CCI based on university classification

Classification	Mean	Std. Dev.
Seniors	331.7	44.1
Juniors	329.4	44.3
Sophomores	328.2	48.4

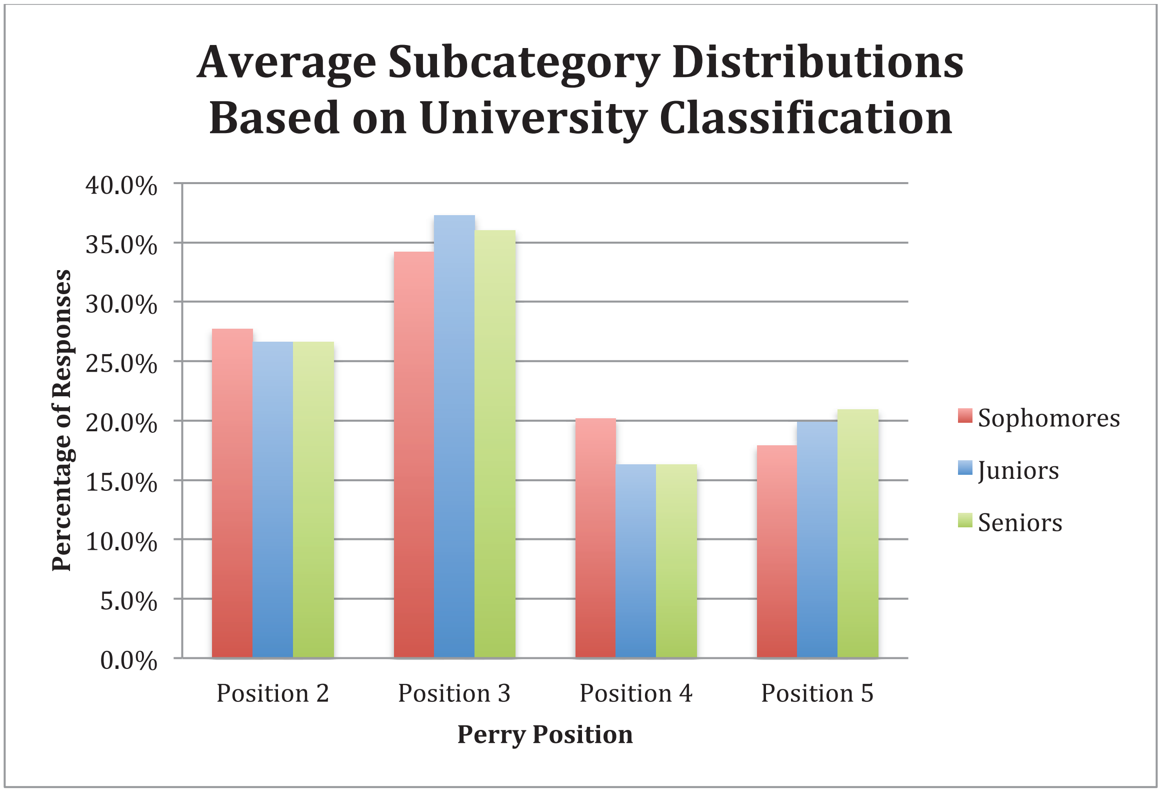

Figure 4.17: Average subcategory percentages when participants are grouped based on university classification

The ANOVA for the CCI suggests there is no significant difference in epistemological development by academic level for electrical and computer engineering students. This contradicts the results of previous studies [42], [43], which found significant growth for engineering students as they progressed through their academic career. Table 4.18 also shows that none of the subcategories had a significant difference. However, the effect sizes for positions 3, 4 , and 5 do suggest that there was a small difference between the different classifications.

Table 4.18: ANOVA results when results are compared based on participants' university classification

Category	SS	df	MS	*F*	*Sig*	η^2
Position 2	61.4	2	30.7	.088	.916	-
Position 3	406.4	2	203.2	1.169	.313	.011
Position 4	777.0	2	388.5	1.998	.138	.019
Position 5	307.3	2	153.7	1.076	.343	.010
CCI	319.0	2	159.5	.075	.928	-

4.3.2. Research experience

Figure 4.18 shows participant distributions based on if they had any research experience. Fifteen percent (N = 32) of participants in the study had conducted at least one semester of academic research. This implies that engineering students are not very likely to participate in undergraduate research and would miss out on any potential, associated benefits with respect to the development of epistemological beliefs.

Figure 4.18: Participant distribution with respect to research experience

Table 4.19 shows that the participants with research experiences had an average CCI of 330.3 ± 42.9. This was slightly larger than the average for participants who did not have any research experience (329.1 ± 46.5). When the results were compared using ANOVA, the difference in the average CCI was not significant [$F(1, 210) = .017$, $p = .895$, $\eta^2 = .000$]. The results suggest that research experience may not influence the development of the epistemological beliefs of electrical and computer engineering students.

The positional subcategories show that participants with research experience had a higher percentage of responses that corresponded to positions three and four of Perry's scheme. Like the CCI, the ANOVA results for the positional subcategories, shown in Table 4.20, suggest that none of the differences were significant in nature.

Table 4.19: Average CCI based on the participants' research experience

Research Exp.	Mean	Std. Dev.
Yes	330.3	42.9
No	329.1	46.5

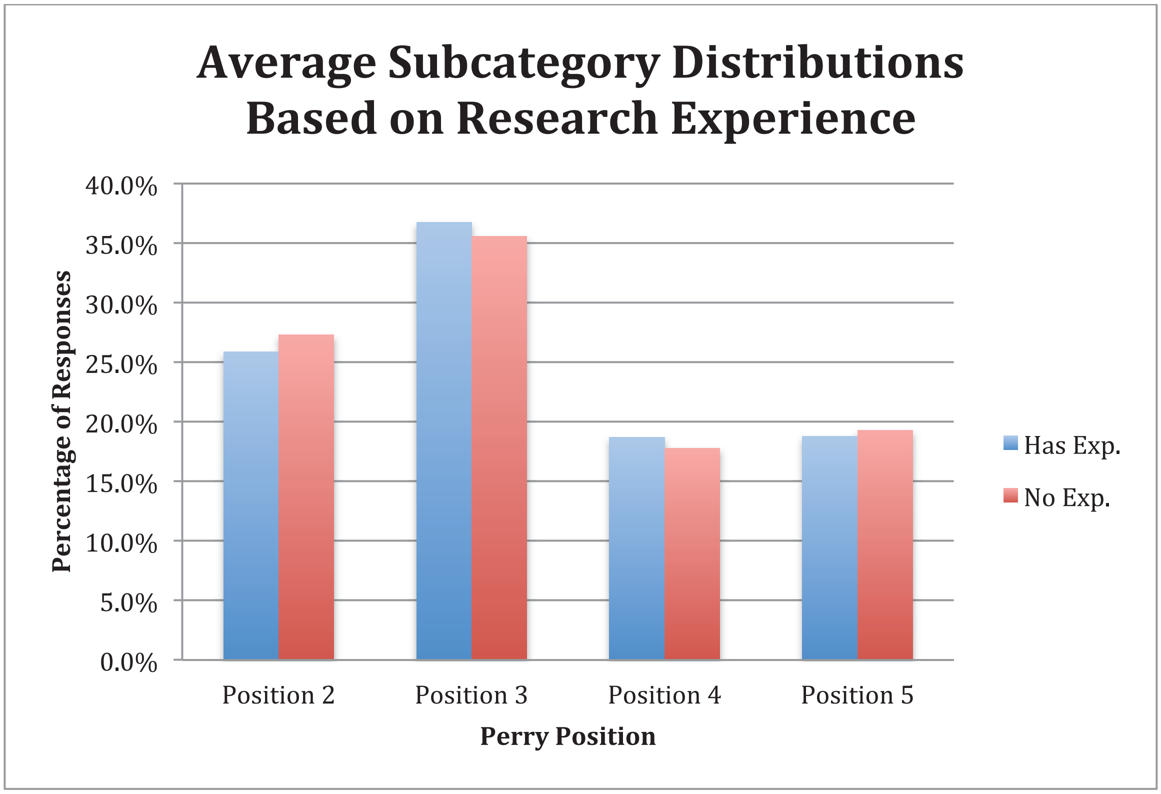

Figure 4.19: Average subcategory percentages when participants are grouped based on research experience

Table 4.20: ANOVA results based on research experience

Category	SS	df	MS	*F*	*Sig*	η^2
Position 2	54.32	1	54.32	.156	.694	-
Position 3	36.28	1	36.28	.208	.649	-
Position 4	21.67	1	21.67	.110	.741	-
Position 5	7.628	1	7.628	.053	.818	-
CCI	36.85	1	36.85	.017	.895	-

4.3.3. Transfer credits

Figure 4.20 shows how the participants were distributed when they were grouped based on if they had any transfer credits. Less than 25% of the participants (N = 51) reported that they had earned some type of transfer credit by the time they participated in the study.

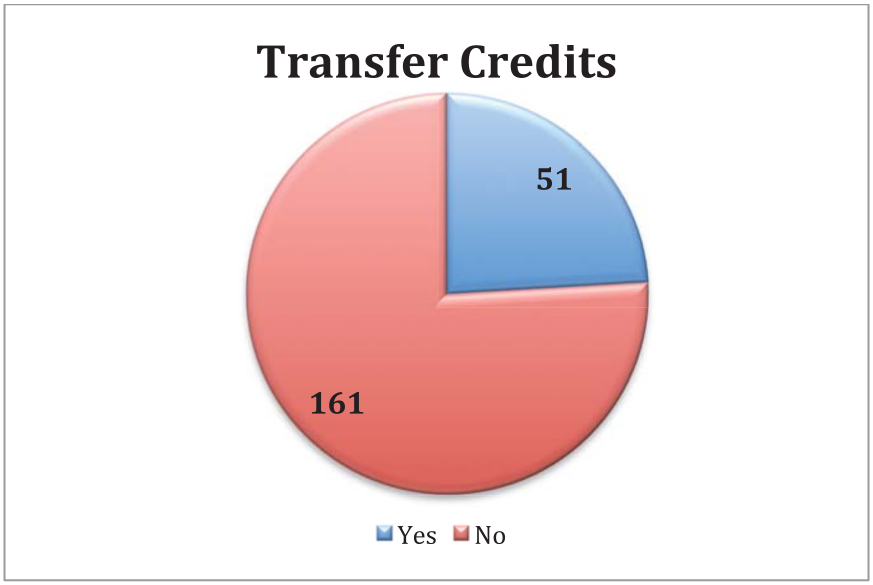

Figure 4.20: Participant distribution with respect to transfer credits

The average CCI values with respect to transfer credits are shown in Table 4.21. Participants with transfer credits had an average CCI of 327.4 ± 46.8, which was lower than the CCI average for participants who had no transfer credits (329.9 ± 45.7). This difference was not significant according to the ANOVA results [$F(1, 210) = 0.115$, $p = .735$, $\eta^2 = .000$]. The positional subcategories averages in Figure 4.21 were mixed as participants with transfer credits had a higher percentage of responses correlate to Position 2 and Position 4 while those with no transfer credits had more responses relating to positions three and five. Like the CCI, none of the subcategory mean differences were found to be significant.

Table 4.21: Average CCI based on the if participants earned transfer credits

Transfer Cred.	**Mean**	**Std. Dev.**
No	329.9	45.7
Yes	327.4	46.8

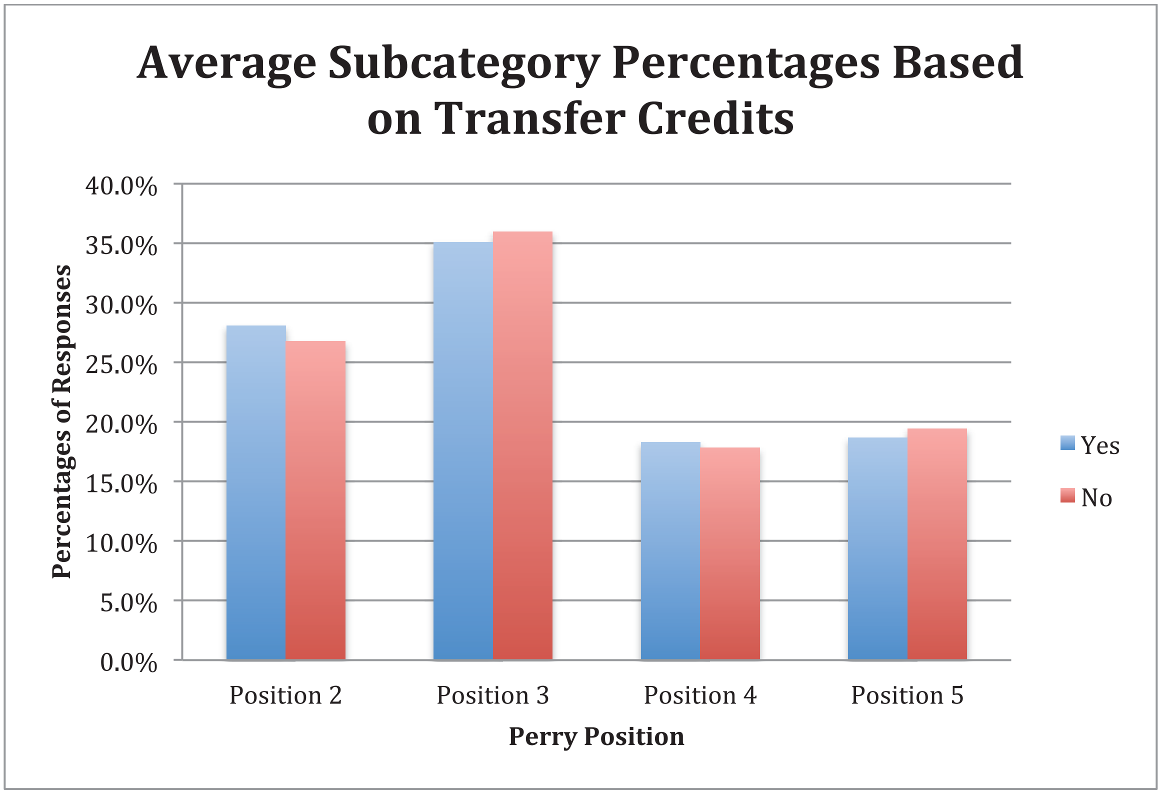

Figure 4.21: Average subcategory percentages when participants are grouped based on transfer credits

Table 4.22: ANOVA results based on if participant earned any transfer credits

Category	SS	df	MS	*F*	*Sig*	η^2
Position 2	67.55	1	67.55	.194	.660	-
Position 3	32.01	1	32.01	.183	.669	-
Position 4	8.941	1	8.941	.045	.832	-
Position 5	21.40	1	21.40	.149	.700	-
CCI	242.5	1	242.5	.115	.735	-

4.3.4. Major

As part of the LEP, participants were supposed to indicate whether they were a computer or electrical engineering major. The participant distribution for major are shown in Figure 4.22. There were more computer engineering majors (N =111) in this study than were electrical engineering majors (N = 92). Nine of the participants provided their department instead of their major and were not included.

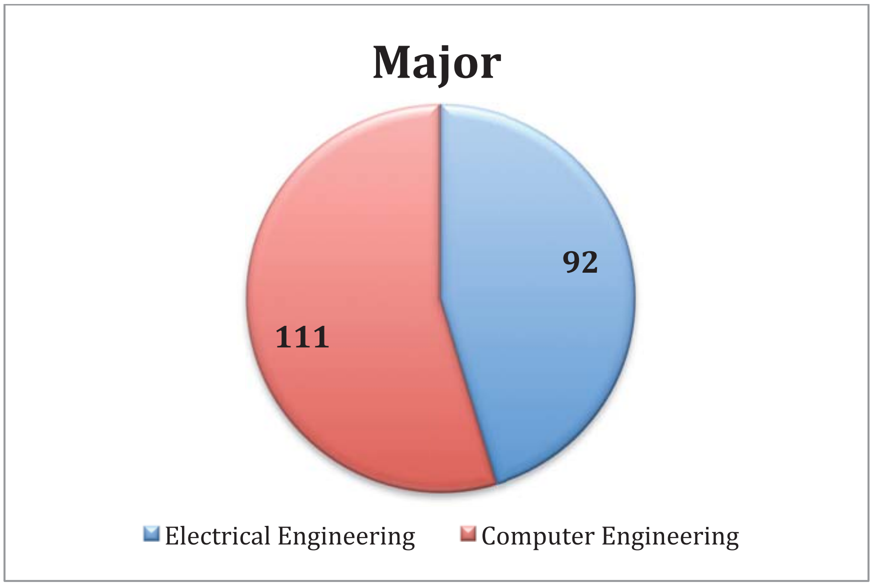

Figure 4.22: Participant distribution with respect to major

Table 4.23 shows the average CCI for both majors. Electrical engineering participants had a higher average CCI (332.5 ± 45.2) than the computer engineering participants (324.4 ± 45.2). The subcategory results in Figure 4.23 show that computer engineering participants had a higher percentage of responses corresponding to positions two and three of Perry's scheme. Electrical engineering participants have a higher percentage of beliefs that correspond to Position 5 (20.7% vs. 17.4).

Table 4.23: Average CCI based on the if participants' major

Major	Mean	Std. Dev.
Electrical Engineering	332.5	45.2
Computer Engineering	324.4	45.2

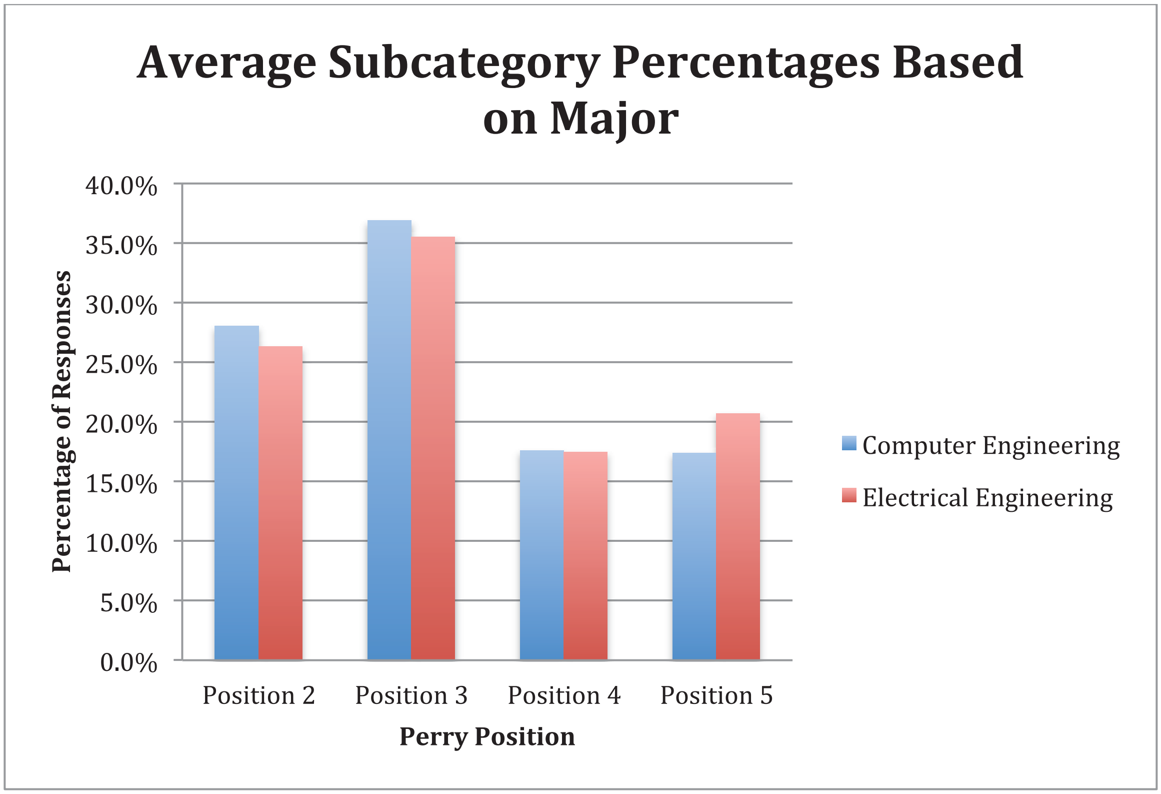

Figure 4.23: Average subcategory percentages when participants are grouped based on major

When the results for computer and electrical engineers are compared using ANOVA, the differences in average CCI were not found to be significant [$F(1, 210) = 1.646$, $p = .201$, $\eta^2 = .008$]. This suggests that while electrical engineering participants self-reported having more advanced beliefs, they are comparable to that of computer engineers. The only subcategory where the mean difference was found to significant was Position 5 [$F(1, 210) = 3.924$, $p = .049$, $\eta^2 = .019$]. This suggests that being an electrical engineering major may be associated with having more relativistic epistemological beliefs.

Table 4.24: ANOVA results based on major

Category	SS	df	MS	*F*	*Sig*	η^2
Position 2	150.2	1	150.2	.432	.512	.002
Position 3	92.95	1	92.95	.548	.460	-
Position 4	.681	1	.681	.004	.952	-
Position 5	548.2	1	548.2	3.924	.049	.019
CCI	3367.1	1	3367.1	1.646	.201	.008

4.3.5. GPA

The background survey also allowed participants to voluntarily provide their overall GPA as well as their departmental GPA. The participants were split into three groups, below a 3.0, between a 3.0 and 3.5, and at or above a 3.5. Figure 4.24 shows how the participants are distributed based on their university GPA. A total of 151 participants in the study reported their university GPA. The percentage of students with a GPA below a 3.0 (27.8%) and between 3.0 and a 3.5 (28.5%) were almost equal. However, the populations were both smaller than that of participants with a GPA at or above a 3.5 (43.7%). The distribution differed from the overall population (which had 36.7% of students below a 3.0, 28.3% between a 3.0 and a 3.5, and 35.0% at or above a 3.5), in that it included more students with a higher GPA. This may have been because it included more sophomores who would not have taken advanced courses that may have caused their GPA to decrease. Another possible explanation is that higher achieving students were more likely to participate in the study, either as an elective activity or for extra credit.

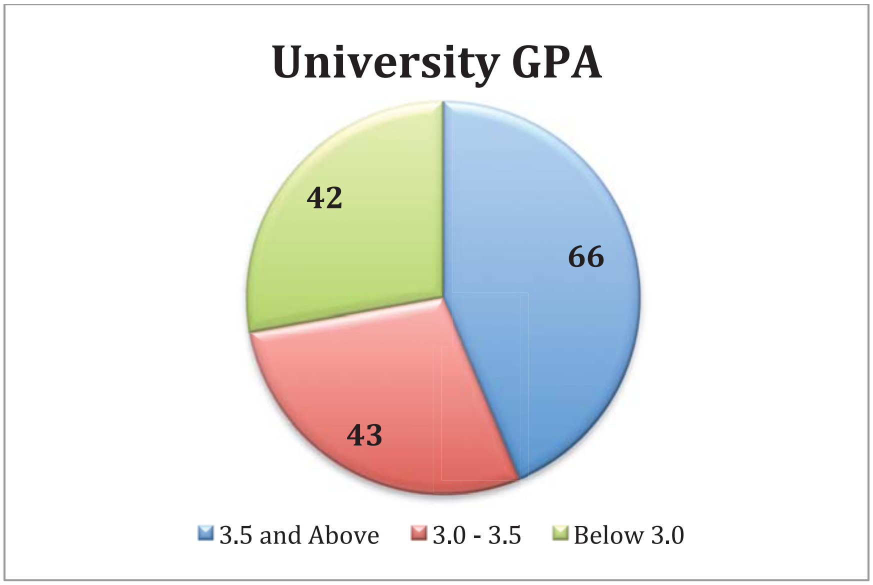

Figure 4.24: Participation distribution based on university GPA

Table 4.25 shows that the average CCI for participants with a GPA 3.5 and above was 333.5 ± 48.3. This was greater than the average CCI for the participants between a 3.0 and a 3.5 (322.7 ± 40.2) and those below a 3.0 (320.9 ± 42.7). For Position 2 and Position 3, the largest percentage of response came from students with GPA's below a 3.0 and participants with a GPA 3.5 and above scored the lowest percentage. Figure 4.25 shows that the order was reversed for the Position 4 and Position 5 subcategories as participants with a GPA at or above a 3.5 had the highest percentage of responses.

Table 4.25: Average CCI based on the participants' university GPA

GPA	Mean	Std. Dev.
3.5 and Above	333.5	48.3
3.0 – 3.5	322.7	40.2
Below 3.0	320.9	42.7

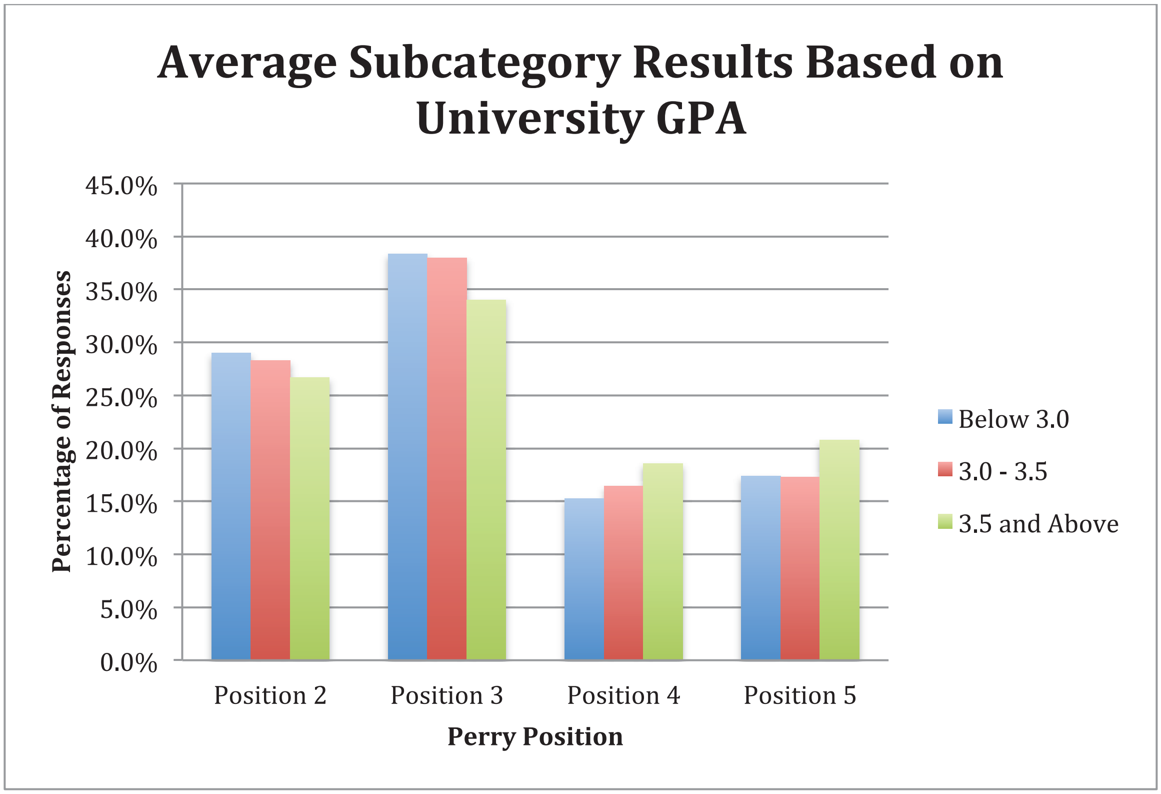

Figure 4.25: Average subcategory percentages when participants are grouped based on university GPA

The ANOVA results in Table 4.26 show that the CCI difference for participants with respect to university GPA was not found to be significant [$F(2,149) = 1.340$, $p = .265$, $\eta^2 = .025$]. However, the effect size suggests that having a higher GPA had a small effect on CCI. None of the subcategories were found to be significant with the Position 3 subcategory being ignored since it failed Levene‘s Test for Equality of Variances test.

Table 4.26: ANOVA results based on university GPA

Category	**SS**	**df**	**MS**	***F***	***Sig***	**η^2**
Position 2	155.0	2	77.51	.236	.790	.003
Position 4	308.6	2	154.3	.798	.453	.010
Position 5	437.8	2	218.9	1.774	.173	.023
CCI	5181.2	2	2590.6	1.340	.265	.018

As for the department GPA, only 71 of the participants provided a response. The participant breakdown is show in Figure 4.26. Participants with a GPA above a 3.5 had made up the large grouping (N = 33) while there was the same number of participants (N = 19) with a GPA between 3.0 and 3.5 as those with a GPA below a 3.0.

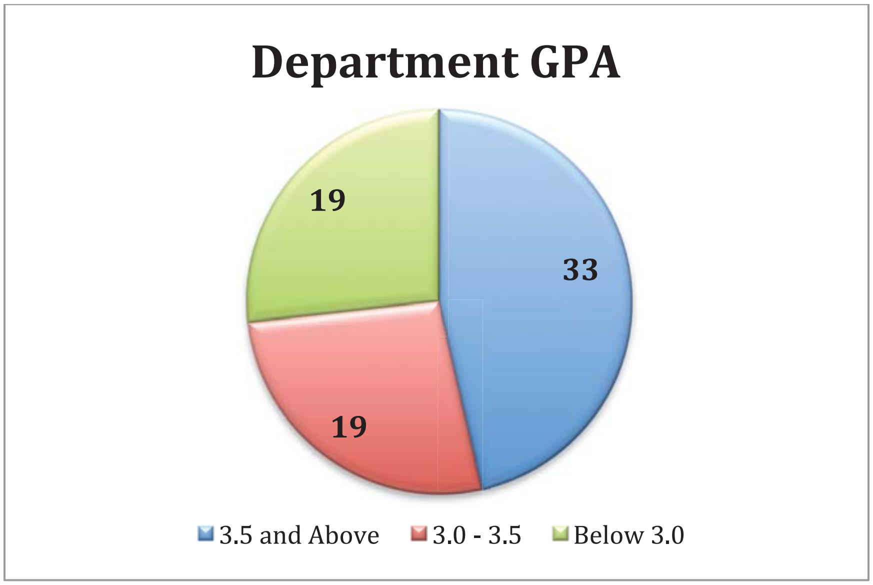

Figure 4.26: Participant distribution with respect to department GPA

Table 4.27 shows the average CCI with respect to the department GPA. Like the university GPA, participants with a department GPA at or above 3.5 had the highest average CCI (330.7 ± 47.2). However, participants with a GPA below a 3.0 (324.5 ± 46.5) scored higher than those with a GPA between a 3.0 and a 3.5 (322.7 ± 31.7). Also, the mean differences between the highest and lowest average CCI was smaller for the department GPA. The subcategory distributions in Figure 4.27 show that the distributions are similar to the university GPA except for Position 2 where the participants with a GPA between 3.0 and 3.5 have the highest percentage of responses.

Table 4.27: Average CCI based on participants' department GPA

GPA	Mean	Std. Dev.
3.5 and Above	330.7	47.2
Below 3.0	324.5	46.9
3.0 - 3.5	322.7	31.7

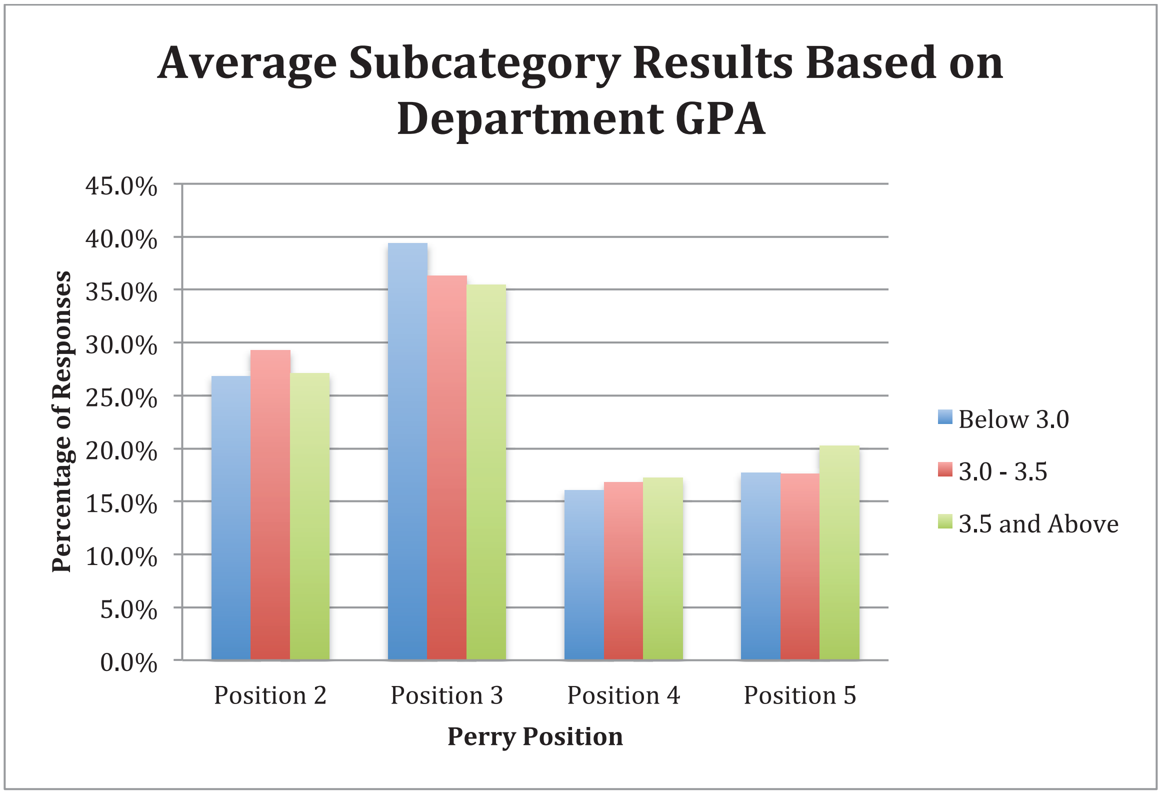

Figure 4.27: Average subcategory percentages when participants are grouped based on department GPA

None of the mean differences with respect to department GPA were considered to be significant. It is possible that it was not found to be significant due to the smaller number or participants who provided their department GPA. This suggests that GPA does not have a significant influence on epistemological beliefs of electrical and computer engineers.

Table 4.28: ANOVA results based on department GPA

Category	SS	df	MS	*F*	*Sig*	η^2
Position 2	71.00	2	35.50	.107	.899	.003
Position 3	189.2	2	94.60	.651	.525	.019
Position 4	17.07	2	8.537	.041	.960	.001
Position 5	120.8	2	60.39	.644	.528	.019
CCI	912.9	2	456.5	.280	.572	.008

4.4. Instructional Context

4.4.1. Direct Problem-Solving course

The participant summary with respect to taking of a course that had a directed problem-solving design is shown in Figure 4.28. Since participants were told not to report courses they were taking during the semester they participated, only those who had completed the course were included. There were 54 participants who had completed at least one DPS course by the time they participated in the study.

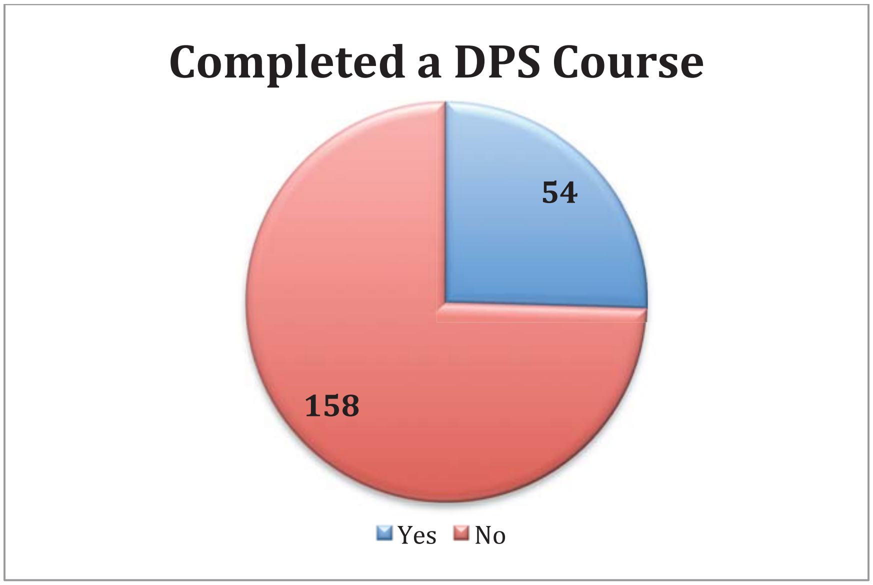

Figure 4.28: Participant distribution with respect to completion of a DPS course

The CCI averages with respect to DPS course completion are shown in Table 4.29. The average CCI of the participants who completed at least one DPS course was 334.1 ± 45.7. This was higher than the participants that had only completed traditional courses, which was 327.6 ± 46.0. The subcategories distributions, shown in Figure 4.29, show that participants that completed a DPS course had a higher percentage of responses correspond to positions four and five. Table 4.30 shows that the ANOAVA analysis found that these mean differences were not significant for either position.

Table 4.29: Average CCI based on participants' completion of a DPS course

DPS	Mean	Std. Dev.
Yes	334.1	45.7
No	327.6	46.0

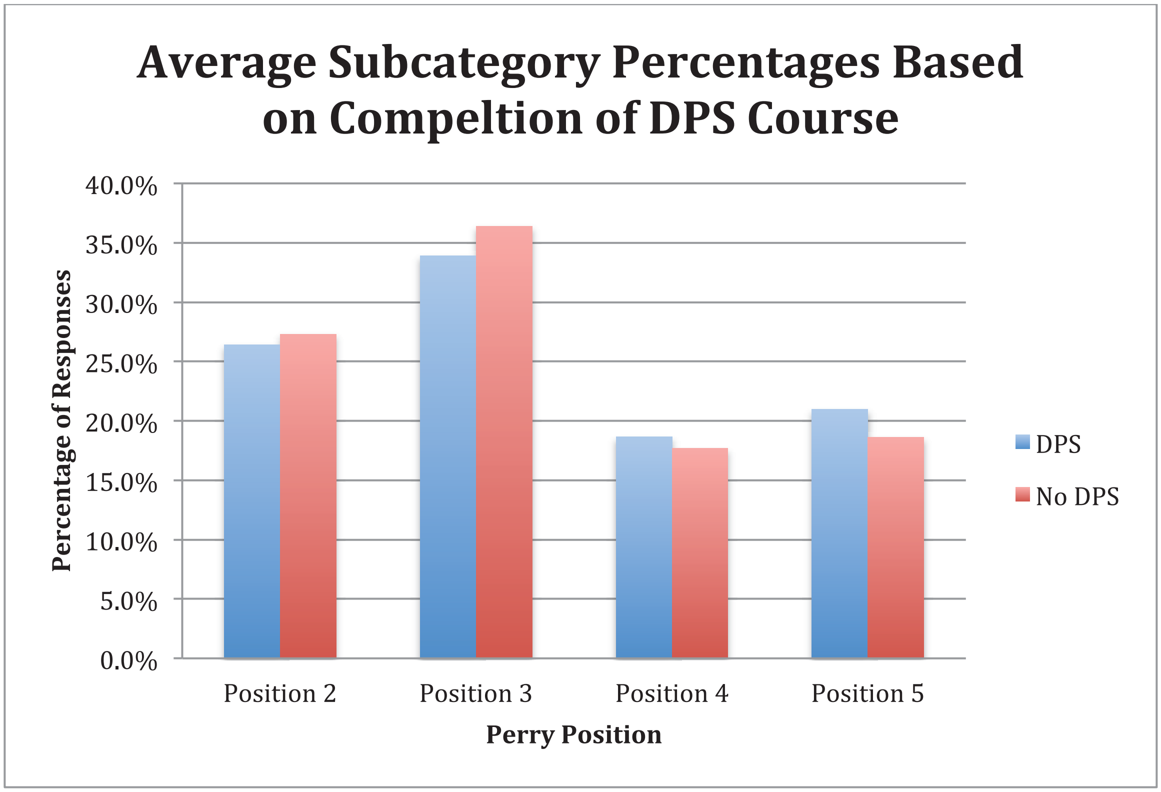

Figure 4.29: Average subcategory percentages when participants are grouped based on completion of a DPS course

Table 4.30: ANOVA results based on the completion of a DPS course

Category	SS	df	MS	*F*	*Sig*	η^2
Position 2	30.57	1	30.57	.088	.768	-
Position 3	251.1	1	251.1	1.445	.231	.007
Position 4	37.45	1	37.45	.190	.663	-
Position 5	217.3	1	217.3	1.525	.218	.007
CCI	1682.4	1	1682.4	.799	.372	.004

4.4.2. Active/Reflexive learning preference

Figure 4.30 shows the distribution of participants with respect to their preference for either active or reflexive learning measured by the ILS. 118 participants in the study were measured to have active learning preference and 94 with a reflexive preference.

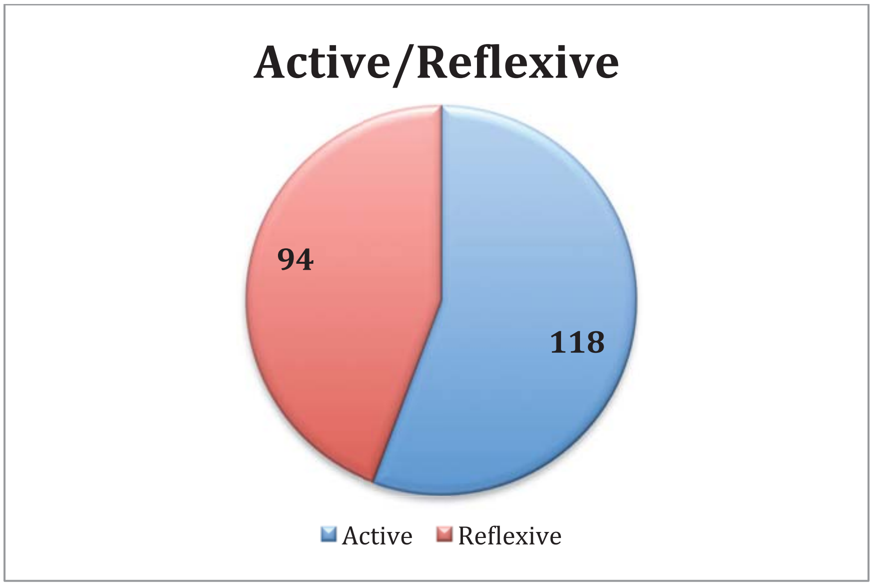

Figure 4.30: Participant distribution with respect to active/reflexive learning preference dimension

Table 4.31 shows the average CCI for the active/reflexive learning preference dimension. Reflexive participants (339.8 ± 41.8) had a higher average CCI than their active counterparts (320.9 ± 47.4). The subcategory results shown in Figure 4.31 show that reflexive participants have a higher percentage of responses that correspond to the multiplicity (position 3: 36.7% vs. 35.0%, position 4: 19.7% vs. 16.5%) and relativistic (21.2% vs. 17.6%) positions that are measured by the LEP.

Table 4.31: Average CCI based on participants' preference for active or reflexive learning

Learning Style	Mean	Std. Dev.
Reflexive	339.8	41.8
Active	320.9	47.4

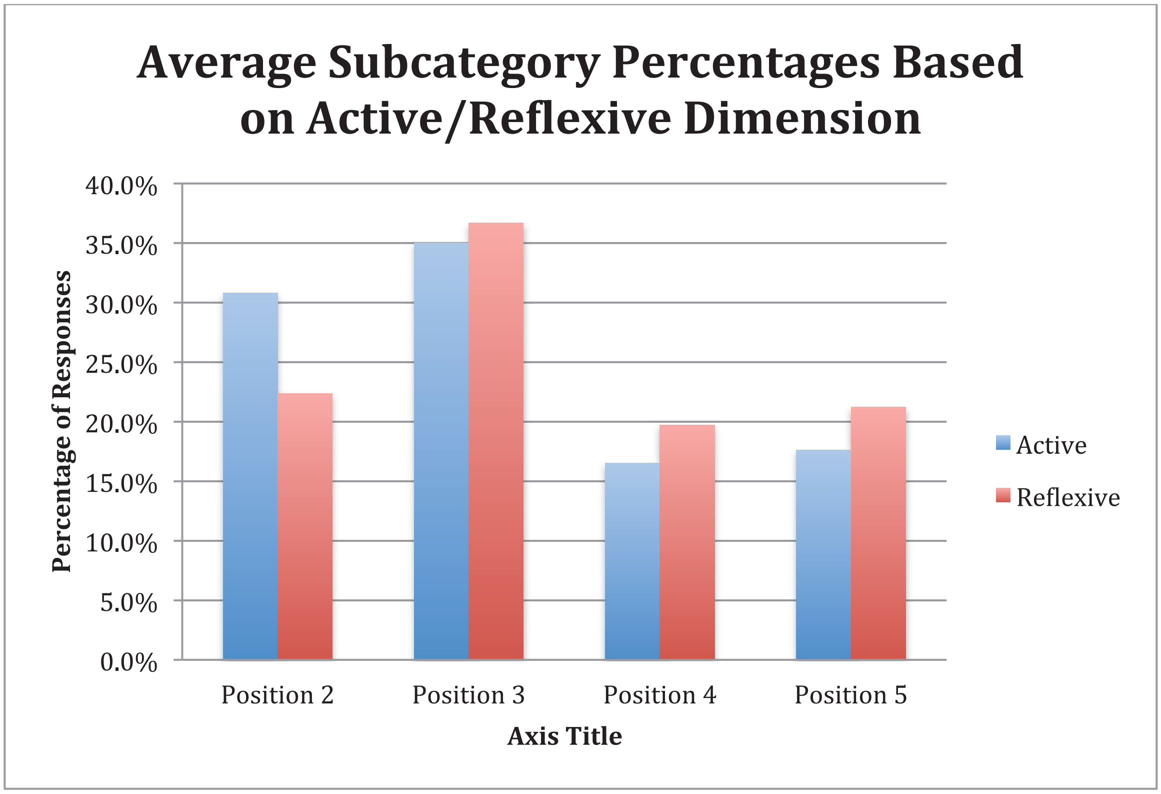

Figure 4.31: Average subcategory percentages when participants are grouped based on active/reflexive learning dimension

The ANOVA results, shown in Table 4.32, show that the difference in the average CCI between active and reflexive participants was significant [$F(1, 210) = 9.202$, $p = .003$, $\eta^2 = .041$]. This suggests that participants with a reflexive learning preference possess more advanced epistemological beliefs. The effect size suggests that the difference in complexity is small in nature. The analysis also found the mean differences for Position 2 [$F(1, 210) = 11.33$, $p = .001$, $\eta^2 = .051$] and Position 5 [$F(1, 210) = 4.880$, $p = .028$. $\eta^2 = .023$] subcategories were found to be significant. The Position 2 results suggest that an active learning preference had a small effect on the frequency participants had a dualistic responds. The same is true for a reflexive learning preference with respect to their relativistic response frequency.

Table 4.32: ANOVA results based on active/reflexive learning preference

Category	SS	df	MS	*F*	*Sig*	η^2
Position 2	3752.5	1	3752.5	11.33	.001	.051
Position 3	147.1	1	147.1	.844	.359	.004
Position 4	537.2	1	537.2	2.760	.098	.013
Position 5	684.7	1	684.7	4.880	.028	.023
CCI	18638.4	1	18638.4	9.202	.003	.041

Participants were also examined with respect to the degree of their active or reflexive learning preference. The participants were split into three groups: those with a moderate or strong active learning preference for, those with a moderate or strong learning preference for reflexive learning, and those with a mild preference for either active or reflexive learning. The mild participants were grouped together because participants at that degree of preference tend to alternative between learning styles in order to match the teaching environment. The participant distributions based on degree of an active or reflexive learning preference are shown in Figure 4.32. The largest group was the students with a mild active or reflexive preference with 107 participants. This was followed by 66 of the participants having a moderate or strong active preference and 39 having a moderate or strong reflexive preference.

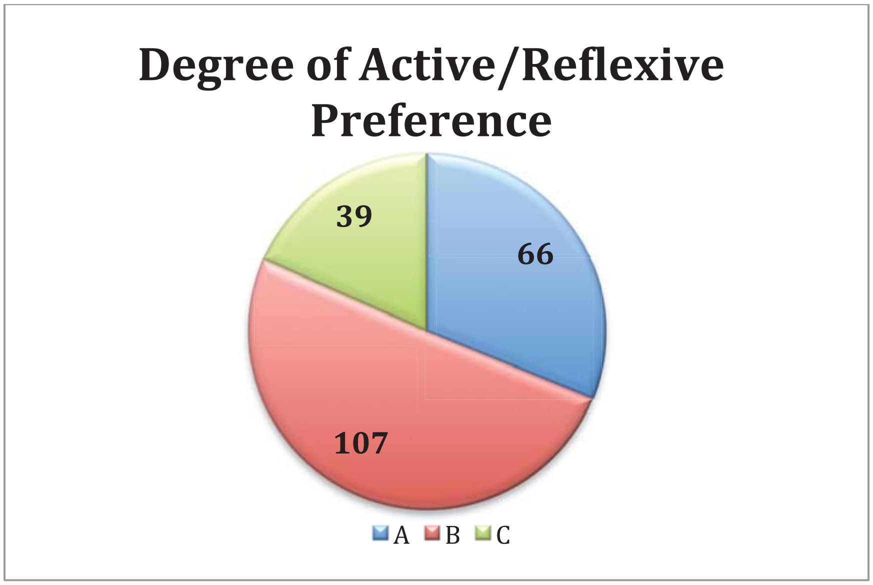

Figure 4.32: Participant distribution with respect to the degree of active or reflexive preference

Note: A – Moderate or Strong Active Learning Preference; B – Mild Active or Reflexive Learning Preference; C – Moderate or Strong Reflexive Learning Preference

The results in Table 4.33 show that the participants with a moderate or strong preference for reflexive learning had the highest average CCI (335.8 ± 41.8) followed by a mild preference for either learning style and a moderate or strong preference for active learning. The subcategory results in Figure 4.33 show the stronger the active preferences, the more beliefs relating to Position 2 a participant had. Also, participants with a stronger reflexive preference had more responses correlate with Position 5. However, the mean differences for the CCI and the subcategories were found to be insignificant.

Table 4.33: Average CCI based on the degree of participants' preference for active or reflexive learning

Degree of Preference	Mean	Std. Dev.
C	335.8	48.3
B	330.7	44.8
A	323.2	46.2

Note: A – Moderate or Strong Active Learning Preference; B – Mild Active or Reflexive Learning Preference; C – Moderate or Strong Reflexive Learning Preference

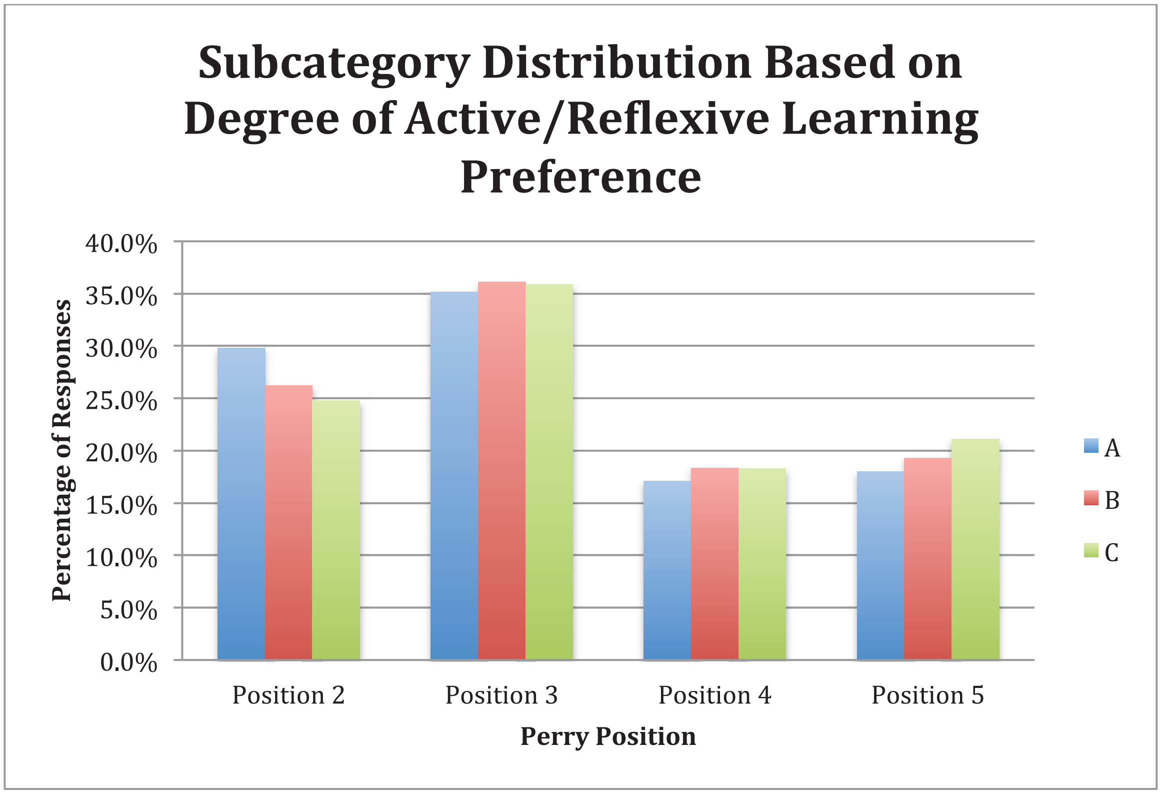

Figure 4.33: Average subcategory percentages when participants are grouped based on the degree of their active/reflexive learning preference

Note: A – Moderate or Strong Active Learning Preference; B – Mild Active or Reflexive Learning Preference; C – Moderate or Strong Reflexive Learning Preference

Table 4.34: ANOVA results when results are compared based on the degree of preference for active and reflexive learning.

Category	SS	df	MS	*F*	*Sig*	η^2
Position 2	774.3	2	387.1	1.115	.330	.011
Position 3	37.7	2	18.9	.107	.898	.001
Position 4	89.9	2	34.9	.188	.838	.002
Position 5	243.5	2	121.8	.851	.428	.008
CCI	4278.0	2	2139.0	1.017	.364	.010

4.4.3. Sensing/Intuitive learning preference

Figure 4.34 shows how the participants were grouped based on the sensing/intuitive learning preference dimension. There were almost twice as many participants with a sensing learning preference (N = 136) as participants with an intuitive preference (N = 76). The CCI results in Table 4.35 show that participants with a sensing learning preference had a lower average CCI (323.6 ± 44.4) than those with an intuitive learning preference (339.5 ± 47.0). This difference was significant according to the ANOVA results [$F(1, 210) = 6.038$, $p = .015$, $\eta^2 = .028$] and suggested that an intuitive learning preference had a small effect on CCI scores. This suggests that the overall epistemological beliefs of ECE students with an intuitive learning preference may be more advanced than those with a sensing preference.

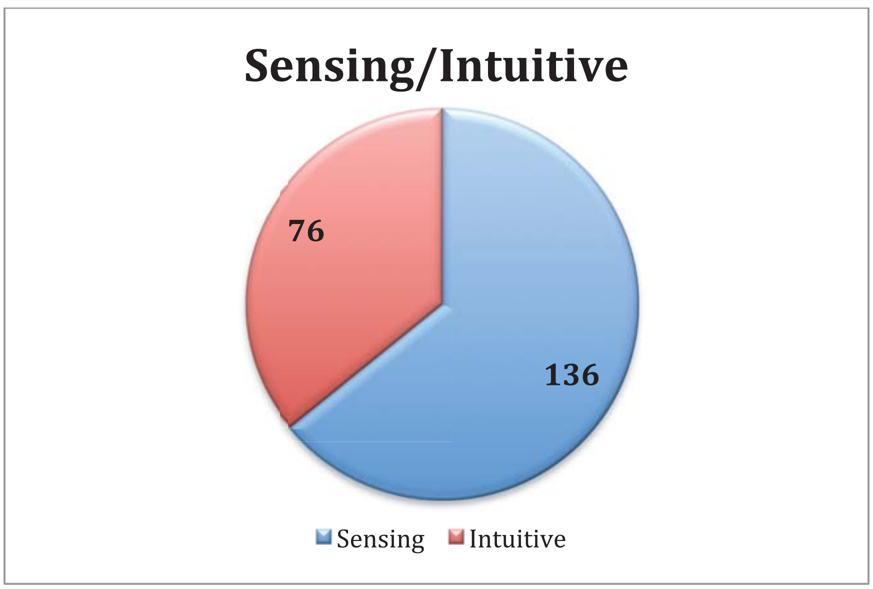

Figure 4.34: Participant distribution with respect to sensing/intuitive learning preference

When the subcategories were analyzed, sensing participants had a higher percentage of responses for positions two and three. The mean differences for positions two and three were not found to be significant, but the effect size for both position did suggest that having a sensing preference had a small effect on having beliefs corresponding to those positions. Figure 4.35 shows that intuitive participants had a higher percentage of responses that related to the higher two positions measured by the

LEP. The differences for both positions were found to be significant, which implies that intuitive learners possess more advanced multiplicity and relativistic epistemological beliefs. Table 4.36 shows the differences for Position 4 [$F(1, 210) = 4.047$, $p = .046$, $\eta^2 = .019$] and Position 5 [$F(1, 210) = 4.975$, $p = .027$, $\eta^2 = .023$] were small in nature.

Table 4.35: Average CCI based on participants' preference for sensing or intuitive learning

Learning Style	**Mean**	**Std. Dev.**
Intuitive	339.5	47.0
Sensing	323.6	44.4

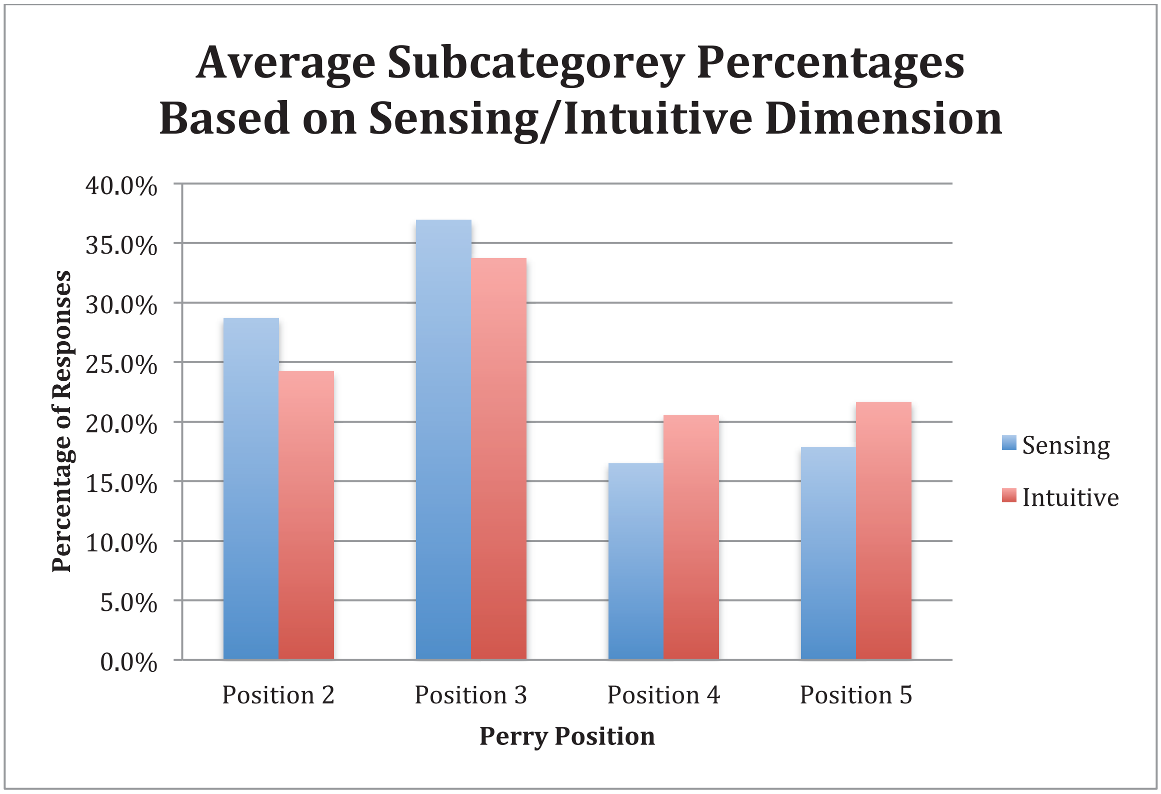

Figure 4.35: Average subcategory percentages when participants are grouped based on sensing/intuitive dimension

Table 4.36: ANOVA results based on sensing/intuitive learning preference

Category	SS	df	MS	*F*	*Sig*	η^2
Position 2	981.3	1	981.3	2.849	.093	.013
Position 3	508.4	1	508.4	2.946	.088	.014
Position 4	782.9	1	782.9	4.047	.046	.019
Position 5	697.7	1	697.7	4.975	.027	.023
CCI	12407.7	1	12407.7	6.038	.015	.028

The participant distributions when the degree of a sensing or intuitive learning preference is also included are shown in Figure 4.36. The most common degree was a mild sensing or intuitive preference (N = 95). The next largest group was participants with a moderate or strong sensing learning preference (N = 85). The smallest group was comprised of participants with a moderate or strong intuitive preference (N = 32).

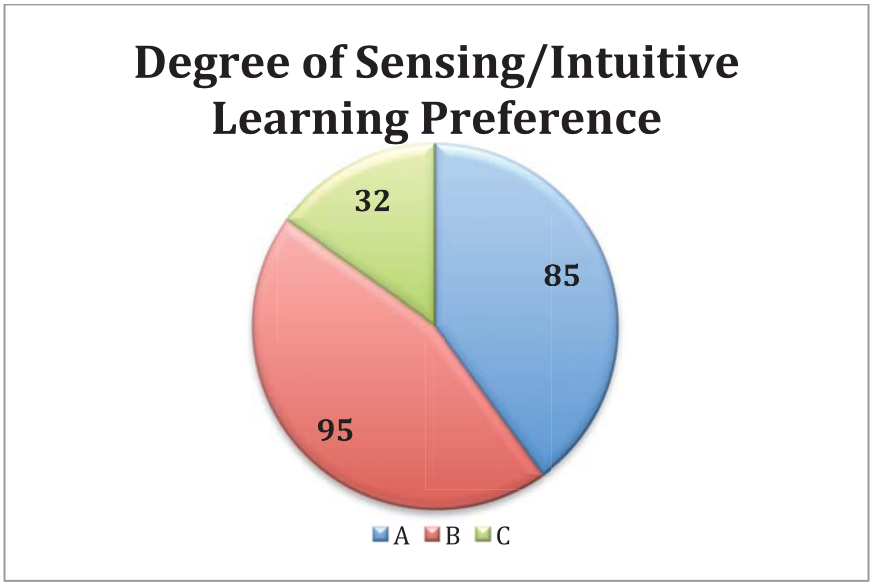

Figure 4.36: Participant distribution with respect to degree of sensing or intuitive learning preference

Note: A – Moderate or Strong Sensing Learning Preference; B – Mild Sensing or Intuitive Learning Preference; C – Moderate or Strong Intuitive Learning Preference

Participants with a moderate or strong preference for intuitive learning had the highest average CCI of 345.6 ± 50.1 followed by the participants with a mild preference (331.8 ± 45.4). The lowest average CCI came from the participants with a moderate or strong sensing learning preference at 320.3 ± 43.1. The subcategory results in Figure 4.37 are similar to when degree is not taken into account. The participants with a moderate/strong sensing learning preference had more responses in accordance with the lower positions examined by the LEP while the stronger intuitive participants had more responses correlate to the higher positions. When the results were examined using ANOVA, the Position 5 subcategory [$F(2, 210) = 3.916$, $p = .049$, $\eta^2 = .028$] and the overall CCI [$F(2, 210) = 3.916$, $p = .021$, $\eta^2 = .018$] were found to be significant.

Table 4.37: Average CCI based on the degree of participants' preference for sensing or intuitive learning

Degree of Preference	Mean	Std. Dev.
C	345.6	50.1
B	331.8	45.4
A	320.3	43.1

Note: A – Moderate or Strong Sensing Learning Preference; B – Mild Sensing or Intuitive Learning Preference; C – Moderate or Strong Intuitive Learning Preference

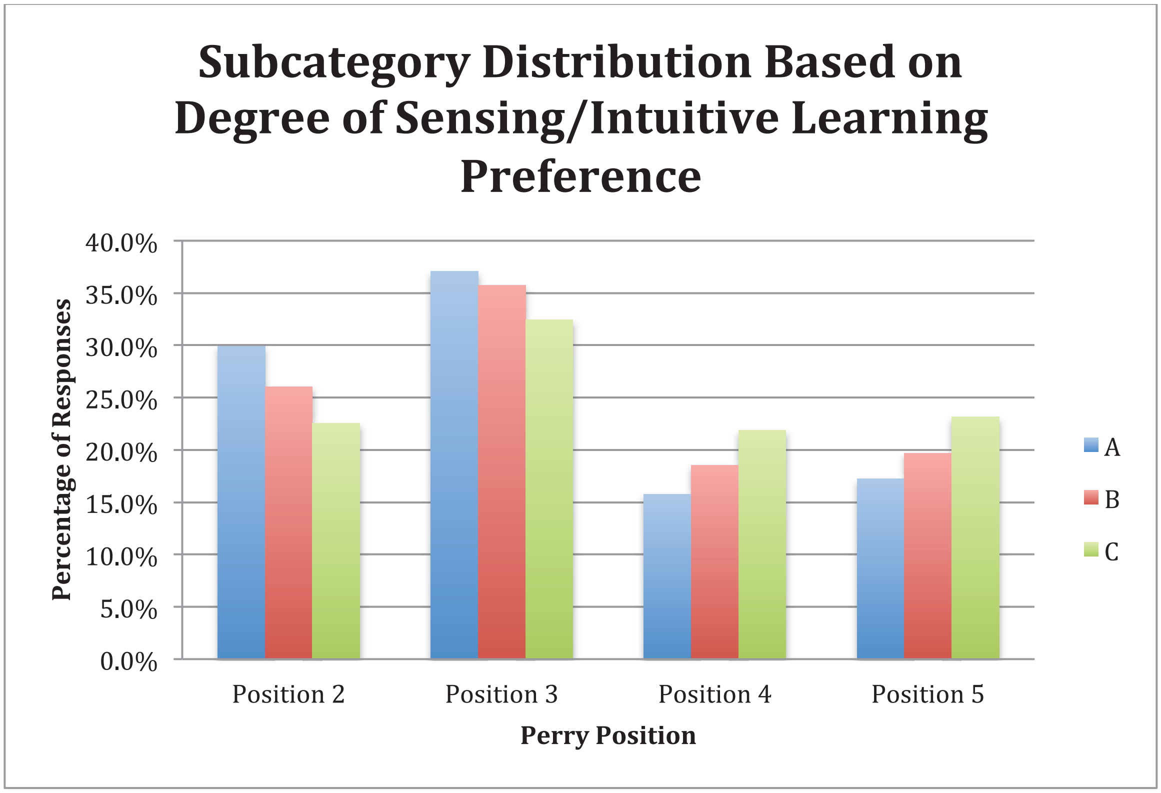

Figure 4.37: Average subcategory percentages when participants are grouped based on the degree of their sensing/intuitive learning preference

Note: A – Moderate or Strong Sensing Learning Preference; B – Mild Sensing or Intuitive Learning Preference; C – Moderate or Strong Intuitive Learning Preference

Table 4.38: ANOVA results when results are compared based on the degree of preference for sensing and intuitive learning.

Category	SS	df	MS	*F*	*Sig*	η^2
Position 2	1452.5	2	726.3	2.112	.124	.020
Position 3	499.3	2	249.7	1.439	.239	.014
Position 4	931.5	2	465.8	2.405	.093	.022
Position 5	857.0	2	428.5	3.057	.049	.028
CCI	16036.1	2	8018.0	3.916	.021	.018

4.4.4. Visual/Verbal learning preference

The participant distribution for the visual/verbal learning preference dimension is shown in Figure 4.38. Almost 80% (N= 169) of the participants in the study were found to have a preference for visual learning. The CCI averages for participants based on their visual or verbal learning preference is shown in Table 4.39. Participants with a visual preference had an average CCI of 330.0 ± 47.2. This was greater than the average CCI of the participants with a verbal preference (326.7 ± 40.8). However, the ANOVA results show that the difference in means was not significant, which suggests that the visual/verbal dimension of Felder and Silverman's Model of Learning Styles does not have an effect on CCI scores.

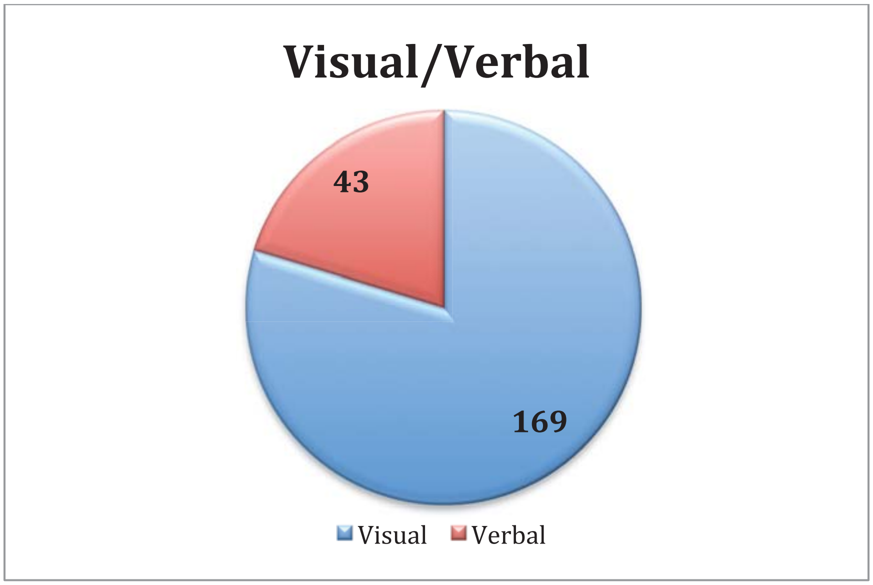

Figure 4.38: Participant distribution with respect to visual/verbal learning preference

The subcategory results in Figure 4.39 show that participants with a visual learning preference had a higher percentage of response correlating with positions 2 and 4 of Perry's Scheme while verbal participants had more responses in line with positions 3 and 5. None of the differences were large enough to be significant according to the ANOVA results shown in Table 4.40.

Table 4.39: Average CCI based on participants' preference for visual or verbal learning

Learning Style	**Mean**	**Std. Dev.**
Visual	330.0	47.2
Verbal	326.7	20.8

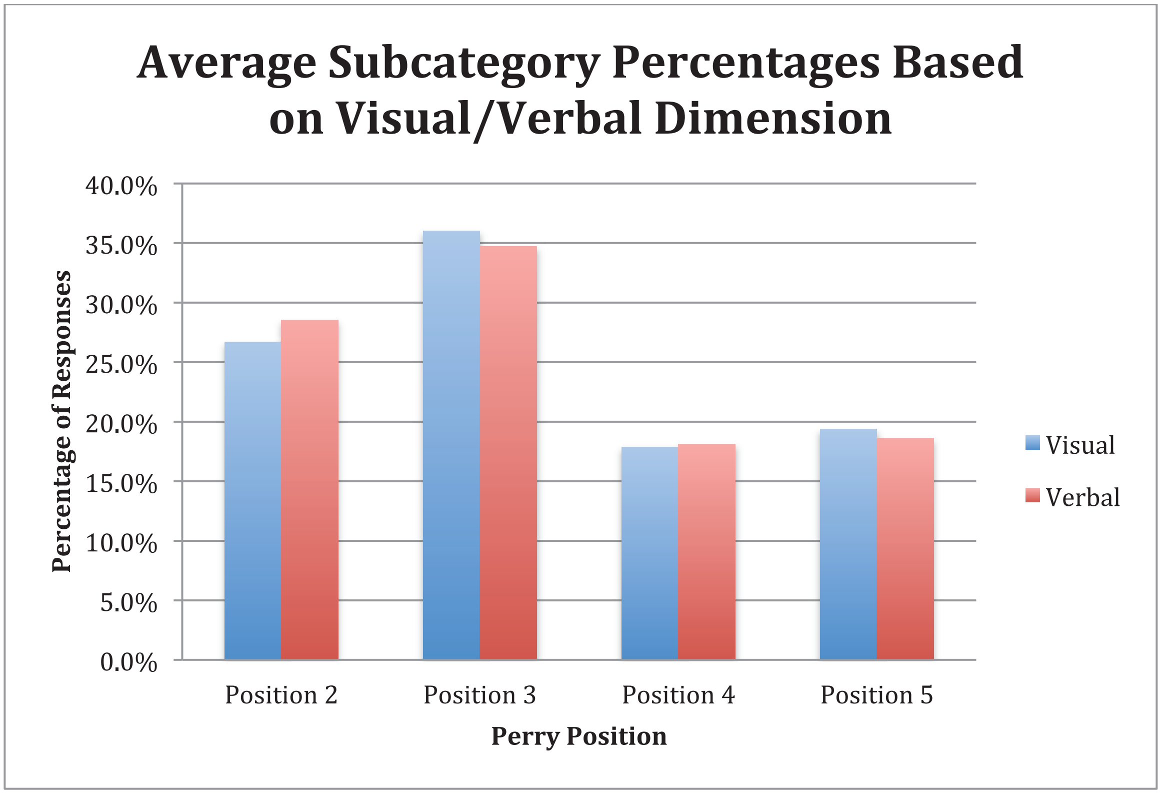

Figure 4.39: Average subcategory percentages when participants are grouped based on visual/verbal dimension

Table 4.40: ANOVA results based on visual/verbal learning preference

Category	SS	df	MS	*F*	*Sig*	η^2
Position 2	118.6	1	118.6	.340	.560	.002
Position 3	59.24	1	59.24	.339	.561	.002
Position 4	1.887	1	1.887	.010	.922	-
Position 5	19.63	1	19.63	.037	.712	-
CCI	363.2	1	363.2	.172	.679	-

The participant distributions with respect to the degree of a participant's visual and verbal preference are shown in Figure 4.40. Two-thirds of the participants had a moderate or strong visual preference.

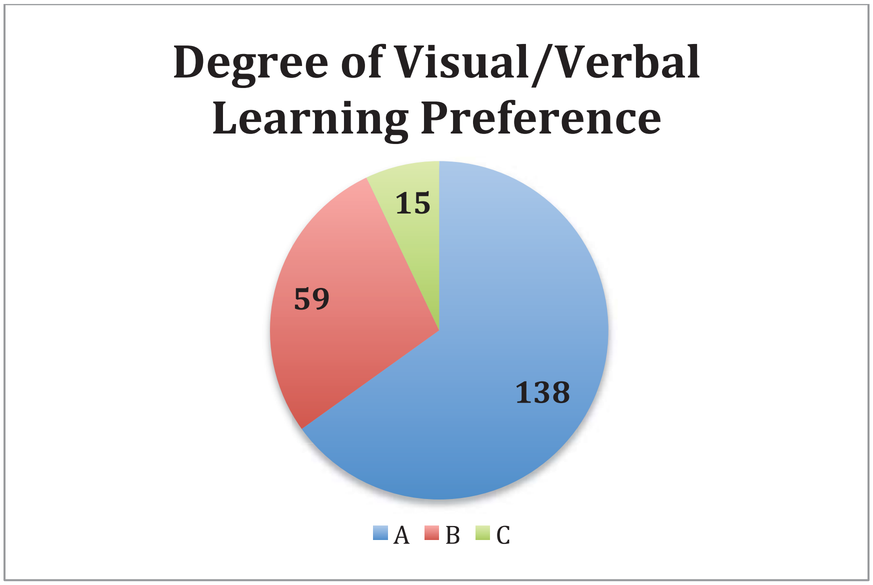

Figure 4.40: Participant distribution with respect to degree of visual or verbal learning preference

Note: A – Moderate or Strong Visual Learning Preference; B – Mild Visual or Verbal Learning Preference; C – Moderate or Strong Verbal Learning Preference

Participants with a mild preference for visual or verbal learning had the highest average CCI at 333.0 ± 45.4. They had the highest percentage of responses that corresponded to positions 4 (18.1%) and 5(20.4%) and the lowest percentage of responses with respect to Position 2 (25.7%). Participants with a moderate or strong visual learning preference scored the next highest CCI with an average of 328.0 ± 47.7. They had the highest percentage of responses that corresponded to Position 3 and the lowest to Position 5. The lowest CCI came from participants with a stronger verbal learning preference (326.5 ± 40.9). The subcategory results in Figure 4.41 shows that these participants had the highest percentage of responses to Position 2 and the lowest for positions 3 and 4. As when degree was no included, none of the subcategories and the CCI mean differences were found to be significant.

Table 4.41: Average CCI based on the degree of participants' preference for visual or verbal learning

Degree of Preference	Mean	Std. Dev.
B	333.0	45.4
A	328.0	47.7
C	326.5	40.9

Note: A – Moderate or Strong Visual Learning Preference; B – Mild Visual or Verbal Learning Preference; C – Moderate or Strong Verbal Learning Preference

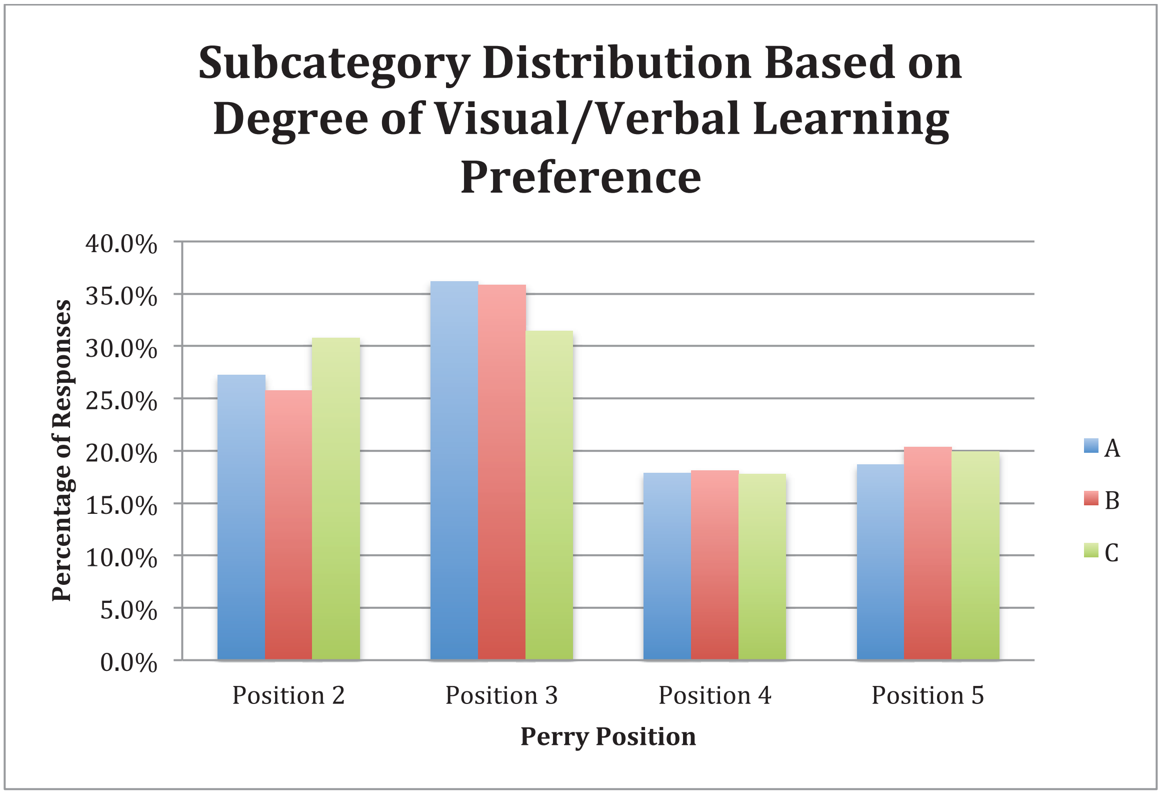

Figure 4.41: Average subcategory percentages when participants are grouped based on degree of visual/verbal learning preference

Note: A – Moderate or Strong Visual Learning Preference; B – Mild Visual or Verbal Learning Preference; C – Moderate or Strong Verbal Learning Preference

Table 4.42: ANOVA results based on the degree of preference for visual and verbal learning

Category	**SS**	**df**	**MS**	***F***	***Sig***	**η^2**
Position 2	316.1	2	158.0	.453	.637	.004
Position 3	304.0	2	152.0	.872	.420	.008
Position 4	2.50	2	1.25	.006	.994	-
Position 5	128.3	2	64.1	.447	.640	.004
CCI	1163.2	2	581.6	.274	.760	.003

4.4.5. Sequential/Global learning preference

Figure 4.42 shows how the participants split according to the sequential/global learning preference dimension. About 60% of the participants (N = 127) identified themselves as having sequential learning preference.

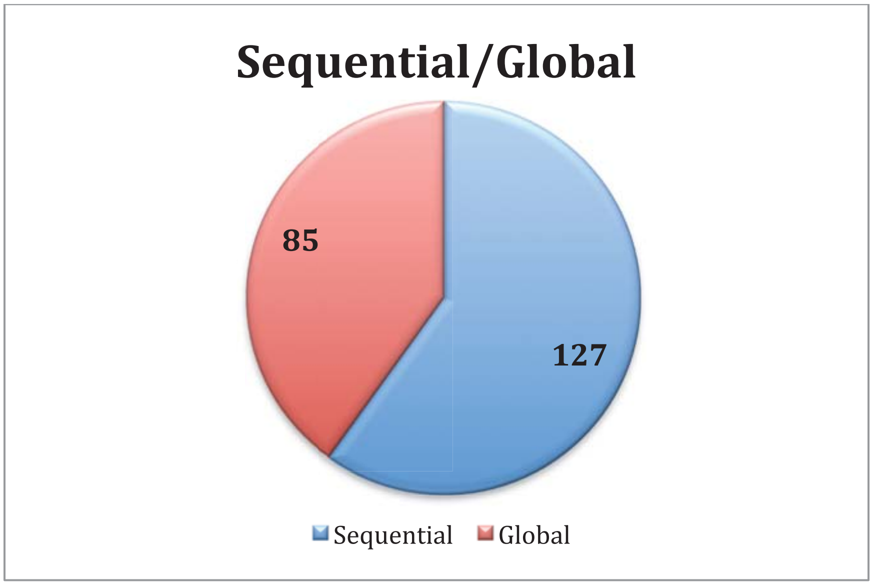

Figure 4.42: Participation distribution with respect to sequential/global learning preference

The results in Table 4.43 show that sequential participants had an average CCI of 327.2 ± 46.7. This was lower than that of the global participants (332.5 ± 44.7). The subcategory results in Figure 4.43 show that the percentages relating to Position 3 and Position 5 were almost identical. Sequential participants had a higher percentage of responses relating to Position 2 while global participants had more responses correlate to Position 4. This difference was not found to be significant for either position when analyzed using ANOVA. This suggests that the sequential/global learning preference does not have a significant role in the complexity of epistemological beliefs.

Table 4.43: Average CCI based on participants' preference for sequential or global learning

Learning Style	Mean	Std. Dev.
Global	332.5	44.7
Sequential	327.2	46.7

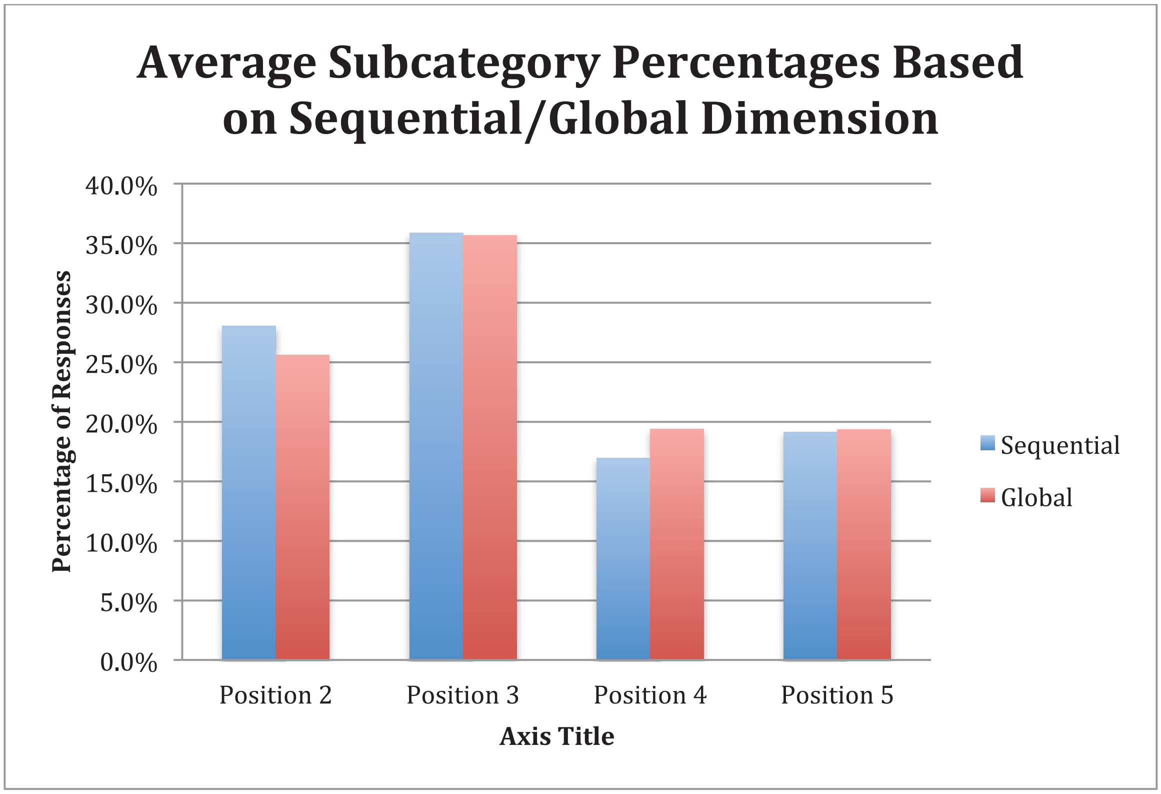

Figure 4.43: Average subcategory percentages when participants are grouped based on sequential/global dimension

Table 4.44: ANOVA results based on sequential/global learning preference

Category	SS	df	MS	*F*	*Sig*	η^2
Position 2	308.9	1	308.9	.889	.347	.004
Position 3	1.718	1	1.718	.010	.921	-
Position 4	311.9	1	311.9	1.593	.208	.008
Position 5	2.105	1	2.105	.015	.904	-
CCI	1443.8	1	1443.8	.685	.409	.003

When degree of preference is also included, over half of the participants had a mild preference for either sequential or global learning. This suggests that most ECE students are more likely to switch between a sequential and global learning style in order to match the teaching style. There were more participants with a stronger preference to sequential learning (N = 59) than those with a stronger global preference (N = 34).

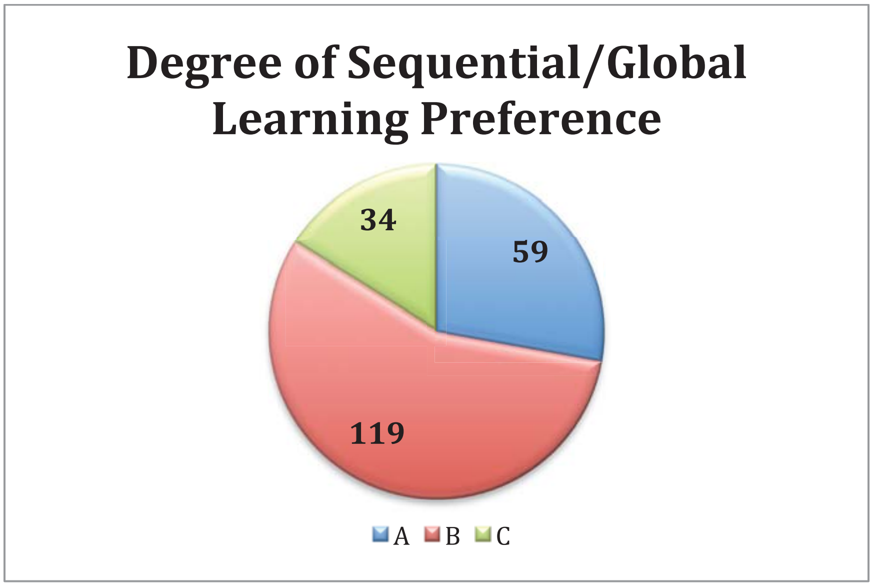

Figure 4.44: Participant distribution with respect to degree of sequential or global learning preference

Note: A – Moderate or Strong Sequential Learning Preference; B – Mild Sequential or Global Learning Preference; C – Moderate or Strong Global Learning Preference

The study results based the degree of a participants' sequential or global learning preference is shown in Table 4.45. Participants with a moderate or strong sequential learning preference had the highest average CCI at 332.8 ± 45.4 despite not having the highest percentage of response for any of the subcategories. The subcategory results in show that these participants did not have the highest percentage of responses for any of the more advanced subcategories. Figure 4.45 shows that participants with a mild preference for sequential or global learning had the highest percentage of response relating to Position 5 (19.7%) while participants with a stronger global preference had the highest percentage for Position 4 (21.3%). However, none of the ANOVA results in Table 4.46 were found to be significant.

Table 4.45: Average CCI based on the degree of participants' preference for sequential or global learning

Degree of Preference	Mean	Std. Dev.
A	332.8	45.4
C	330.8	47.1
B	327.1	47.1

Note: A – Moderate or Strong Sequential Learning Preference; B – Mild Sequential or Global Learning Preference; C – Moderate or Strong Global Learning Preference

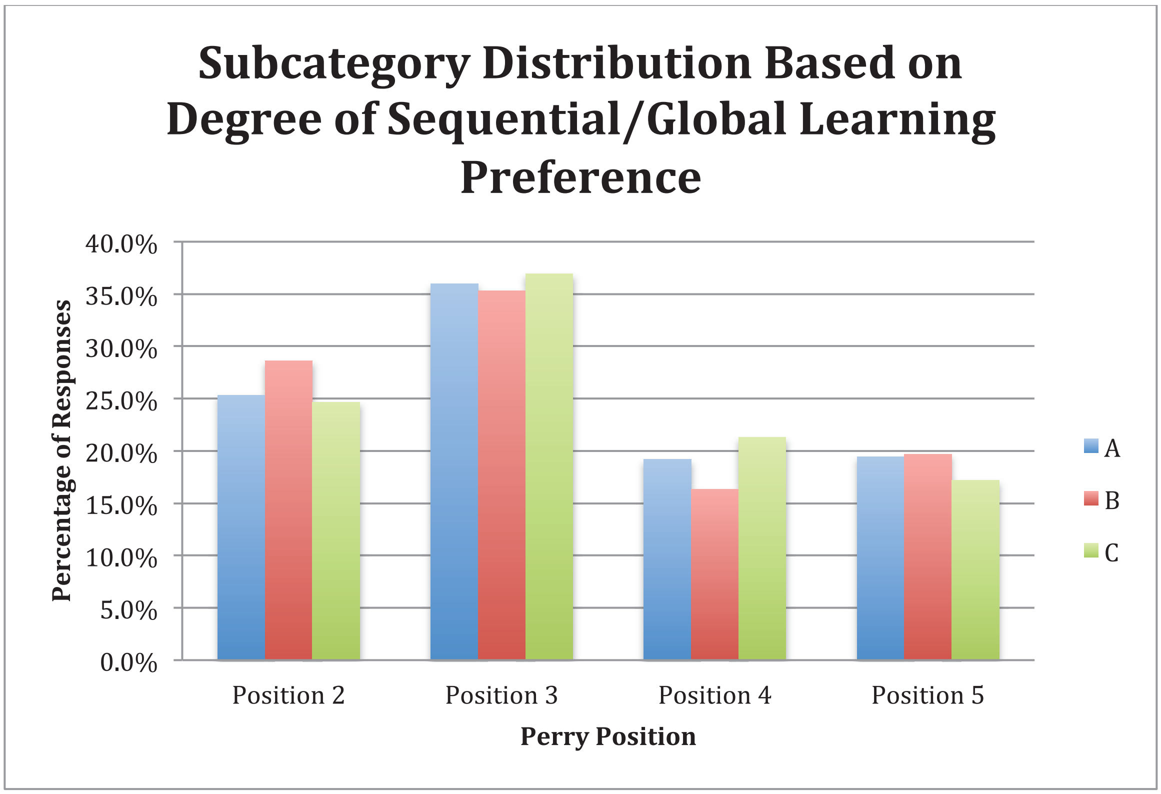

Figure 4.45: Average subcategory percentages when participants are grouped based on degree of sequential/global learning preference
Note: A – Moderate or Strong Sequential Learning Preference; B – Mild Sequential or Global Learning Preference; C – Moderate or Strong Global Learning Preference

Table 4.46: ANOVA results when results are compared based on the degree of preference for sequential and global learning

Category	**SS**	**df**	**MS**	***F***	***Sig***	**η^2**
Position 2	664.7	2	332.4	.956	.386	.009
Position 3	72.6	2	36.3	.207	.813	.002
Position 4	777.1	2	388.5	1.998	.138	.019
Position 5	168.4	2	84.2	.587	.557	.006
CCI	1386.5	2	692.3	.327	.721	.003

4.4.6. Learning preference types

Table 4.47 shows how the participants were grouped into the sixteen possible learners with respect to Felder and Silverman's Model of Learning Styles[46]. The most common type of learner in the study was one with active, sensing, visual, and sequential learning preferences. This was expected as these dimensions were found to be most common in previous studies of learning preferences using the ILS[169], [181], [191]. However, this type of learner had the third-lowest average CCI. The highest average CCI belonged to the students who had reflexive, intuitive, verbal, and sequential learning preferences at 357.8 ± 60.4. This was also expected as these learning preferences mirror the teaching preferences of engineering professors[46]. This result suggests that being immersed in educational settings that match your learning preferences gave students the best chance to develop epistemologically.

Table 4.47: Distribution of participants overall learning preferences as measured by the ILS

Degree	N	%	Mean	Std. Dev
RIVES	4	1.9	357.8	60.4
RIVIS	15	7.1	353.3	46.7
RIVIG	16	7.5	347.8	46.4
RSVIG	13	6.1	345.8	38.6
AIVEG	3	1.4	344.7	34.0
AIVIS	10	4.7	341.2	45.9
RSVIS	24	11.3	333.4	40.0
ASVIG	22	10.3	330.5	41.2
AIVES	4	1.9	328.8	47.9
RSVES	11	5.2	328.5	30.9
RIVEG	9	4.2	328.4	35.9
AIVIG	15	7.1	319.5	53.7
ASVEG	5	2.4	313.8	58.7
ASVIS	54	25.5	313.5	48.9
ASVES	5	2.4	309.8	38.6
RSVEG	2	0.9	290.0	18.4

4.5. Industrial

4.5.1. Internships and co-op rotations

The participant distribution with respect to internship and co-ops is shown in Figure 4.46. Students were grouped based on if they had completed at least one internship or co-op rotation. A third of the of the study's participants (N = 70) reported that they had done so.

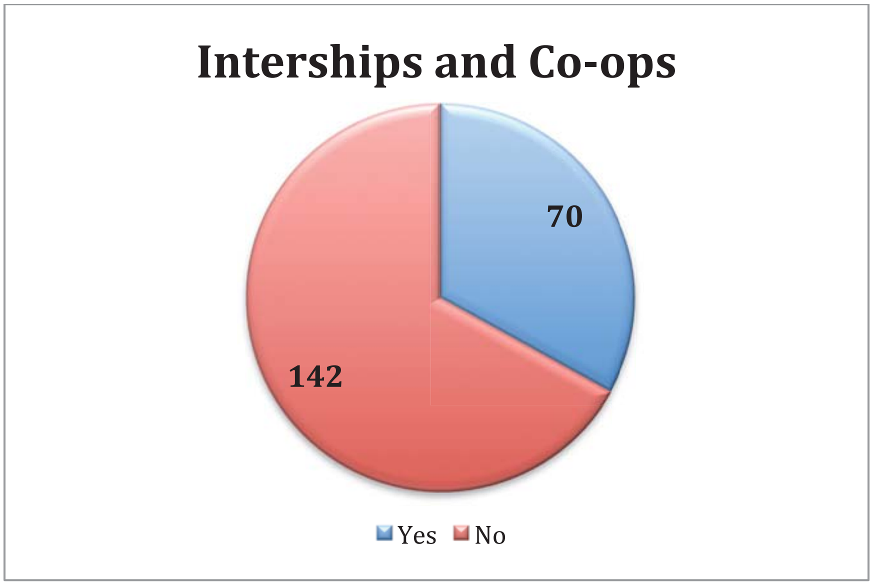

Figure 4.46: Participant distribution with respect to completions of internships and co-op rotations

Students who had completed an internship or co-op had an average CCI of 328.5 ± 46.6. This was less than the average CCI of the students with no industry experience, who had an average CCI of 329.7 ± 45.7. The ANOVA results [$F(1, 210) = .028$, $p = .868$, $\eta^2 = .000$] suggested that there was no significant difference between the two groups. The results for the positional subcategories in Figure 4.47 show that participants with industrial experience had a higher percentage of responses correlate to Position 3. The difference was not found to be significant [$F(1, 210) = 3.808$, $p = .052$, $\eta^2 = .018$] but the effect size suggests that internships and co-op rotations may have a small effect.

Table 4.48: Average CCI based on participants participation in an internship or co-op rotation

Industrial Exp.?	Mean	Std. Dev.
No	329.7	45.7
Yes	328.5	46.4

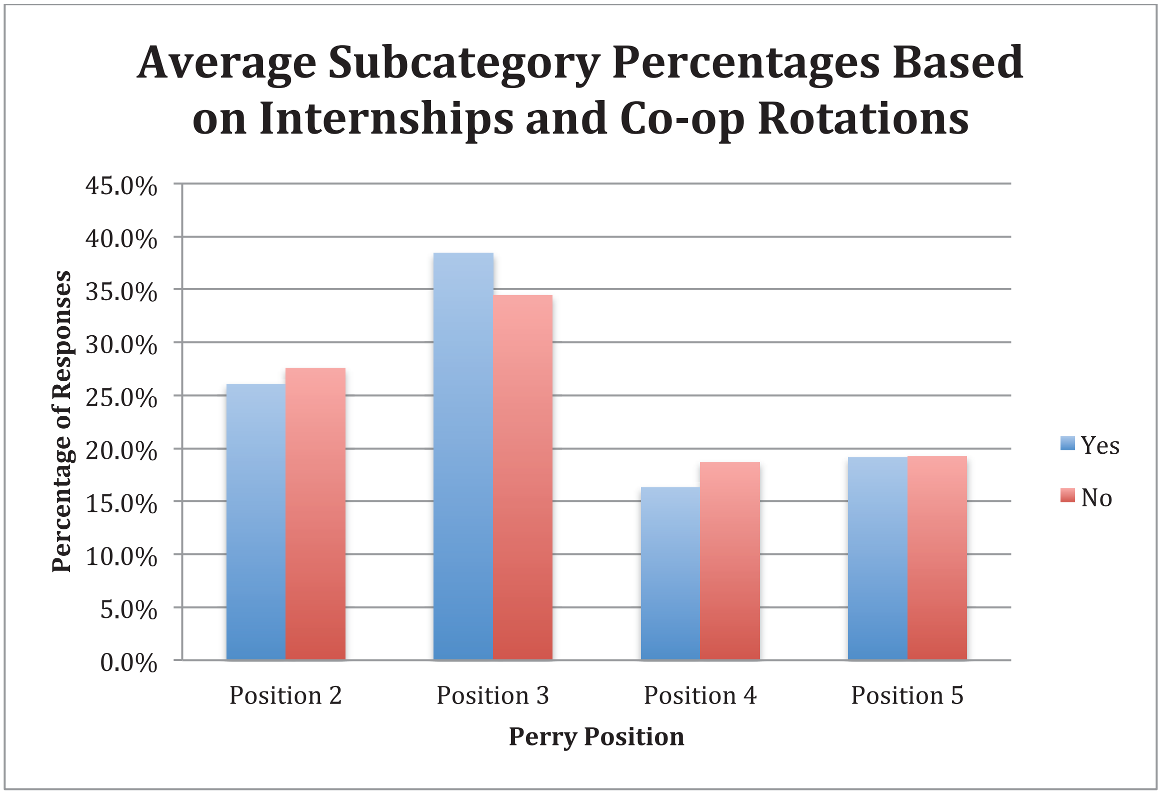

Figure 4.47: Average subcategory percentages when participants are grouped based on internships and co-op rotations

Table 4.49: ANOVA results based on participation in an internship or co-op rotation

Category	SS	df	MS	*F*	*Sig*	η^2
Position 2	90.90	1	90.90	.261	.610	.001
Position 3	654.5	1	654.5	3.808	.052	.018
Position 4	226.5	1	226.5	1.155	.284	.005
Position 5	1.427	1	1.427	.010	.921	-
CCI	58.72	1	58.72	.028	.868	-

4.6. Discussion

The participants of this study had an average CCI of 329.3 ± 45.9. Only 6.6% (n= 14) of the participants had a CCI at or above 400 and a majority of those participants were underclassmen. A little over a half of LEP responses correlated with positions three and four of Perry's scheme which have been designated as multiplicity positions by researchers [53]. The next highest average subcategory percentage correlated to the dualistic Position 2 at 27.1%. The smallest correlation was for position 5 (19.2%), which describes relativistic epistemological beliefs.

The results suggest that the participants had less advanced beliefs when the results were compared to previous studies. The average CCI was 14 points lower than what Moore [44] measured in his study and at least 20 points lower than most of the groups examined by Culver et al. [31]. When comparing the subcategory distributions of the study to Culver, participants in this study had a higher average number of responses correlating to Position 2 and a lower average correlate to Position 4. This suggests that ECE students at Purdue may possess more dualistic beliefs and less multiplistic beliefs. One possible reason for this difference is that Culver used a modified version of the LEP in their study that was designed for engineering students. This may have allowed participants to better understand the items they were evaluating.

Overall, there was no significant epistemological development when the participants were examined with respect to their university classification. This is in contrast with prior studies that focused exclusively on engineering students. Both Pavelich and Moore [30], [42] and Wise et al. [32] found that engineering students' epistemological beliefs on average evolve one full position with respect to Perry. This amount of growth was found to be significant, which suggested that epistemological development was correlated to academic classification. There are several possible reasons for this disparity. The first relates to how the participants were grouped based on classification. Previous studies either examined students at distinct points in the college progression [30], [32], [42] or grouped participants based on if they were underclassmen or upperclassmen [88], [89]. Participants in this study were grouped based on traditional academic classifications no matter how many semesters that had been at that classification. This type of grouping would allow students who had taken fewer courses to be considered a higher classification from earning college credit through AP courses. Another possible reason for this may be the distribution of the participants in the study. There were only 38 university senior who participated in the study. The lack of seniors may have kept certain differences from reaching significant levels of difference, particularly for the department classification.

The decision to use the LEP to measure epistemological beliefs may also have contributed to the differing results with respect to academic classification. Previous studies examining engineering epistemological beliefs [42], [43] with respect to Perry [20] have measured epistemological development through semi-structured interviews since it is believed to be the best way to assess epistemological beliefs [81]. Pen-and-paper inventories such as the LEP have been found to be conservative when evaluating epistemological beliefs and can measure them to be lower than they actually are [76]. This suggests that some participants, particularly upperclassmen, may possess more advanced epistemological beliefs than what was measured in the study.

Another possible explanation is that different engineering majors may have varying effects on epistemological development. The populations of both the Pavliech and Moore [42] and Wise et al. [32] studies included engineers from multiple disciplines. It is unknown how many electrical and computer engineering students were included in their studies and whether their development patterns matched the overall trends found. It is possible that the development patterns found in those studies differ from the patterns of ECE students.

The study also quantitatively examined several factors used to represent the contexts of the TIDE framework to explore their potential impact on the epistemological beliefs and development of electrical and computer engineering students. Previous work that measured beliefs with respect to Perry either did not take these factors into account [42] or did not find any significant results [32]. Table 4.50 shows the individual characteristics that were found to potentially influence epistemological development. This study found differences for factors in the sociocultural (gender, ethnicity, citizenship, neighborhood), academic (major), and instructional (active/reflexive learning preference, sensing/intuitive learning preference) contexts. Understanding what individual differences influence the epistemological beliefs of electrical and computer engineering students could allow for better decisions in the design of ECE curriculums and ultimately lead to better problem solvers being produced.

Table 4.50: Summary of individual differences examined

Factor	Analyzed	Hypothesized Effect	Measured Effect
Gender	X	X	X
Ethnicity	X		X
Domestic/International	X	X	X
Neighborhood	X		X
Parent's Education	X	X	
Income	X	X	
Research Experience	X	X	
Transfer Credits	X		
Major	X	X	X
University GPA	X	X	
Department GPA	X	X	
Design Competitions*		X	
Change of Major*			
Study Abroad*			
Direct Problem-Solving	X	X	
Active/Reflexive Learning Preference	X	X	X
Sensing/Intuitive Learning Preference	X	X	X
Visual/Verbal Learning Preference	X	X	
Sequential/Global Learning Preference	X	X	
Internships and Co-ops	X	X	
Military Experience*			

Note: * - Not measured due to inadequate number of participants to do an ANOVA analysis

A majority of the studies that have examined the epistemological beliefs of students outside of the U.S. have done so within the context of a non-U.S. formal education environment and even fewer have looked at this with respect to engineering students. With more international students attending U.S. universities, understanding the different beliefs of international students may help design courses that can benefit both groups of students and lead to more engineers equipped with the advanced beliefs believed to be needed in order to be effective problem solvers. In this study, international students self-reported themselves to have a higher average CCI than their domestic counterparts. This result suggests that the cultural and academic environments for elementary and high school students in international countries foster more successful opportunities for epistemological growth. It is also possible that cultural differences between domestic and international participants allowed for different interpretations of items within the LEP. Since this study was one of the first to compare U.S. and international engineering students immersed in the same academic environment, more analysis is needed to determine if this trend holds over other populations.

The participants' ethnicity was found to have an influence on the number of responses that correlated to Position 2 of Perry's Scheme. This result suggests that cultural differences that can be found within different ethnicities may play a part in how often individuals view knowledge in a dualistic manner. However, the differences for ethnicity could be explained by whether a participant was a domestic or international student.

This study also found that male electrical and computer engineering students had a higher average CCI than female students. This result suggests that male ECE students may have more complex set of epistemological beliefs. It also contradicts the results of previous studies where male engineering participants self-reported themselves to have less advanced epistemological beliefs [88]. It is possible that the subject matter and the teaching styles in electrical and computer engineering lend themselves to gender patterns that have been normally attributed to male students [22]. More analysis of electrical and computer engineering students would be necessary to confirm if this implication is true.

The neighborhoods in which participants grew up were found to have an impact on the number of LEP responses that corresponds to Position 4. This position represents a multiplistic view where multiple justifications can be used to support knowledge that unknown. Since this knowledge is unknown, all possible explanations and their reasoning are valid. This type of thinking could be fostered in an environment where an individual is exposed to multiple views on knowledge. This is more likely to occur in people immersed in an urban neighborhood due to the population densities and diversity that exist in those neighborhoods.

Electrical engineering participants were also found to have more responses correlate to Position 5 as compared to their computer engineering counterparts. This suggests that electrical engineers are more likely to view knowledge in a relativistic manner than computer engineers. It also suggests that different engineering majors may have significant differences in their epistemological beliefs. This finding could challenge the assumption that all engineering majors can be grouped together when they are evaluated in research studies. This also strongly suggests the need for more research to understand why these differences might be occurring.

Both university and department GPA were not found to be significant variables for the epistemological development of electrical and computer engineering students. Participants with a university GPA below 3.5 were found to have more LEP responses correlate to Position 3 of Perry's Scheme. Previous engineering epistemology research had not found any correlation between GPA and epistemological beliefs despite evidence that GPA does influence epistemological development [36], [74], [178]. While Position 3 is normally associated with beliefs of multiplicity, it represents a more naïve version of those beliefs.

The learning preference distributions measured by the ILS found that participants in the study were more likely to be active, sensing, visual, and sequential. This matched the results of previous research of engineering students' learning preferences [168], [169], [181]. When the participants were compared on individual learning preference dimensions, there was a significant difference in the CCI between participants with an active learning preference and those with a reflexive learning preference. This result was expected since most engineering courses are taught in a lecture format where students are passive participants who are expected to internalize the information that is provided to them. This teaching style lends itself towards those who have a reflexive learning preference. Active participants were found to have more dualistic beliefs while reflexive participants had more relativistic epistemological beliefs.

The study also found that participants with an intuitive learning preference had more responses that corresponded to Position 4 and Position 5 as well as a higher CCI than participants with a sensing preference. This may have been due to the teaching style of most engineering courses where the main focus is on concepts that are expressed through symbols [46]. This teaching style is geared more towards the preferences of an intuitive learner, which gives them an advantage with respect to processing new knowledge and its impact on their epistemological beliefs. The degree of a sensing or intuitive preference also had an effect on Position 5 responses and the overall epistemological beliefs of ECE students. Felder believed that the milder the degree of a learning preference, the easier it would be for one to alternate between learning preferences[181]. This would suggest that students with a mild learning preference would have an advantage because they would have the best chance to adjust to the teaching style of a course.

It was the belief of this study that experiences like internships and co-op rotations would influence the epistemological beliefs of electrical and computer engineering students because they allow students to be exposed to more ill-defined problems and ways of thinking that they may not encounter in an academic setting. This exposure would allow more opportunities for students to face these conflicts and feel what Bendixen and Rule[122] referred to as epistemic doubt. However, there was no significant difference when results were compared with respect to students who had and did not have internship or co-op experiences.

One possible explanation for the lack of a significant difference for students who have completed an internship or co-op rotation and those that did not is that the students underwent some type of epistemological regression. This can occur when individuals encounter views of knowledge that the students cannot resolve and incorporate into their own beliefs. Instead of just maintaining their current level, individuals revert to more naïve beliefs, i.e. "non-linear development paths".

Another possible explanation is that the LEP cannot accurately measure the impact that academic research, internships, and co-op have on epistemological beliefs. This may be due to the fact the LEP infers beliefs from the individual's ideal learning environment. Since these experiences occur outside the context of the LEP, it may not be able to expose any epistemological differences related to having those experiences. It may require a new or modified inventory or data collection approach such as interviews in order to properly measure the influence of the industrial context.

4.7. Conclusion

This study examined the epistemological beliefs of electrical and computer engineering students and the potential impact that the different contexts of the TIDE framework had on the development of these beliefs. Most participants were found to have epistemological beliefs that corresponded to a multiplistic view of knowledge. Factors within all three of the original contexts of the TIDE framework that were evaluated were found to have significant influence on epistemological beliefs across the overall population. The proposed industrial context was not found to influence the epistemological beliefs of electrical and computer engineering students.

5. IMPLICATIONS, FUTURE WORK, AND CONCLUSIONS

5.1. Implications

Different Engineering Majors May Have Different Patterns of Epistemological Development

There was no significant difference in CCI averages when students were compared with respect to academic level/classification. This suggests that the epistemological beliefs of electrical and computer engineering students may not evolve with respect to Perry's scheme [20]. This result contradicts the results of other studies that have examined the epistemological beliefs of engineering students [32], [42]. This could imply that certain engineering major curriculums provide more opportunities that trigger epistemological development.

Most research that examined the epistemological beliefs of engineering students have included all engineering majors in their populations [34], [35], [97]. This was due to the assumption based on Biglan [41] that there was no difference in the epistemological beliefs of students across all engineering majors. However, the curriculums across engineering majors may have differences (e.g. different teaching methods) that can provide more opportunities that allow students' epistemological beliefs to develop. This study has established epistemological profiles for two engineering majors that are commonly grouped together in a university setting. The electrical engineering participants were found to have more responses that corresponded to Position 5 of the Perry Scheme than their computer engineering counterparts. This result suggests that the assumption that all engineering majors have similar epistemological development patterns may not be accurate. More research is needed to determine if this trend holds true for other populations. If the gap is present, then educators in both K-12 and universities may need to add more opportunities for students to undergo epistemological development through more student exposure to ill-structured problems that challenge their views on knowledge. One possible way to do this would be to shift curricula to have more experiential courses.

Matching of Learning Preferences to Teaching Preferences Matter

Most prior studies looking at the learning preference of students have done so to establish the distribution of preferences within an engineering program. This study found that the participants whose learning preferences matched the preferred teaching styles of most electrical and computer engineering faculty in two of the four dimensions of Felder and Silverman's [46] model of learning styles were found have a significant impact on the CCI scores and subcategory distributions of participants. The participants in these dimensions whose learning preference matched the teaching preferences of most engineering professors were found to have more responses correlate to the more advanced Perry positions. However, the participants who have these learning preferences have been the minority of engineering students in this and previous studies [169], [181]. This implies that most students are in engineering courses that may not allow them to maximize their epistemological development. While this result does not mean that students should only be in courses that are taught to match their learning preference, it does provide evidence that courses should be presented using several teaching styles in order to maximize their impact on students and/or, as has been tried, offer multiple sections with different styles of pedagogy such as a traditional lecture and directed problem-solving.

Focus on International Engineering Students in U.S. Academic Environment

As international students become a larger percentage of the undergraduate engineering population, understanding their epistemological development patterns will be important in order to allow them to maximize their educational experiences. Previous research on the epistemological beliefs of international engineering students within a U.S. education setting [90] only examined doctoral students who did their undergraduate work outside of the U.S. and did not compare them to domestic students. This study provided an initial look at the differences between U.S. and international engineering students immersed the same educational setting with respect to their epistemological beliefs. The comparison allowed for an assessment of the current state of the epistemological beliefs for both types of engineering students. International students scored a higher average CCI than domestic students, suggesting that international students may be getting more out of the ECE curriculum with respect to epistemological beliefs. Since this is one of the first studies to examine the epistemological beliefs of students with respect to domestic and international students, more research on this topic is needed to determine if this trend holds for other ECE populations. One potential way to account for the differences between domestic and international students is to present new topics and knowledge in a manner that students can relate to culturally.

5.2. Future Work

While this study has made headway with respect to exploring the epistemological beliefs of electrical and computer engineering students, there are still many avenues that can be explored. One such avenue would be to explore the actual development of beliefs over an extended period of time. Previous work with engineering students looked at development at various points during their academic career. The next step would be to expand the pool of participants to include electrical and computer engineering students who have graduated and moved into industry. This would allow researchers to further examine more factors that may influence epistemological beliefs outside the confines of a colligate environment as well as exploring epistemological development.

Another idea for future work would be to repeat the study multiple times using different epistemological belief models. One instance should use a multidimensional model of epistemological beliefs like Schommer [23], Hofer [74], or Schraw et al. [71] to see how well they relate to engineering students. Another would use a model that was designed more for how individuals approach ill-structured problems like the Reflective Judgment Model. In order to account for the growing international student population in engineering and to work around the fact that most inventories were tested and validate using students in the humanities, the inventories used may need to be edited and or cross-culturally validated. Doing this would build upon previous literature with respect to the comparison of the dimensionality of epistemological beliefs [192] and allow researchers to investigate if there is any overlap between the two with respect to engineers. In addition, the studies should have a mixed-method design where qualitative data is gathered to gain more insight into students' reasoning for why they have certain views.

This study was the product of looking at ways to improve the problem solving skills of electrical and computer engineers, particularly their ill-structured problem solving skills. While research has found a link between epistemological beliefs and problem solving [144], there has not been much published looking at the link for engineers. A study that examines how strong the link is between the complexity of an individual's epistemological beliefs and their ability to solve both structured and ill-structured problems would be highly beneficial to the epistemological development research and help to establish expectations of individuals when they have certain views of knowledge. This would also need to be examined over time to correlate epistemological development with the growth of problem solving skills.

5.3. Conclusion

This study examined the potential impact that the different contexts of the TIDE framework had on the epistemological beliefs of electrical and computer engineering student. The study found significant factors for the sociocultural context (gender, domestic vs. international) on the overall population, the academic context (research experience, transfer credits, major) between the underclassmen and upperclassmen, and the instructional context (active vs. reflexive, sensing vs. intuitive) for the overall population and between the underclassmen and upperclassmen. These results support previous finding on the epistemological beliefs of engineering students, while also suggesting some new factors that could influence the development of epistemological beliefs. The study also proposed a new context to describe the potential influence of internship, co-ops, and work experience on epistemological beliefs called the industrial context. While I was not able to find any significant influence for this context in this study, I believe that it is something that should continue to be examined for engineering students.

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APPENDICES

A. BACKGROUND SURVEY

Background Information (All response are optional)

What is your name?

What is your email address?

What is your gender?
___ Male ___ Female ___ Do not wish to provide

What is your citizenship status?
____ U.S. Citizen/Permanent Resident ____ International

If you selected international, please enter your country of origin

---

Choose your native language
____ Native English Speaker ____ Non-native English Speaker

If you checked Non-native English Speaker, what is your native language?

What would you consider to be your race? If you do not wish to provide this information please type N/A
____White ____ Hispanic or Latino ____ Black or African American

____ Native American or American Indian ____ Asian / Pacific Islander

____ Other ____ Do not wish provide

Please select the environment that best describes the environment where you grew up
____Urban ____ Suburban ____ Rural

Are you the first person in your family to attend college?
____ Yes ____ No

What is the highest level of education completed by your father?
_____ No schooling completed _____ Nursery school to 8th grade
_____Some high school, no diploma
_____ High school graduate, diploma or the equivalent (for example: GED)
_____ Some college credit, no degree _____ Trade/technical/vocational training
_____ Associate degree _____ Bachelor's degree
_____ Master's degree _____ Professional degree
_____ Doctorate degree _____ Unknown

What is the most advanced degree of your mother?
_____ No schooling completed _____ Nursery school to 8th grade
_____Some high school, no diploma
_____ High school graduate, diploma or the equivalent (for example: GED)
_____ Some college credit, no degree _____ Trade/technical/vocational training
_____ Associate degree _____ Bachelor's degree
_____ Master's degree _____ Professional degree
_____ Doctorate degree _____ Unknown

What is the total yearly income (before taxes) of your parents/guardians? (values are in U.S. dollars)
_____ Under $25,000 _____ $25,000 - $39,999
_____ $40,000 - $49,999 _____ $50,000 - $74,999
_____ $75,000 - $99,999 _____ $100,000 - $124,999
_____ $125,000 - $149,999 _____ Over $150,000
_____ Do Not Know _____ Do not wish to provide

Check if any of these classifications apply to you.
_____ Delay in Progress _____Co-do _____ Transfer Credit

What is your current Purdue classification?
___ Sophomore ___ Junior ___Senior

What is your current program classification (Where you are as ECE students)?
___ Freshman ___ Sophomore ___ Junior ___Senior

Do you wish to provide you provide your GPA
___ Yes ___ Don't know my GPA _____ No

If yes, please list below
Current Purdue GPA: ________________________________
Current ECE GPA: ________________________________

Please check classes that you have taken:
___ ECE 201 ___ ECE 201H ___ ECE 202 ___ ECE 202H
___ ECE 207 ___ ECE 208 ___ ECE 255
___ ECE 264 (Traditional ___ ECE 264 (DPS)
___ ECE 270(Traditional) ___ ECE 270(DPS)
___ ECE 301 ___ ECE 302 ___ ECE 311 ___ ECE 337
___ ECE 362 ___ ECE 364 ___ ECE 368 ___ ECE 402
___ ECE 437 ___ ECE 468 ___ ECE 469 ___ ECE 477
___ EPCS 411 ___ EPCS 412 ___ PHYS 171 ___ PHYS 172
___ MA 165 ___ MA 166 ___ MA 261 ___ MA 265
___ MA 266

Check if you have participated in any of the following
___ Military If yes, how many years? _______
___ Co-op If yes, how many rotations? ______
___ Internship If yes, how many rotations? ______
___ Summer Research If yes, how many semesters (summer research counts as one semester? ______
___ Work Experience If yes, please list the number of employers and months of employment
___ Study Abroad If yes, how many semesters?
___ Student Design Competitions If yes, how many? ______

B. LEARNING ENVIRONMENT PREFERENCES

LEARNING ENVIRONMENT PREFERENCES

This survey asks you to describe what you believe to be the most significant issues in your **IDEAL** LEARNING ENVIRONMENT. Your opinions are important to us as we study how students think about teaching and learning issues. We ask, therefore, that you take this task seriously and give your responses some thought. We appreciate your cooperation in sharing what you find most important in a learning environment.

The survey consists of five sections, each representing a different aspect of learning environments. In each section, you are presented with a list of specific statements about that particular area. Try not to focus on a specific class or classes as you think about these items; focus on their significance in an *ideal* learning environment *for you.*

We ask that you do two things for each section of the instrument:

1. Please **rate** each item of the section (using the 1-4 scale provided below) in terms of its significance or importance to your learning.
2. Review the list and **rank** the three most important items to you as you think about your *ideal learning environment* by writing *the item numbers* on the appropriate spaces at the bottom of the answer sheet.

Please mark your answers on the separate answer sheet provided, and be sure to indicate both your ratings of individual items **and** *your ranking of the top 3 items in each section*. It is very important that you indicate your top three choices for each question area by writing the ITEM NUMBER in the spaces provided (1st choice, 2nd choice, 3rd choice).

Rating Scale:

1	**2**	**3**	**4**
Not at all significant	**Somewhat significant**	**Moderately significant**	**Very significant**

Before you begin, you may be asked to provide us with some background information. This information will be used to examine group differences; your name or social security number may be used at some point in the future if a follow-up survey is required. ALL RESPONSES WILL BE KEPT CONFIDENTIAL. Again, thank you very much for sharing with us your ideas about learning.

DOMAIN ONE:
COURSE CONTENT/VIEW OF LEARNING

MY IDEAL LEARNING ENVIRONMENT WOULD:

1. Emphasize basic facts and definitions.
2. Focus more on having the right answers than on discussing methods or how to solve problems.
3. Insure that I get all the course knowledge from the professor.
4. Provide me with an opportunity to learn methods and solve problems.
5. Allow me a chance to think and reason, applying facts to support my opinions.
6. Emphasize learning simply for the sake of learning or gaining new expertise.
7. Let me decide for myself whether issues discussed in class are right or wrong, based on my own interpretations and ideas.
8. Stress the practical applications of the material.
9. Focus on the socio-psycho, cultural and historical implications and ramifications of the subject matter.
10. Serve primarily as a catalyst for research and learning on my own, integrating the knowledge gained into my thinking.
11. Stress learning and thinking on my own, not being spoonfed learning by the instructor.
12. Provide me with appropriate learning situations for thinking about and seeking personal truths.
13. Emphasize a good positive relationship among the students and between the students and teacher.

PLEASE BE SURE TO REVIEW THE ABOVE LIST AND MARK YOUR THREE MOST SIGNIFICANT ITEMS (BY ITEM NUMBER) IN THE LINES PROVIDED ON THE ANSWER SHEET.

Rating Scale:

1	2	3	4
Not at all significant	**Somewhat significant**	**Moderately significant**	**Very significant**

DOMAIN TWO:
ROLE OF INSTRUCTOR

IN MY IDEAL LEARNING ENVIRONMENT, THE TEACHER WOULD:

1. Teach me all the facts and information I am supposed to learn.
2. Use up-to-date textbooks and materials and teach from them, not ignore them.
3. Give clear directions and guidance for all course activities and assignments.
4. Have only a minimal role in the class, turning much of the control of course content and class discussions over to the students.
5. Be not just an instructor, but more an explainer, entertainer and friend.
6. Recognize that learning is mutual--individual class members contribute fully to the teaching and learning in the class.
7. Provide a model for conceptualizing living and learning rather than solving problems.
8. Utilize his/her expertise to provide me with a critique of my work.
9. Demonstrate a way to think about the subject matter and then help me explore the issues and come to my own conclusions.
10. Offer extensive comments and reactions about my performance in class(papers, exams, etc.).
11. Challenge students to present their own ideas, argue with positions taken, and demand evidence for their beliefs.
12. Put a lot of effort into the class, making it interesting and worthwhile.
13. Present arguments on course issues based on his/her expertise to stimulate active debate among class members.

PLEASE BE SURE TO REVIEW THE ABOVE LIST AND MARK YOUR THREE MOST SIGNIFICANT ITEMS (BY ITEM NUMBER) IN THE LINES PROVIDED ON THE ANSWER SHEET.

Rating Scale:

1	2	3	4
Not at all significant	**Somewhat significant**	**Moderately significant**	**Very significant**

DOMAIN THREE:
ROLE OF STUDENT/PEERS

IN MY IDEAL LEARNING ENVIRONMENT, AS A STUDENT I WOULD:

1. Study and memorize the subject matter--the teacher is there to teach it.
2. Take good notes on what's presented in class and reproduce that information on the tests.
3. Enjoy having my friends in the class, but other than that classmates don't add much to what I would get from a class.
4. Hope to develop my ability to reason and judge based on standards defined by the subject.
5. Prefer to do independent research allowing me to produce my own ideas and arguments.
6. Expect to be challenged to work hard in the class.
7. Prefer that my classmates be concerned with increasing their awareness of themselves to others in relation to the world.
8. Anticipate that my classmates would contribute significantly to the course learning through their own expertise in the content.
9. Want opportunities to think on my own, making connections between the issues discussed in class and other areas I'm studying.
10. Take some leadership, along with my classmates, in deciding how the class will be run.
11. Participate actively with my peers in class discussions and ask as many questions as necessary to fully understand the topic.
12. Expect to take learning seriously and be personally motivated to learn the subject.
13. Want to learn methods and procedures related to the subject--learn how to learn.

PLEASE BE SURE TO REVIEW THE ABOVE LIST AND MARK YOUR THREE MOST SIGNIFICANT ITEMS (BY ITEM NUMBER) IN THE LINES PROVIDED ON THE ANSWER SHEET.

Rating Scale:

1	2	3	4
Not at all significant	**Somewhat significant**	**Moderately significant**	**Very significant**

DOMAIN FOUR:
CLASSROOM ATMOSPHERE/ACTIVITIES

IN MY IDEAL LEARNING ENVIRONMENT, THE CLASSROOM ATMOSPHERE AND ACTIVITIES WOULD:

1. Be organized and well-structured--there should be clear expectations set (like a structured syllabus that's followed).
2. Consist of lectures (with a chance to ask questions) because I can get all the facts I need to know more efficiently that way.
3. Include specific, detailed instructions for all activities and assignments.
4. Focus on step-by-step procedures so that if you did the procedure correctly each time, your answer would be correct.
5. Provide opportunities for me to pull together connections among various subject areas and then construct an adequate argument.
6. Be only loosely structured, with the students themselves taking most of the responsibility for what structure there is.
7. Include research papers, since they demand that I consult sources and then offer my own interpretation and thinking.
8. Have enough variety in content areas and learning experiences to keep me interested.
9. Be practiced and internalized but be balanced by group experimentation, intuition, comprehension, and imagination.
10. Consist of a seminar format, providing an exchange of ideas so that I can critique my own perspectives on the subject matter.
11. Emphasize discussions of personal answers based on relevant evidence rather than just right and wrong answers.
12. Be an intellectual dialogue and debate among a small group of peers motivated to learn for the sake of learning.
13. Include lots of projects and assignments with practical, everyday applications.

PLEASE BE SURE TO REVIEW THE ABOVE LIST AND MARK YOUR THREE MOST SIGNIFICANT ITEMS (BY ITEM NUMBER) IN THE LINES PROVIDED ON THE ANSWER SHEET.

Rating Scale:

1	2	3	4
Not at all significant	**Somewhat significant**	**Moderately significant**	**Very significant**

DOMAIN FIVE:
EVALUATION PROCEDURES

EVALUATION PROCEDURES IN MY IDEAL LEARNING ENVIRONMENT WOULD:

1. Include straightforward, not "tricky," tests, covering only what has been taught and nothing else.
2. Be up to the teacher, since s/he knows the material best.
3. Consist of objective-style tests because they have clearcut right or wrong answers.
4. Be based on how much students have improved in the class and on how hard they have worked in class.
5. Provide an opportunity for me to judge my own work along with the teacher and learn from the critique at the same time.
6. Not include grades, since there aren't really any objective standards teachers can use to evaluate students' thinking.
7. Include grading by a prearranged point system(homework, participation, tests, etc.), since I think it seems the most fair.
8. Represent a synthesis of internal and external opportunities for judgement and learning enhancing the quality of the class.
9. Consist of thoughtful criticism of my work by someone with appropriate expertise.
10.Emphasize essay exams, papers, etc. rather than objective-style tests so that I can show how much I've learned.
11.Allow students to demonstrate that they can think on their own and make connections not made in class.
12.Include judgments of the quality of my oral and written work as a way to enhance my learning in the class.
13.Emphasize independent thinking by each student, but include some focus on the quality of one's arguments and evidence.

PLEASE BE SURE TO REVIEW THE ABOVE LIST AND MARK YOUR THREE MOST SIGNIFICANT ITEMS (BY ITEM NUMBER) IN THE LINES PROVIDED ON THE ANSWER SHEET.

Rating Scale:

1	2	3	4
Not at all significant	**Somewhat significant**	**Moderately significant**	**Very significant**

LEARNING ENVIRONMENT PREFERENCES ANSWER SHEET

STUDENT CODE NUMBER: ___________________

Rating Scale:	1 Not at all significant	2 Somewhat significant	3 Moderately significant	4 Very significant

For each domain, record your rating of each item (using the rating scale described above) on the lines by the appropriate item numbers.

DOMAINS

Course Content/ View of Learning	Role of Instructor	Role of Student/Peers	Classroom Atmosphere	Evaluation Procedures
1.______	1.______	1.______	1.______	1.______
2, ______	2, ______	2, ______	2, ______	2, ______
3. ______	3. ______	3. ______	3. ______	3. ______
4. ______	4. ______	4. ______	4. ______	4. ______
5. ______	5. ______	5. ______	5. ______	5. ______
6. ______	6. ______	6. ______	6. ______	6. ______
7. ______	7. ______	7. ______	7. ______	7. ______
8. ______	8. ______	8. ______	8. ______	8. ______
9. ______	9. ______	9. ______	9. ______	9. ______
10. ______	10. ______	10. ______	10. ______	10. ______
11. ______	11. ______	11. ______	11. ______	11. ______
12. ______	12. ______	12. ______	12. ______	12. ______
13. ______	13. ______	13. ______	13. ______	13. ______

Now record your **TOP THREE CHOICES** for each domain area by writing the **ITEM NUMBERS**, not your ratings, of these choices in the spaces provided below. (For example, if you consider item # 2 the most significant issue for your own learning related to the domain of "Role of Instructor," write "2" next to "1st" under that domain below.)

COURSE CONTENT	ROLE OF INSTRUCTOR	ROLE OF STUDENT/PEERS	CLASSROOM ATMOSPHERE	EVALUATION PROCEDURES
1ST______	1ST_____	1ST______	1ST______	1ST_______
2ND______	2ND_____	2ND______	2ND______	2ND_______

3RD______ 3RD_____ 3RD______ 3RD______ 3RD_______

C. INDEX OF LEARNING STYLES

Enter your answers to every question on the ILS scoring sheet. Please choose only one answer for each question. If both "a" and "b" seem to apply to you, choose the one that applies more frequently.

1. I understand something better after I

   a) try it out.

   b) think it through.

2. I would rather be considered

   a) realistic.

   b) innovative.

3. When I think about what I did yesterday, I am most likely to get

   a) a picture.

   b) words.

4. I tend to

   a) understand details of a subject but may be fuzzy about its overall structure.

   b) understand the overall structure but may be fuzzy about details.

5. When I am learning something new, it helps me to

   a) talk about it.

   b) think about it.

6. If I were a teacher, I would rather teach a course

   a) that deals with facts and real life situations.

b) that deals with ideas and theories.

7. I prefer to get new information in

   a) pictures, diagrams, graphs, or maps.

   b) written directions or verbal information.

8. Once I understand

   a) all the parts, I understand the whole thing.

   b) the whole thing, I see how the parts fit.

9. In a study group working on difficult material, I am more likely to

   a) jump in and contribute ideas.

   b) sit back and listen.

10. I find it easier

   a) to learn facts.

   b) to learn concepts.

11. In a book with lots of pictures and charts, I am likely to

   a) look over the pictures and charts carefully.

   b) focus on the written text.

12. When I solve math problems

   a) I usually work my way to the solutions one step at a time.

   b) I often just see the solutions but then have to struggle to figure out the steps to get to them.

13. In classes I have taken

   a) I have usually gotten to know many of the students.

   b) I have rarely gotten to know many of the students.

14. In reading nonfiction, I prefer

a) something that teaches me new facts or tells me how to do something.

b) something that gives me new ideas to think about.

15. I like teachers

a) who put a lot of diagrams on the board.

b) who spend a lot of time explaining.

16. When I'm analyzing a story or a novel

a) I think of the incidents and try to put them together to figure out the themes.

b) I just know what the themes are when I finish reading and then I have to go back and find the incidents that demonstrate them.

17. When I start a homework problem, I am more likely to

a) start working on the solution immediately.

b) try to fully understand the problem first.

18. I prefer the idea of

a) certainty.

b) theory.

19. I remember best

a) what I see.

b) what I hear.

20. It is more important to me that an instructor

a) lay out the material in clear sequential steps.

b) give me an overall picture and relate the material to other subjects.

21. I prefer to study

a) in a study group.

b) alone.

22. I am more likely to be considered

    a) careful about the details of my work.

    b) creative about how to do my work.

23. When I get directions to a new place, I prefer

    a) a map.

    b) written instructions.

24. I learn

    a) at a fairly regular pace. If I study hard, I'll "get it."

    b) in fits and starts. I'll be totally confused and then suddenly it all "clicks."

25. I would rather first

    a) try things out.

    b) think about how I'm going to do it.

26. When I am reading for enjoyment, I like writers to

    a) clearly say what they mean.

    b) say things in creative, interesting ways.

27. When I see a diagram or sketch in class, I am most likely to remember

    a) the picture.

    b) what the instructor said about it.

28. When considering a body of information, I am more likely to

    a) focus on details and miss the big picture.

    b) try to understand the big picture before getting into the details.

29. I more easily remember

    a) something I have done.

    b) something I have thought a lot about.

30. When I have to perform a task, I prefer to

a) master one way of doing it.

b) come up with new ways of doing it.

31. When someone is showing me data, I prefer

a) charts or graphs.

b) text summarizing the results.

32. When writing a paper, I am more likely to

a) work on (think about or write) the beginning of the paper and progress forward.

b) work on (think about or write) different parts of the paper and then order them.

33. When I have to work on a group project, I first want to

a) have "group brainstorming" where everyone contributes ideas.

b) brainstorm individually and then come together as a group to compare ideas.

34. I consider it higher praise to call someone

a) sensible.

b) imaginative.

35. When I meet people at a party, I am more likely to remember

a) what they looked like.

b) what they said about themselves.

36. When I am learning a new subject, I prefer to

a) stay focused on that subject, learning as much about it as I can.

b) try to make connections between that subject and related subjects.

37. I am more likely to be considered

a) outgoing.

b) reserved.

38. I prefer courses that emphasize

    a) concrete material (facts, data).

    b) abstract material (concepts, theories).

39. For entertainment, I would rather

    a) watch television.

    b) read a book.

40. Some teachers start their lectures with an outline of what they will cover. Such outlines are

    a) somewhat helpful to me.

    b) very helpful to me.

41. The idea of doing homework in groups, with one grade for the entire group,

    a) appeals to me.

    b) does not appeal to me.

42. When I am doing long calculations,

    a) I tend to repeat all my steps and check my work carefully.

    b) I find checking my work tiresome and have to force myself to do it.

43. I tend to picture places I have been

    a) easily and fairly accurately.

    b) with difficulty and without much detail.

44. When solving problems in a group, I would be more likely to

    a) think of the steps in the solution process.

    b) think of possible consequences or applications of the solution in a wide range of areas.

D. INSTRUUCTIONS FOR COMPLETING EPISTEMOLOGIAL PROFILE

Login to your machine and open an Internet browser.

Go to the following links to access the surveys you will be taking. We ask that your fill out the background information first. You can complete the LEP or ILS inventories in whatever order you choose. When completed, do not exit and get the attention of the proctor. When they have gathered the necessary data from your surveys, you can log out.

Background information survey:
https://www.surveymonkey.com/s/RMCSYV9

Learning Environment Preferences (LEP) Inventory
https://www.surveymonkey.com/s/MVYWJ9H

Index of learning Styles (ILS) Inventory
http://www.engr.ncsu.edu/learningstyles/ilsweb.html

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VITA

Askia Hill is from Tuskegee, Alabama. He received is Bachelor's of Science degree in Computer Engineering with a minor in Mathematics from the University of Maryland Baltimore County in 2008. His undergraduate work earned him the GEM Fellowship and in the fall of 2008, he entered the Ph.D program in the school of Electrical and Computer Engineering at Purdue University. While completing his degree, he served as a teaching assistant for the advanced C programming course at Purdue. His work as a teaching assistant earned him a Magoon Excellence in Teaching Award in 2011. His research interests include the epistemological development of undergraduate and graduate engineering students, problem-solving skills of engineering students, computational thinking, and parallel compilers.