Future Engineering Professors' Conceptions of Learning and Teaching Engineering

Ana Teresa Torres Ayala

University of South Florida, ana.t.torres@gmail.com

Follow this and additional works at: http://scholarcommons.usf.edu/etd

Part of the Engineering Commons, and the Higher Education and Teaching Commons

Scholar Commons Citation
Torres Ayala, Ana Teresa, "Future Engineering Professors' Conceptions of Learning and Teaching Engineering" (2013). Graduate Theses and Dissertations.
http://scholarcommons.usf.edu/etd/4412

This Dissertation is brought to you for free and open access by the Graduate School at Scholar Commons. It has been accepted for inclusion in Graduate Theses and Dissertations by an authorized administrator of Scholar Commons. For more information, please contact scholarcommons@usf.edu.
Future Engineering Professors’ Conceptions of Learning and Teaching Engineering

by

Ana T. Torres Ayala

Dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Curriculum and Instruction with an emphasis in Higher Education, College Teaching Department of Adult, Career and Higher Education College of Education University of South Florida

Major Professor: Thomas Miller, EdD
Member: James Eison, PhD
Member: Deirdre Cobb-Roberts, PhD
Member: Glenn G. Smith, PhD
Member: Robert Sullins, EdD

Date of Approval: July 12, 2012

Keywords: Faculty Development, Engineering Education, Graduate Education, Doctoral Students, Qualitative Research

Copyright © 2012, Ana T. Torres Ayala
Dedication

This work is dedicated to my family, my first and best teachers. I could not have made it without *mi equipo de apoyo* (my support team): my parents, Francisco Torres and Lydia Ayala, my grandmother and first teacher, Margarita Torres, my brother and dearest friend, Diego Torres, and my husband and greatest supporter, Benjamin Santos. Thanks to our children, Adriana and Alejandro for bringing so much joy to my life. The extended Torres, Ayala, Santos and Visbal families provided much appreciated prayers and support throughout my studies.

This work is also dedicated to professors – past, present, and future – who strive every day to find better ways to help students learn.
Acknowledgements

Thanks to Dr. Thomas Miller for not only guiding me in the development of this work but also for his thoughtful and wise counsel in my personal and professional development. Thanks to my dissertation committee: Dr. James Eison, Dr. Deirdre Cobb-Roberts, Dr. Glenn Smith, and Dr. Robert Sullins for providing constructive feedback and encouragement throughout the years of this project. My gratitude also goes to professors who gave me opportunities to develop my research skills while I worked with them on their projects, once again Dr. Glenn Smith, Dr. Paul Dosal, and Dr. Monica Cox. Heartfelt thanks also go to my colleague Dr. Marilyn Armstrong, for all the hours spent discussing both of our research studies, as well as for her patient and unwavering support.

Many friends, classmates, and colleagues, encouraged me from near and far especially my PhD buddy, Carmeda Stokes, my ENLACE colleagues: particularly Athanasia Fitos and Dr. Edwin Estevez, my ATLE colleagues: Dr. Diane Williams and Dr. Yenni Djajalaksana, the people of USF’s Office of Student Success, my GEECS friends and mi familia de AAHHE (my AAHHE family).

This research was supported in part by the Leslie C. Robins Dean’s Excellence Award for Outstanding Doctoral Students at the University of South Florida.

Last but not least, thank you to this study’s participants for their willingness to take time from their busy schedules to share with me their experiences and insights. Without their generosity, this dissertation could not have been written.
# Table of Contents

List of Figures .................................................................................................................. iii

List of Tables..................................................................................................................... iv

Abstract............................................................................................................................. vi

Chapter 1: Introduction..................................................................................................... 1
  Statement of the Problem ................................................................................................. 1
  Conceptual Framework ................................................................................................. 2
  Purpose of the Study ..................................................................................................... 6
  Why study future engineering faculty? ........................................................................... 6
  Research Questions ....................................................................................................... 7
  Research Design ........................................................................................................... 8
  Significance of the Study ............................................................................................. 8
  Definitions of Terms ..................................................................................................... 9
  Delimitations ................................................................................................................ 10
  Limitations ................................................................................................................... 11
  Chapter Summary ....................................................................................................... 12

Chapter 2: Review of the Literature ............................................................................. 13
  Epistemological Beliefs................................................................................................. 13
  Conceptions of Learning .............................................................................................. 18
  Learning Engineering .................................................................................................. 20
  Conceptions of Problem Solving ............................................................................... 21
  Conceptions of Teaching in Higher Education .......................................................... 22
  Conceptions of Teaching in Engineering .................................................................... 27
  Development of Beliefs about Teaching ..................................................................... 31
  Chapter Summary ....................................................................................................... 32

Chapter 3: Method .......................................................................................................... 33
  Introduction .................................................................................................................. 33
  Research Questions ..................................................................................................... 33
  Research Design .......................................................................................................... 34
  Phenomenography ....................................................................................................... 35
  Thematic Analysis ....................................................................................................... 38
  Participant Selection ................................................................................................... 39
  Instruments .................................................................................................................. 40
List of Figures

Figure 1: Pratt (1998) General Model of Teaching ........................................ 3

Figure 2: Beliefs about Teaching System Model ............................................. 5

Figure 3: Interactions within the *Embedded Systemic Model* of Epistemological Beliefs .......................................................... 17

Figure 4: Learning Goals in Engineering Courses ........................................... 20

Figure 5: Participants ...................................................................................... 48
List of Tables

Table 1: Interview Protocol ................................................................. 41
Table 2: Emerging Conceptions of Learning Engineering ...................... 51
Table 3: Categories of Conceptions of Learning Engineering ................. 52
Table 4: Emerging Conceptions of Teaching Engineering .................... 54
Table 5: Categories of Conceptions of Teaching Engineering ............... 54
Table 6: Category 1: Learning Engineering as Acquiring ..................... 63
Table 7: Category 2: Learning Engineering as Understanding ............... 66
Table 8: Category 3: Learning Engineering as Practicing ..................... 70
Table 9: Category 4: Learning Engineering as Applying ..................... 73
Table 10: Category 5: Learning Engineering as Developing .................. 79
Table 11: Category 6: Learning Engineering as Maturing ..................... 85
Table 12: Outcome Space for Future Engineering Professors’ Conceptions of Learning Engineering ......................................................... 96
Table 13: Category 1: Teaching Engineering as Delivering Knowledge ......103
Table 14: Category 2: Teaching Engineering as Helping Understand Engineering Knowledge ................................................................. 109
Table 15: Category 3: Teaching Engineering as Motivating Students .........114
Table 16: Category 4: Teaching Engineering as Helping Students Learn How to Approach Problems ......................................................... 119
Table 17: Category 5: Teaching Engineering as Preparing Students to Make Socially Conscious Decisions ........................................... 123

Table 18: Outcome Space for Future Engineering Professors’ Conceptions of Teaching Engineering ............................................. 137
Abstract

Conceptions of learning and teaching shape teaching practices and are, therefore, important to understanding how engineering professors learn to teach. There is abundant research about professors’ conceptions of teaching; however, research on the conceptions of teaching of doctoral students, the future professors, is scarce. Furthermore, there is a need to understand not just future engineering professors’ conceptions of teaching but also their conceptions of learning. The purpose of this study was to explore qualitative variations in future engineering professors’ conceptions of learning and teaching as well as understanding how they came to these conceptions.

The research questions that guided this qualitative study are the following: 1) How do future engineering professors describe their conceptions of learning engineering?, 2) How do future engineering professors describe the basis of their conceptions of learning engineering?, 3) How do future engineering professors describe their conceptions of teaching engineering?, and 4) How do future engineering professors describe the basis of their conceptions of teaching engineering?

Twenty doctoral engineering students interested in academic careers were interviewed. A phenomenographic approach was used to explore variations in conceptions of learning and teaching. The basis of conceptions of learning and teaching were explored using thematic analysis.
Six variations in future engineering professors’ conceptions of learning engineering emerged and included learning engineering as 1) acquiring knowledge, 2) gaining an understanding, 3) practicing problem solving, 4) applying knowledge, 5) developing an approach, and 6) maturing. Each conception of learning was described by seven dimensions or features: focus, nature of knowledge, view of engineering, strategies, assessments, interactions, and relational. Participants described the basis for their conceptions of learning engineering through four general themes: undergraduate student experience, research, graduate school experience, and prior teaching experiences.

Five categories of conceptions of teaching engineering emerged and included teaching engineering as 1) delivering knowledge, 2) helping understand and apply concepts, 3) motivating students, 4) helping students learn how to approach problems, and 5) preparing students to make socially conscious decisions. In describing conceptions of teaching, five dimensions were identified: focus, strategies, use of students’ prior knowledge, faculty-student interaction, conception of learning, and projects. Observing professors, student experience, talking about teaching, and teaching experience were described by participants as the basis for their conceptions of teaching engineering.

The findings of this study are consistent with previous categorizations of university professors’ conceptions of teaching from teacher-centered/content-oriented to student-centered/learning-oriented. However, this study contributes to the literature of engineering education and faculty development by contextualizing the conceptions of learning and teaching of future engineering professors. Furthermore, this study provides richer descriptions of variations in other aspects of teaching and learning engineering such as future professors’ views on student interactions, student development,
assessment, motivation, problem solving, assumptions about knowledge, teaching and learning strategies.

In addition, this study contributes to our understanding of how professors learn about teaching. In particular, the exploration of the basis for the conceptions of learning and teaching opens new avenues to explore how conceptions of teaching and learning evolve over time. This study closes with implications for faculty development and suggestions for further research.
Chapter 1: Introduction

Statement of the Problem

A commonly held view among administrators, educators and students is that expert knowledge is sufficient for one to be a competent professor (Boyer, 1990). This mindset is prevalent in traditional Ph.D. programs particularly in engineering. Training researchers, not preparing graduates for teaching roles, is the primary focus of these programs. Job announcements and interviews for faculty positions in engineering tend to focus on demonstrating research qualifications not the capacity to teach (Fox & Hackerman, 2003, p. 44). However, when new faculty members are hired they often are required to quickly become teachers, while at the same time balance other responsibilities like research, grant writing, and service.

For the most part, doctoral engineering students have learning experiences that are very traditional: teacher-oriented and focused on transmitting knowledge. Doctoral education “does not provide enough systematic preparation for the various roles a faculty member must fulfill, including teaching” (Austin, et al., 2009). Nonetheless, new faculty members may be asked to teach in ways that are different than how they were taught. Since teaching practice is influenced by the teacher’s personal theories or conceptions of knowledge, learning, teaching and the student-teacher interaction (Rando & Menges, 1991; Trigwell, Prosser, & Waterhouse, 1999), this change requires a major shift in the person’s thinking and a considerable amount of re-training.
Conceptions of learning and teaching are also important to the development of competent teachers. Studies comparing novice and expert teachers (Dunkin, 2002) suggest that "expert teachers differ from their less experienced colleagues in the complexity and sophistication of their thoughts about teaching" (p.43). It is possible that the development of more and more appropriate conceptions of learning and teaching may aid new teachers.

Although there is abundant research exploring faculty’s conceptions of teaching (Kane, Sandretto, & Heath, 2002; Kember, 1997; Samuelowicz & Bain, 2001), research exploring the conceptions of doctoral students – the future faculty – is scarce. Few researchers have focused on the conceptions of engineering professors (Donald, 1992; McKenna & Yalvac, 2007; Van Driel, Bulte, & Verloop, 2007) and even fewer on the conceptions of future engineering professors (Huang, Yellin, & Turns, 2005). Furthermore, the development of these conceptions in a disciplinary context like engineering is not well understood.

Conceptual Framework

To explore conceptions of teaching and learning it is essential to understand the basic elements and relationships in teaching. To understand how these conceptions are formed it is necessary to explore what personal theories and cultural influences shape conceptions of teaching and learning. This section describes several models that guide this study in these areas.

The General Model of Teaching proposed by Pratt (1998) includes elements and relationships that are essential in teaching. It is based on Pratt’s explorations of the
teaching perspectives of hundreds of college and adult education teachers. The elements (Figure 1) in the model are: learners, teachers, content, context and ideals.

![Diagram of the General Model of Teaching by Pratt (1998)](image)

*Figure 1. Pratt (1998) General Model of Teaching (p. 4)*

There are relationships, represented by lines, between three of the elements in the model. Teachers have different means of engaging learners with the content (line X), interacting with learners (line Y) and establishing instructor content credibility (line Z) (p.6).

Pratt attributed differences in teaching perspectives to each individual’s “belief that some elements (and relationships) are more important than others” (p. 7). This is defined as the teacher’s commitment in teaching:

“a sense of loyalty, duty, responsibility or obligation with one or more elements within the General Model of Teaching. It is revealed through the way a person teaches (actions), what a person is trying to accomplish (intentions), and
statements of why those actions and intentions are reasonable, important or justifiable (beliefs)” (Pratt, 1998, p. 7).

For example, some teachers are committed to the learners. They are focused on the learners’ intellectual development, self-confidence or self-esteem. Other teachers are committed to their content. These teachers are passionate about their field or profession and expect the same from their students. A third type of commitment is to the context. Teachers committed to context expressed “a need to locate learning in authentic contexts of practice and social relations” (p. 9). The fourth type of teachers believe that teaching ought to be governed by a commitment to an ideal like social justice or equality. More than anything it is a commitment to a set of values (p.10).

The literature on distance learning (Moore, 1993) points to another type of relationship overlooked by Pratt in this model and that is the relationship among learners. Learner to learner interaction has been proven a resource for learning in distance and face-to-face active learning environments. In addition, some educators emphasize the importance of working effectively in groups to function in modern society. This emphasis on collaboration may be considered a dual commitment to the learner’s development and to an authentic professional context.

The beliefs on which these commitments in teaching are based on are not independent entities. They are part of a belief system influenced by the individual’s epistemological beliefs. Epistemological beliefs are “beliefs about the nature of knowledge” (Duell & Schommer-Aikins, 2001). The Beliefs about Teaching System
Model presented in Figure 2 was derived from a model of epistemological beliefs created by Schommer-Aikins (2004).

Figure 2. Beliefs about Teaching System Model

In this model, beliefs about teaching are directly influenced by the individuals’ self-concept, perceptions of the teaching context, beliefs about knowledge, and beliefs about learning. Teaching is also indirectly influenced by ways of knowing beliefs and cultural relational views. Schommer-Aikins argued that cultural relational views influence educational beliefs. This model assumes that persons coming from cultures that are predominantly horizontal (preoccupied with relationships of equality), will have different educational beliefs than other persons that come from vertical cultures (where
relationships are focused on maintaining status and power structures). For example, depending on cultural relational views individuals could have very different beliefs about the student-teacher relationship. In the field of engineering, cultural differences could have a significant impact. In 2008, over half of all doctoral students enrolled in engineering programs in the U.S. were foreign nationals (Gibbons, 2009).

**Purpose of the Study**

The purpose of this study was to explore qualitative variations in future engineering professors’ conceptions of learning and teaching. Learning and teaching engineering includes, to a great degree, the development of problem solving and design skills (Donald, 2002). Beliefs about how these skills are developed were also explored.

Understanding how doctoral engineering students come to these conceptions is also of interest. Therefore, this study also explored the justifications future professors gave for their conceptions.

**Why study future engineering faculty?**

Engineering is a particularly interesting context in which to study conceptions of teaching and learning. The status of teaching in science, technology, engineering, and mathematics (STEM) is less than ideal (Baldwin, 2009). Despite years of efforts to improve STEM teaching and learning, a large proportion of STEM faculty receives little, if any, formal training for teaching and teaching practices are rarely influenced by education research. As in other disciplines, most STEM professors teach as they were taught. In general, instructional culture in has resisted change (p.10).
Studies on disciplinary differences suggest that academic culture influences teaching’s stature and practice. Biglan (1973) classified engineering as a “hard applied” discipline. According to his study, teachers in this area tend to prefer research over teaching. Relatively abundant public and corporate funding for research in engineering may perpetuate this pattern. Not surprisingly, professors in these disciplines tend to spend the least amount of time on teaching preparation (Neumann, Parry, & Becher, 2002).

As the next generation of professors is socialized into the academy, these prevailing views on teaching and research are passed on to them. The prestige accorded to research assistantships relative to teaching appointments is one more indicator given to graduate students of the value given to teaching in their discipline. In fact, the best and brightest doctoral graduates in engineering may not have any teaching experience and, if they do, teaching assignments tend to be perceived as an impediment to making progress in research (Borrego, 2008).

**Research Questions**

The following research questions were addressed in this study:

1. How do future engineering professors describe their conceptions of learning engineering?

2. How do future engineering professors describe the basis of their conceptions of learning engineering?

3. How do future engineering professors describe their conceptions of teaching engineering?
4. How do future engineering professors describe the basis of their conceptions of teaching engineering?

**Research Design**

A review of the literature (see Chapter 2) revealed that prior studies of conceptions of learning and teaching have not explored the conceptions of future professors. In addition to the specific population under study, little prior research explored how professors justify or develop those conceptions.

This study explored future engineering professors’ conceptions through qualitative research methods. More precisely, phenomenography and thematic analysis were used to answer the four research questions identified above. As will be discussed in Chapter 3, phenomenography aims to reveal the qualitatively different ways in which participants experience and conceptualize an aspect of the world. In this study, the aspect is learning and teaching in the engineering context.

**Significance of the Study**

The retirement of the large Baby-boomer faculty cohort will soon create a period of opportunity to transform engineering education. The pedagogical development of the future professors who will replace them will be essential to improving engineering education in any meaningful way.

This study is a starting place from which to understand future engineering professors’ conceptions of learning and teaching in the engineering context. Beliefs and assumptions are at the deepest level of any culture and are essential to understanding it. By exploring future engineering professors’ conceptions of learning and teaching, this
study also expands and enriches the bodies of research on instructional culture and epistemology of engineering educators (The Steering Committee of the National Engineering Education Research Colloquies, 2006).

**Definitions of Terms**

*Beliefs* - statements of why a person’s “actions and intentions are reasonable, important or justifiable” (Pratt, 1998, p. 7).

*Conceptions* - different ways of experiencing, conceptualizing, seeing or understanding (Marton & Pong, 2005, p. 336).

According to Pratt (1992):

Conceptions are specific meanings attached to phenomena which then mediate our response to situations involving those phenomena. We form conceptions of virtually every aspect of our perceived world, and in so doing, use those abstract representations to delimit something from, and relate it to, other aspects of our world. (p. 204)

*Cultural relational views* – are an individual’s perceptions of the predominate way people associate with each other (Schommer-Aikins, 2004, p. 24)

*Epistemological beliefs* – are beliefs about the nature of knowledge (Duell & Schommer-Aikins, 2001).

*Future engineering faculty* – doctoral students in engineering programs who intend to pursue teaching careers in higher education
Phenomenography – a qualitative research approach that aims to reveal the qualitatively different ways in which people experience and conceptualize various aspects of the world (Ashworth & Lucas, 2000; Marton, Dall'Alba, & Beaty, 1993).

Ways of knowing – “different perspectives from which … [to] … view reality and draw conclusions about truth, knowledge and authority” (Belenky, Clinchy, Goldberger, & Tarule, 1986, p. 3).

Delimitations

This study was limited to doctoral engineering students in the U.S. who are interested in academic careers. Future faculty members who come from industry or other countries were not included in this study due to obvious challenges identifying and contacting persons in this situation.

In addition, this study did not include students in Engineering Education programs. These programs emphasize the study of how engineering is best taught, learned and practiced ("Graduate Programs - School of Engineering Education, Purdue University," 2009). The preparation these students receive for a teaching career is exceptional but as such it is not typical of the majority of PhD recipients in engineering.

Finally, the conceptions explored in this study were limited to the future professors’ understanding of undergraduate engineering education. Although these future professors are likely to teach graduate students too, graduate education is a sufficiently different context that it will not be explored in the present investigation.
Limitations

As with any study that involves interview data, there are threats to the interpretative validity of the data analysis. Conceptions or beliefs are not easily measured or self-reported. They can only be inferred from interview data (Rokeach, 1968). The interpretation depends on the quality of data acquired in the interviews. Doctoral students in engineering seldom have the need or opportunity to reflect on the learning and teaching process while in graduate school. Therefore, the questions posed had the potential to be difficult for the students to answer. Attempts were made in the creation of the interview protocol to facilitate participants’ reflection from concrete to more abstract aspects of learning and teaching. Questions about the individual’s background were asked first. Questions about teaching were then asked since this is what most doctoral students are concerned about. Finally, questions about the learning process were asked.

Additionally, study participants responded to the questions based on what they thought was expected of them and not on what they really believed. This may have been troublesome in those individuals who have had some type of coursework on teaching and were influenced by what they perceive as the expected answer. Attempts were made in the invitation letter and the interview protocol to assure participants that there were no wrong or right answer to any of the questions.

Lastly, in selecting participants it was decided to sample participants from multiple universities. Doing this increases the potential diversity of student perspectives obtained. A disadvantage of this approach is that it precludes a detailed analysis on how the local context influences student conceptions. It may also feed into the “universalized” narratives told by engineers (Pawley, 2009) that portray “a specific engineering context –
engineering within an American engineering education system – as broad and undifferentiated, with little localized variability or heterogeneity of practice” (p. 310). It is not the intention of this study to perpetuate this type of narrative. On the contrary, the use of a phenomenographic research approach was an attempt to bring to light variations in future engineering educators’ epistemologies and conceptions of teaching.

Chapter Summary

This chapter introduced: the problem, the conceptual framework that guides this study, the purpose of the study, the research questions, the research design, the significance of the study and the terminology. A short discussion of the limitations and delimitations completed this chapter.

Chapter 2 examines literature on educational research, psychology and engineering education related to conceptions of teaching and learning. Chapter 3 describes the method used, including the phenomenographic approach, participant selection criteria, instrumentation, data collection procedures and data analysis plan. Chapter 4 describes the findings related to conceptions of learning held by future engineering faculty. Findings related to conceptions of teaching are presented in Chapter 5. Finally, conclusions of the study, implications of the findings, and suggestions for future research are discussed in Chapter 6.
Chapter 2: Review of the Literature

This review draws from the literature on educational research, psychology and engineering education to inform the present exploration of the future engineering professors’ conceptions of teaching and learning. Major topics explored include epistemological beliefs, the learning task in engineering, conceptions of problem solving, conceptions of learning, conceptions of teaching and the development of those conceptions.

Epistemological Beliefs

Epistemological beliefs are beliefs about the nature of knowledge and learning. They influence conceptions of learning and teaching. Intellectual development theories that explore epistemological beliefs can inform our understanding of the development of future educators’ conceptions of learning and teaching.

There are many diverse studies on epistemological beliefs (Duell & Schommer-Aikins, 2001; Hofer & Pintrich, 1997). The majority of these studies, including the seminal work by Perry (1970) and Belenky, Clinchy, Goldberger, & Tarule (1986), were concerned with undergraduate students’ intellectual development and how epistemological beliefs affect approaches to learning and educational outcomes. Although much of the existing research on epistemological beliefs is based on studies of undergraduate students, their findings can help inform our understanding of graduate students’ epistemologies.
Baxter-Magolda (1992, 2004) expanded her study of college students to follow their development after graduation. The Epistemological Reflection (ER) model is a theory of personal epistemology based on a 16-year longitudinal study. Interviews began when participants were college freshmen at around age 18 and continued regularly until at least age 34.

In her studies Baxter-Magolda assumed personal epistemology is socially constructed, context-bound, best understood through naturalistic inquiry, and consist of fluid patterns that vary by individual experience (2004, p. 36).

The ER model consists of four ways of knowing. Some of these have gender-related reasoning patterns. Baxter-Magolda points out that these patterns are not exclusive to one gender (p. 34). Each is described as follows:

- **Absolute Knowing** – Persons at this stage believe knowledge is certain and authorities have the knowledge and the answers. Absolute knowers tend to think that there are absolute right or wrong answers to questions.
  - Receiving Pattern – used more often by women in the study, it “focused on listening and recording knowledge to learn” (p. 34).
  - Mastery Pattern – Used more often by men, focused on active class participation with the intent to acquire knowledge from authorities.

- **Transitional Knowing** – Persons at this stage believe some knowledge is certain and some is not. Authorities are not expected to be all knowing but are expected to provide explanations on the applicability of knowledge.
  - Interpersonal Pattern – used more often by women, focused on interacting with others to learn in the uncertain areas (p. 35).
Impersonal Pattern – used more often by men in the study, focused on defending the student’s own perspective

- Independent Knowing – Persons at this stage accept that knowledge is not certain and they take responsibility for their own learning. This means independent knowers are focused on “thinking for themselves, sharing views with peers to expand their thinking, and expecting teachers to promote independent thinking and avoid judging students’ opinions” (p. 37)

- Contextual Knowing – Persons at this stage see themselves as constructors of their own knowledge. They believe that “knowledge exists in a context and is judged on evidence relevant to that context” (p. 37).

It is important to point out that even though age and educational level tend to correlate with higher levels of intellectual development, this is not always the case (Jehng, Johnson, & Anderson, 1993, p. 32) and it should not be assumed that graduate students have reached higher stages of development.

Perry (1970), Belenky et al. (1986) and Baxter-Magolda (2004) used longitudinal studies to explore students’ epistemological beliefs. Subsequent researchers developed surveys or questionnaires guided in part by theories developed by earlier researchers (Duell & Schommer-Aikins, 2001).

Many researchers in this area tended to have an unidimensional view of epistemological belief where the student developed along a single continuum (Duell & Schommer-Aikins, 2001). The beliefs about knowledge identified in these studies could be arranged on an Objectivism – Subjectivism continuum. On one extreme is pure
objectivism where knowledge exists independently of the learner’s interest in it or awareness of it (Pratt, 1998). On the other extreme is subjectivism where knowledge is something intimately determined by the learner (p. 22).

Schommer (1990) proposed a multidimensional system of epistemological beliefs. The study found a system of independent beliefs, with distinct effect on comprehension and learning.

In their study of university students’ epistemological beliefs, Jehng, Johnson, & Anderson (1993) expanded the Schommer framework. It contained five factors about the nature of knowledge and learning (p. 26):

1. Certainty of knowledge – Knowledge is more likely to be certain and unchanging than tentative and predictable.
2. Omniscient authority – Knowledge is handed down by teachers and other experts rather than formed by independent reasoning.
3. Orderly process – The learning process tends to be regular rather than irregular.
4. Innate ability – The ability to learn is innate rather than acquired.
5. Quick learning – Learning is an immediate rather than a slow process of accumulating knowledge.

In a later revision, Schommer-Aikins (2004) proposed an embedded systemic model of epistemological beliefs. She argued that individual beliefs develop in different stages. This multidimensional model consists of connected beliefs about knowledge, learning, ways of knowing, and cultural relational views (Figure 3).
Schommer-Aikins argued that the cultural relational views influence all educational beliefs. Persons coming from cultures that are predominantly horizontal (preoccupied with relationships of equality) are likely to have different views of the student-teacher relationship than persons that come from vertical cultures (where relationships are focused on maintaining status and power structures). These cultural differences could have a significant impact in the field of engineering where a considerable portion of the graduate students and faculty are foreign nationals.

This review of the literature on epistemological beliefs informs the study here proposed. The most relevant findings come from the work by Baxter-Magolda and Schommer-Aikins. Baxter-Magolda identified a personal epistemology theory drawn from college graduates similar in age to graduate students. She also explored how gender
is related to some patterns of reasoning. In addition, the conceptual framework of the study (Chapter 1) is based on Schommer-Aikins’ systemic model of epistemological beliefs. It assumes beliefs are interconnected and part of a system.

**Conceptions of Learning**

Much of what is known about conceptions of learning comes from studies beginning in the 1970s and conducted at Göteborg University (Sweden) by Ference Marton and Roger Säljö. Säljö (1979, as cited by Pratt, 1988, p. 26) studied how university students think about learning. He identified five variations of the learning concept at three distinct stages. A description of each follows:

*Learning as quantitative changes in knowledge*

1) Learning is an increase in knowledge

2) Learning is memorization with the purpose of reproducing knowledge to the satisfaction of the authority.

*Bridging conceptions*

3) Learning is “the acquisition of information and procedures so they can be used or applied in practice” (p. 27)

*Learning as qualitative changes in knowledge*

4) Learning is the “reconstruction of knowledge in ways that are personally meaningful to the learner”. (p. 29)

5) Learning is a “complex interpretative process aimed at understanding reality and self as co-determinant.” (p. 29)

Later on Marton, Dall'Alba, & Beaty (1993, p. 277) identified a sixth conception
of learning: changing as a person. This study also revealed a skill dimension of learning where the way of seeing things becomes *what* is learned.

Within the engineering context, a study of engineering students in a first year foundation course (Marshall, Summer, & Woolnough, 1999) revealed the following conceptions of learning:

*Conception (A):* Learning as memorizing definitions, equations and procedures

*Conception (B):* Learning as applying equations and procedures

*Conception (C):* Learning as making sense of physical concepts and procedures

*Conception (D):* Learning as seeing phenomena in the world in a new way

*Conception (E):* Learning as a change as a person (p. 304)

These categories reflect the context of the engineering discipline but are mostly consistent with the Marton et al. and Säljö et al. findings.

While Marshall et al., Marton et al. and Säljö et al. studied the conceptions of university students, Prosser and Trigwell (1999) studied university teacher’s conceptions of learning. They revealed five conceptions of the learning of their students:

*Conception A:* Learning as accumulating more information to satisfy external demands

*Conception B:* Learning as acquiring concepts to satisfy external demands

*Conception C:* Learning as acquiring concepts to satisfy internal demands

*Conception D:* Learning as conceptual development to satisfy internal demands

*Conception E:* Learning as conceptual change to satisfy internal demands

While Conceptions A through C are self-explanatory, the similarities in Conceptions D and E require further clarification. Teachers with Conception D saw
learning as “involving a process of developing meaning through the construction of fuller, more elaborate and systematic knowledge of phenomena within a particular world view.” (p. 149) Teachers with Conception E saw that development happening “through a paradigm shift in the students’ world view”. (p. 149)

**Learning Engineering**

In a recent study, Sheppard et al. (2009) explored teaching and learning practices in U.S. engineering schools. The study makes some suggestions about the learning goals in engineering courses (Figure 4). “Knowing that” goals or “knowing the fundamental principles, theories, and concepts of engineering.” (p.32) Engineering students also need to acquire ‘know how’ or how to “generate models and analyze problems using theories, principles and concepts” (p. 34).

*Figure 4. Learning Goals in Engineering Courses (Source: Sheppard et al. 2009, p. 32)*
This is what Donald (2002) also calls the integration of knowledge into systems or into the problem solving process (p. 70). In fact, she argues that in engineering, contrary to other fields, the concern for procedural knowledge is greater than concern for declarative knowledge. According to Donald, in engineering “learning is viewed as a pyramid in which basic knowledge is synthesized and applied in different ways at the top” (Donald, 2002, p. 71).

Professors also have other concerns beyond the need for students to demonstrate knowledge or learn how to apply and synthesize knowledge. They expressed a need to develop “learning strategies that [students] will be able to apply throughout their professional lives” (p. 71). In other words, they are interested in students learning how to learn.

**Conceptions of Problem Solving**

Problem solving is an essential skill in engineering. In a study of chemistry and physics university teachers, Trigwell et al. (2002) explored their conceptions of problem solving from the students’ perspective. Two qualitatively different ways of experiencing problem solving are suggested.

The first perspective sees the problem experienced as unproblematic to the students. This implies that the problem can be immediately recognized by the student “without any substantial analysis and disciplinary knowledge is then applied to the problem” (p. 244). Two variations exist in how this disciplinary knowledge is conceived: a) as bits of information and skills, or b) as a more coherent body of knowledge.
The second perspective sees the problem experienced as challenging for the students. This implies a need for the student to deconstruct the problem to make sense of it. There are variations in what the problem is deconstructed or mapped into something c) external to the student, d) internal, or e) a phenomenon in the world.

These five variations define the different ways in which teachers in this study conceptualized problem solving:

**Category A:** Applying what you know to the problem in terms of pre-existing bits of information and skills.

**Category B:** Applying what you know to the problem in terms of pre-existing related principles and procedures

**Category C:** Mapping the problem into formalism in terms of pre-existing disciplinary concept structure

**Category D:** Relating the problem of knowledge structure in terms of pre-existing conceptual structure

**Category E:** Relating the problem to a phenomenon in terms of the phenomenon representing the problem (p. 248).

These variations in conceptions of problem solving may be related to variation in conceptions of teaching (p. 249).

**Conceptions of Teaching in Higher Education**

Conceptions of teaching can either help or hinder new faculty members’ efforts to become effective teachers. These conceptions, or beliefs, help one make sense of the
world, but they can also screen, redefine, distort, or reshape thinking and information processing (Pajares, 1992).

Samuelowicz’s (1999) dissertation explored faculty members’ educational beliefs and teaching practices. The study involved interviews and questionnaires from thirty-seven professors from multiple disciplines. She identified seven orientations to teaching among professors in terms of nine belief dimensions. The belief dimensions identified (p. 118) included:

1. Desired learning outcomes
2. Expected use of knowledge
3. Responsibility for organizing or transforming knowledge
4. Nature of knowledge
5. Students’ existing conceptions
6. Teacher-student interaction
7. Control of content
8. Students’ professional development
9. Interest and motivation

The study reveals seven ways in which professors understand teaching. Teaching as:

1. imparting information,
2. transmitting structured knowledge,
3. facilitating understanding,
4. helping students develop expertise,
5. preventing misunderstandings,
6. negotiating understanding, and
7. encouraging knowledge creation.

In another widely cited series of studies Trigwell & Prosser (Prosser & Trigwell, 1999; 1997) conducted a phenomenographic study from an analysis of 24 faculty members. From it, six conceptions of teaching were identified:

Conception A: Teaching as transmitting concepts of the syllabus
Conception B: Teaching as transmitting the teachers' knowledge
Conception C: Teaching as helping students acquire concepts of the syllabus
Conception D: Teaching as helping students acquire teacher' knowledge
Conception E: Teaching as helping students develop conceptions
Conception F: Teaching as helping students change conceptions

These six conceptions can be further categorized into one of two teaching approaches: Information Transmission/Teacher-Focused or Conceptual Change/Student-Focused Approach (Trigwell & Prosser, 1996). Each approach is described by Trigwell et al, as follows:

*Information Transmission/Teacher-Focused (ITTF) Approach.* “This approach is one in which the teacher adopts a teacher-focused strategy, with the intention of transmitting to the students information about the discipline. In this transmission, the focus is on facts and skills, but not on the relationships between them. The prior knowledge of students is not considered to be important and it is assumed that students do not need to be active in the teaching-learning process.” (p. 80)
Conceptual Change/Student-Focused (CCSF) Approach. “This approach is one in which teachers adopt a student-focused strategy to help their students change their world views or conceptions of the phenomena they are studying. Students are seen to have to construct their own knowledge, and so the teacher has to focus on what the students are doing in the teaching-learning situation. A student-focused strategy is assumed to be necessary because it is the students who have to re-construct their knowledge to produce a new world view or conception. The teacher understands that he/she cannot transmit a new world view or conception to the students.” (p. 80)

These approaches are consistent with Kember’s (1997) major synthesis of research into university academics’ conceptions of teaching. Kember arranged the conceptions identified by prior research along one of two categories: student-centered/learning-oriented or teacher-centered/content-oriented. Faculty exhibiting student-centered/learning-oriented views see teaching as facilitating learning. Faculty with teacher-centered/content-oriented views tended to see teaching as transmitting knowledge.

Trigwell and Prosser (2004) later created a paper-and-pencil instrument meant to measure approaches to teaching. It has been widely used in various studies. Nonetheless, there are criticisms to this taxonomy (Meyer & Eley, 2006) and the validity of the instrument used.

In general, studies that use questionnaires or surveys to examine teacher’s conceptions have potential problems with the validity of the data acquired through these
methods (Kane, et al., 2002). It is too easy for the researcher’s own expectations and conceptions to be built into these types of instruments. Data collected in this matter may yield very different results from what may have been collected if teachers had been allowed to articulate their conceptions in interviews.

In addition to the identification of conceptions of teaching, researchers also explored the relationship between beliefs about teaching and teaching practice. Dunkin (2002) explored the teaching conceptions of novice and award-winning faculty. Novice teachers had just one or two general conceptions of effective teaching as opposed to the award-winning teachers who had more and more complex conceptions.

Previous research suggests that faculty’s teaching approaches and students’ approaches to learning – and consequently learning outcomes - are related. In fact, studies suggest that students in classes taught by instructors that reported a CCSF teaching approach, were less likely to assume a surface approach to teaching, than students whose instructor reported ITTF approach (Kember & Gow, 1994; Trigwell, et al., 1999).

Missing from the research on conceptions of teaching in higher education are a longitudinal view of the development of these conceptions and how changes in conception relate to teaching practice (Kane, et al., 2002). With few exceptions, prior studies did not consider the career stage of the participants either. By studying the conceptions of future faculty and what influences them, the study here proposed should contribute to the understanding of how professors’ conceptions develop.
Conceptions of Teaching in Engineering

A limitation of most of the major studies on professors’ conceptions of teaching was that they were based on samples that included faculty from various disciplines making it difficult to consider the disciplinary context in the analysis of results. There are a few small studies that contribute to understanding conceptions of teaching in the engineering context. These studies are reviewed in this section.

An educator’s conception of what they teach may be important to how they teach. A recent qualitative study (Pawley, 2009) of ten engineering faculty members explored their definitions of engineering. The study found three narratives describing engineering:

- Engineering as applied science and math – mathematics is viewed as the root of both engineering and science and engineering as “an obligatory passage point between science and society” (p. 317)
- Engineering as solving problems – extended engineering to the solution of ‘real problems’ that ‘mattered’. Problems were seen as somewhat already formed by society which engineers just picked up and solved.
- Engineering as making things – connected to “the physical construction of highly technical and mechanized products” (p. 317).

These differing views on what is engineering may result in differences on how professors teach and evaluate student learning.

Several studies indicate that engineering teachers prefer to teach through lectures (Brawner, Felder, Allen, & Brent, 2001; Wirt, et al., 2004), are inclined to be content-focused (Kember & Kwan, 2000), teacher-centered (McKenna & Yalvac, 2007) or student-directing (Van Driel, et al., 2007). Although environmental factors can constrain
teaching approaches, the results of these studies suggest engineering teachers tend to have teacher-centered/content-oriented views.

Jehng et al, theorized how the field of study could influence engineering students’ beliefs about knowledge and learning:

“The structure of knowledge in engineering and the natural sciences also tends to be systematic and sequential. … In essence, these disciplines seem to be filled with orderliness and precision, at least from the perspective of the undergraduates. After functioning in such an intellectual climate for years, students seem to have a strong tendency to believe that the nature of knowledge is certain and solutions to problems can be reached within certain timeframe. Advice from experts is considered to be highly credible and learning can be viewed as a process in which an individual follows a limited set of orders to pursue already-formulated truths.” (Jehng, et al., 1993)

It is evident that these types of student experiences and beliefs may later have a powerful effect on the conceptions of teaching and practices of engineering faculty. Even the engineering specialization may have an effect on professors’ beliefs. In a study of professors in a Mechanical Engineering department, Quinlan (2002) found that faculty in the Thermosciences division saw themselves as lecturers or models while faculty from the Design division saw themselves as facilitators or advisors (p. 56). Views of faculty roles in the Design division may be influenced by the nature of their courses. In recent years, engineering curricula have incorporated courses whose sole focus engineering design. This courses are often first year or capstone courses where students work in close consultation with faculty on design projects.
According to Prosser and Trigwell (1999) teachers in “hard applied” disciplines, which include engineering, scored higher in a teacher-focused approach scale. On the other hand, a few studies presented instances in which the majority of engineering faculty express a preference for an “intermediate” or transitional conception of teaching. In a study of engineering teachers at a Dutch institution, Van Driel, Bulte, & Verloop (2007) found the vast majority of participants had a student-directing conception of teaching.

“… this conception is characterized by an intensive relationship of teachers with their students. That is, teachers adopting this conception expressed the desire to meet their students frequently and preferably in small groups, in order to stimulate and support student learning. Therefore, they claimed to need a high number of lessons. Moreover, they appeared to meet students apart from regular lessons, in order to give them extra explanations or feedback.” (p. 114)

Teachers that had this conception also expressed a belief that “a fixed amount of subject matter needs to be covered, in order to maintain a ‘high standard’ of education” (p. 115). In summary, this student-directing conception is represented by “the image of students being engaged in different sorts of learning activities, which are carefully being planned and controlled by teachers in order to cover a fixed amount of subject matter” (p. 115). Other teachers who participated in the study expressed teacher-centered conceptions, with the smallest proportion of teachers adopting student-centered conceptions.

While focused on the teaching strategies of engineering faculty members, McKenna’s (2007) study also suggests engineering educators “align more with a teacher-
centered perspective” (p. 415). McKenna also argues that although engineering educators are motivated by concerns for student learning, professors’ teaching approaches were adopted based on how the teacher learned (p. 416).

An exhaustive search of the literature resulted in the identification of just one study related to the conceptions of teaching of future engineering professors (Huang, et al., 2005). The study involved focus groups, interviews and observations of a group of doctoral students and a postdoctoral associate who participated in a teaching portfolio program. The program engaged students in discussion and reflection about teaching as part of the process of creating a teaching portfolio to be used in job searches. As participants in this program, this group of students was self-selected and atypical.

The results were reported in three general categories: 1) the attitudes, beliefs and conceptions of teaching, 2) teaching as decision making, and 3) on the road to the scholarship of teaching. The data reported and its analysis is unclear. It is presented as a group of quotations grouped by category with no overarching themes, patterns or qualitative different variations of participants’ thoughts.

What can be inferred from the limited data reported is that the study’s participants thought about teaching in terms of the activities they engaged in and that the content was a major component in their conceptions of teaching. Students also viewed assessment as an integral part in teaching. They expressed different views on good teaching, such as: reflecting about teaching, providing feedback or encouraging students. Although the data reported and analysis is somewhat unclear, this study highlights the need to further explore how these future educators think about teaching.
Development of Beliefs about Teaching

It has been suggested that teaching approach is related to teacher characteristics and prior experiences (Prosser, Ramsden, Trigwell, & Martin, 2003; Taylor, 2003). Bieber & Worley's (2006) study participants indicated that their view of faculty life was rooted in their undergraduate experience. Pajares (1992) reviewed several additional studies supporting the notion of teaching beliefs being influenced by images of teaching observed as students (p. 322).

Power and River, and Bolin (1990) (as cited by Pajares) also indicated that previous industry working experiences can influence teaching beliefs. Indeed, having craft knowledge can increase the individual’s self-efficacy.

As previously indicated, there are very few studies of the teaching beliefs of graduate students. One of them does suggest that graduate education does little to help students further develop more appropriate and complex conceptions of teaching. In a longitudinal study of students in a graduate education program, Taylor (2003) found graduate school had little impact on their teaching perspectives. Surprisingly, a teacher-centered perspective was predominant among these education students. On the contrary, Saroyan, Dagenais & Zhou (2009) reported significant changes in graduate students’ conceptions of teaching and learning after they completed a course on teaching.

Research on epistemological beliefs also supports the relationship of educational beliefs and prior educational experiences. Doctoral education in particular may be seen as a socialization process for faculty careers (Austin & McDaniels, 2006). It is complex, ongoing bidirectional process in which doctoral students engage with others to help them understand faculty life.
Reflection and collaboration may also have an effect on the development of conceptions of teaching. McKenna, Yalvac, & Light (2009) studied engineering faculty teaching approaches. Results of the study suggest that “faculty engagement level in reflective and collaborative education-focused activities is a significant factor that contributes to their adoption of more student-centered teaching approaches” (p. 25). This is also supported by the study on future engineering professors’ thoughts about teaching (Huang, et al., 2005). Participants of the study commented that the reflections they engaged on as part of the Teaching Portfolio Program helped shape their conceptions of teaching.

Chapter Summary

This chapter reviews the research literature on epistemological beliefs, the learning task in engineering, conceptions of problem solving, conceptions of learning, conceptions of teaching and the development of those conceptions.
Chapter 3: Method

Introduction

The principal goal of this study was to explore future engineering professors’ conceptions of learning and teaching engineering. This study also explored the experiences that future engineering professors thought influenced their conceptions. A review of the research literature revealed abundant research on students’ conceptions of learning (Marton, et al., 1993; Säljö, 1979) and professors’ conceptions of teaching (Kember, 1997; Samuelowicz & Bain, 2001). However, the conceptions of learning and teaching of future professors, particularly those in engineering, had not been adequately explored. This chapter describes the research methods used to explore the conceptions of learning and teaching of future engineering professors.

Research Questions

The research questions addressed in this study are:

1. How do future engineering professors describe their conceptions of learning engineering?

2. How do future engineering professors describe the basis of their conceptions of learning engineering?

3. How do future engineering professors describe their conceptions of teaching engineering?
4. How do future engineering professors describe the basis of their conceptions of teaching engineering?

The rest of the chapter examines the phenomenographic approach, sample criteria, instrumentation, data collection procedures and data analysis plan.

**Research Design**

Qualitative research methods were used to answer the research questions.

According to Creswell (2008, p. 232), qualitative research is “a means for exploring and understanding the meaning individuals or groups ascribe to a social or human problem.” From this exploration, a complex picture of the problem or issue under study emerges.

At the center of qualitative research is not an interest on physical behaviors but on understanding the meaning participants hold about the issue under study (Creswell, 2008; Maxwell, 2005). Additionally, qualitative research helps understand “the process by which events and actions take place” (Maxwell, 2005, p. 23). Because qualitative researchers study a relatively small number of individuals “they are able to understand how events, actions and meanings are shaped by the unique circumstances in which these occur.” (Maxwell, 2005, p. 22)

The use of qualitative research methods contributes to the development of a complex picture of the issue under study by helping researchers understand three key areas. They help understand: 1) the meaning given by participants to the issue, 2) the process by which actions take place and 3) how the context influences those meanings and processes.
By revealing participants’ understanding of learning and teaching in the engineering context, qualitative research methods help answer the research questions explored by this study. More specifically, phenomenography was used to explore variations in the conceptions of learning and teaching. This answers research questions 1 and 3: How do future engineering professors describe their conceptions of learning engineering? and How do future engineering professors describe their conceptions of teaching engineering?. To explore what the participants described as the bases of their conceptions of learning and teaching, a different research method called thematic analysis was used. Each of these methods is discussed in more details below.

**Phenomenography**

Qualitative methods, particularly phenomenography, have been used in prior studies on conceptions or beliefs of teaching and learning (Marton, et al., 1993; Samuelowicz, 1999; Trigwell, Prosser, & Taylor, 1994). Phenomenography is a research approach that arose from studies on learning conducted at Göteborg University (Sweden) by Ference Marton and colleagues (Marton & Booth, 1997). Researchers from this group studied the different ways students experienced the learning process.

Phenomenography aims to reveal the qualitatively different ways in which people experience and conceptualize various aspects of the world (Marton, et al., 1993, p. 278; Ashworth & Lucas, 2000). According to Bowden (2005), the object of study in phenomenography is the relation between the research subjects and an aspect of the world (as cited in Mann, Dall'Alba, & Radcliffe, 2007).
Phenomenography assumes the world is neither purely objective nor subjective. Marton & Booth (1997) argue: "The world is not a real world 'out there' and a subjective world 'in here'. The world is not constructed by the learner, nor is it imposed upon her; it is constituted as an internal relation between them. There is only one world, but it is a world we experience, a world in which we live..." (p. 13) Consequently, phenomenography adopts what Marton (1988) calls a “second-order” perspective in which things are described as they appear to people.

The different ways of experiencing, conceptualizing, seeing or understanding are called “conceptions” (Marton & Pong, 2005, p. 336). They are the basic unit of description in phenomenography. Each conception has two intertwined aspects:

1) referential - “the global meaning of the object conceptualized”, and
2) structure – “the specific combination of features that have been discerned and focused on” (p. 335)

The outcome space of phenomenography includes both a description of qualitative variations in conceptions and “the structural relationships linking these” [conceptions] (Åkerlind, 2005, p. 329).

Interviews are the most common data source in phenomenographic studies (Åkerlind, 2005, p. 323). Their objective is to reveal participants' very own conceptions. In order for phenomenographic researchers to achieve this, it is imperative for them to 'bracket', or set aside, their own preconceived ideas (Ashworth & Lucas, 2000, p. 297) during interviews and data analysis. Among the presuppositions that need to be bracketed are: "importing earlier research findings; assuming pre-given theoretical structures or
particular interpretations; presupposing the investigator's personal knowledge and belief” (p. 298).

Phenomenography has been criticized for lacking common concrete data analysis procedures. Nonetheless, there are some common goals that generally guide phenomenographic data analysis (Akerlind, 2005). These include: maintaining an open mind during the analysis, minimizing presuppositions; "maintaining a focus on the transcripts and the emerging categories of descriptions as a set”; starting the analysis with "a search for meaning, or variation in meaning" across transcripts; supplementing the initial analysis with a "search for structural relationships between meanings" (p. 323-324).

Given the variations in methods used, phenomenography is most commonly referred to as a research approach. It has been adopted successfully by higher education researchers to produce useful insight into learning and teaching (Entwistle, 1997, p. 128-129) and was recently identified as an emerging methodology within engineering education research (Case & Light, 2011).

To illustrate the impact of phenomenographic research in higher education, some examples can be examined. Marton, Dall'Alba & Beaty (1993), for example, used a phenomenographic approach to study the conceptions of learning of British university students in a Social Science Foundation course. Marton and colleagues interviewed 29 students about their view of learning. The subsequent analysis resulted in the identification of six different conceptions of learning. Relations and commonalities between those conceptions were also identified. This and other similar phenomenographic studies conducted by Marton, Saljö and their colleagues have been
widely cited and influential in our understanding of the learning process.

Prosser, Trigwell and Taylor (1994) also used phenomenography to study professors' conceptions of learning and teaching. A total of 24 teachers from two Australian universities participated in the study. Six teachers from each of the universities' chemistry and physics departments were interviewed. Interviews focused on the teachers' approach to teaching, their conceptions of learning and their conceptions of teaching. Questions included: "What do you mean by teaching (learning) in this subject?" and "How would you know if a student had learned something in this course?" Interview transcripts were read and discussed by all three researchers. An initial set of categories was agreed upon. They were later refined after further reading and discussion. After several rounds of individual analysis and group discussion, the researchers identified five categories of conceptions of learning and six categories of conceptions of teaching. Referential and structural components of the conceptions were discussed as well as the relationship between conceptions of learning and teaching.

**Thematic Analysis**

Thematic analysis was used to explore what participants described as the basis for their conceptions of learning and teaching. Thematic analysis is a method for “identifying, analysing, and reporting patterns (themes) within data” (Braun & Clarke, 2006). Although thematic analysis is more of a recursive process than a linear process, several general phases have been identified. These phases are: 1) familiarization with the data, 2) generation of initial codes, 3) search for themes, 4) review of themes, 5) definition of themes, and 6) writing the results.
Participant Selection

A group of participants with diverse background and experiences who could talk about their understanding of teaching and learning was selected. Past experiences as well as some demographic factors were considered in selecting participants with diverse perspectives.

Prior phenomenographic studies used samples of 20 to 30 participants. They rarely included less than 20 participants but it was not unusual to select more than 30. Given the possibility that it would be difficult to recruit doctoral students for this study, the target sample size was on the lower side: 20 participants.

The sample consisted of doctoral engineering students from multiple schools who identified themselves as interested in academic careers. As previously mentioned, students in Engineering Education programs were not part of this study because their programs include education courses that are not typically included in the majority of doctoral engineering programs.

In addition to being interested in a teaching career, it was desirable to select students who were committed to their studies and had successfully completed at least one year in their doctoral program. It was also assumed that students who had completed one or more years of doctoral studies were more likely to have completed at least a semester as a teacher assistant. While it would have been ideal to select more advanced doctoral students (e.g. those with two years of studies completed or already accepted into candidacy), adopting a higher criteria would have severely limited the pool of potential study participants. Therefore, the less restricting one-year of studies requirement was adopted.
Among the experiences that could help participants understand and talk about learning and teaching are: being a teacher assistant (TA) or teacher, participation in the American Society of Engineering Education (ASEE), taking credited coursework on teaching, and taking teaching or TA workshops. Participation in ASEE was considered because their student chapters tend to attract graduate engineering students interested in academic careers (Torres-Ayala, Bumblauskas, Verleger, 2010). The students selected participated of at least one of these experiences.

Demographic factors were not the focus of this study. However, the conceptual framework implies that cultural views may influence beliefs about teaching and learning. Therefore, some demographic factors were considered in the selection of a diverse group of participants.

**Instruments**

Two instruments were used in this study. The first was a short questionnaire (Appendix D) on the general background and demographic information of each participant. At the top of the questionnaire is the Informed Consent statement. Participants confirm in the questionnaire that they provide consent. This was followed by questions on contact and background information. Background information of interest included prior teaching experience, industry experience, prior coursework on teaching, or involvement in the ASEE. The questionnaire was available on the web server provided by the University of South Florida.

The second instrument was the interview guide (Appendix E). The interview began with follow-up questions on the participant’s background. Most of the interview
consisted of open-ended questions on the participants’ conceptions of teaching and learning, assessment, student and teacher roles. Throughout the conversation, participants were be asked to explain what their conceptions were based on. Evidence probes were used to “ask how a person knows and how they came to their conclusions.” (Rubin, 2005)

Interview questions were based on the research questions of this study, the conceptual framework and findings from the literature review. The interview questions are found on Table 1.

Table 1

*Interview Protocol*

<table>
<thead>
<tr>
<th>Background</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ Please tell me a bit more about your background, for example where did you grow up and went to school?</td>
</tr>
<tr>
<td>□ Please tell me a bit about your academic background.</td>
</tr>
<tr>
<td>□ Tell me briefly about your prior teaching experience</td>
</tr>
<tr>
<td>□ Tell me briefly about your Teaching Assistance experience</td>
</tr>
<tr>
<td>□ Can you also describe briefly your professional background?</td>
</tr>
<tr>
<td>□ Why are you interested in an academic career?</td>
</tr>
<tr>
<td>□ Tell me briefly about how you are preparing for an academic career.</td>
</tr>
<tr>
<td>□ Tell me more about the courses/training on teaching you completed.</td>
</tr>
</tbody>
</table>
Table 1 (continued)

Teaching

☐ Imagine yourself as a professor of engineering. Then imagine yourself teaching Engineering, what images come to mind? [Alternative: What will you do in a typical class period? In a typical week?] Any other images that come to mind?

☐ What is teaching? [Alternative: How do you define teaching?]

☐ What do you think are the primary purposes or goals of teaching engineering? [Alternative: What should be achieved through teaching engineering?]

☐ Tell me more about the roles and responsibilities of engineering teachers.

☐ What experiences, if any, do you think have influenced your view on teaching?

Learning

☐ When I say the phrase “Learning Engineering”, what images come to mind? Any other images that come to mind?

☐ What is learning? [Alternative: How would you define learning?]

☐ How do you think students learn?

☐ What is it that engineering students learn? [Alternatives: What are engineering students taught? What types of thinking do engineering students learn?]

☐ How do (will) you know your students have learned?

☐ How do students know that they have learned?

☐ Tell me more about the roles and responsibilities of engineering students.

☐ What experiences, if any, do you think have influenced your view on learning?
Wrap-up

☐ What other experiences, if any, do you think have influenced your views on teaching and learning?

☐ Is there anything else that you would like to add about teaching or learning engineering?

The order of the questions (Appendix E) was structured to improve the flow of the conversation and guide the interviewee from concrete questions to more complex and abstract ones. A previous version of the interview guide was piloted with three future engineering professors. This final version of the protocol was tested with one future professor.

Researcher’s Role

My interest in this topic stems from my background as an engineer as well as my experiences as a college instructor and graduate student. In this section, I will explore how these experiences could help or hinder this study. I describe how my past experiences, interests and concerns shape my role as a researcher.

In 1992, I began my studies in Computer Engineering at a public university in Puerto Rico. I later went to a private university in New York to obtain a Masters degree in Engineering. I spent close to seven years at these two schools. As a traditional age, full-time student I was immersed in their engineering education cultures. I also had the
opportunity to experience the culture of yet another engineering school when I spent a summer doing research at a public university in Iowa. Two internships at corporations in Massachusetts, one with a defense contractor and the other with a telecommunications provider, completed my engineering training. My experiences at these three schools put me in contact with a handful of excellent engineering professors. However, my perception of the majority of professors was that they were brilliant people who could not, or some would not, teach well. My experience with engineering culture continued when I worked for over four years as a member of technical staff at a large telecommunications manufacturer in Illinois. At this company I also had the opportunity to work in international settings. Through all of these experiences, I learned the language, norms and values of engineering.

After working in industry, I turned to education. I spent a year teaching computer technology courses at two career colleges in Florida. Each trimester I taught four to six courses in anything from Word Processing to Computer Programming and Internet Technologies. This experience led me to reflect on what constituted good teaching and what I could do to better help my students learn. I also got to experience first hand the challenges faced by college professors that do not have a strong foundation in college or university teaching.

I later came to the University of South Florida and became a student in the Higher Education program. I was exposed to various theories of learning and teaching and how these impact classroom practice. I frequently wondered how I would have learned about the process of learning and teaching if I had decided to pursue a doctoral degree in engineering instead of education and how this would have changed the type of teacher
that I was becoming.

My interest in improving engineering education and teaching led me to scholarly writing and research on faculty development in particular the development of the future faculty. Like others, I strongly believe that significantly more can be done to prepare doctoral students for academic careers. Like Akerlind (2008), I think that faculty members’ development should not only focus on teaching skills and methods but also on developing their conceptual understanding of the nature of teaching and learning (p.633). In fact, I believe that preparing future faculty, like faculty development, should be reframed as professional learning (Webster-Wright, 2009). I believe that to better understand how new professors learn to teach, it is necessary to understand their preconceptions of the learning and teaching processes. I see this study as a stepping stone in the exploration of this learning process.

My background and experiences may have helped, or hindered, my attempts to understand the context in which the study participants work. Nonetheless, there was a risk that the participants may perceive me with skepticism or distrust due to my unusual professional and academic history. Although up to a certain point I perceive doctoral engineering students as my peers, I am also aware that my gender (female) and ethnicity (Latino) may have led them to perceive me as an outsider in such a male dominated field as engineering. I tried to mitigate these risks by purposely trying to earn the participants trust. I shared with them my technical and academic background, tried to demonstrate sympathy and understanding of the challenges faced by doctoral engineering students, and to communicate my genuine interest in understanding the participants’ thoughts about these concepts.
Recruitment Procedures

As previously discussed, the target sample size for this study was twenty participants. In the first round of recruitment, ASEE Student Chapters’ faculty advisors and student leaders at eight institutions that had doctoral engineering programs but no Engineering Education programs were asked to either nominate or forward the invitation to students who fit the criteria for this study (Appendix A).

The invitation was an electronic request for participation (Appendix B) that introduced the study, as well as the risks and benefits of participating. The e-mailed invitation also included the Informed Consent form and asked students to fill out the background questionnaire on the web. As appreciation for participation in the study, each participant was offered a $10 iTunes or Amazon.com gift card. This recruitment effort did not result in a sufficient number of volunteers, making a second round of recruitment necessary. The second round of recruitment was conducted at other engineering schools that had dormant ASEE Student chapters. At the end of the second round, only 16 participants had been interviewed. This made it necessary to extend recruitment to an additional public university that did not have either active or dormant ASEE Chapter but where I had professional contacts. In the end, faculty or student leaders from a total of 19 schools were contacted.

Participants

A total of 24 doctoral students volunteered for this research study by completing the background questionnaire. Two volunteers later did not have time to schedule interviews. One volunteer did not respond to a request for more background information.
One volunteer was dropped from the pool after a closer review of the eligibility criteria deemed the person ineligible. Seven universities were represented in the participant pool.

As presented in Figure 5, among the 20 participants, males comprised 65% while females made up the reminder 35%. Thirty-five percent self-identified as international students from such regions as Asia, Latin America and the Middle East. Among the 13 domestic participants, one was African American, one was Asian American, seven were White and four provided only their country of origin as USA. Other background information such as TA experience, teaching experience, industry experience, education courses, workshops on teaching, or involvement in ASEE are presented in Figure 5. Collectively, 85% had industry experience, 75% had teaching experience, 100% were teaching assistants for at least one semester, 40% were involved in the ASEE at some level, 70% had completed some type of coursework on teaching, and 75% had attended some type of workshop on teaching. It is unknown at this time whether the participant pool is representative of its cohort of future engineering professors.
<table>
<thead>
<tr>
<th>Pseudonym</th>
<th>Residency</th>
<th>Gender</th>
<th>Ethnicity or Region of Origin</th>
<th>TA experience</th>
<th>Teaching experience</th>
<th>Industry Experience</th>
<th>Courses</th>
<th>Training</th>
<th>Involvement in ASEE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alan</td>
<td>Domestic</td>
<td>M</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Bill</td>
<td>Domestic</td>
<td>M</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Brandy</td>
<td>Domestic</td>
<td>F</td>
<td>African American</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Brenda</td>
<td>Domestic</td>
<td>F</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Brent</td>
<td>Domestic</td>
<td>M</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Feng</td>
<td>International</td>
<td>M</td>
<td>China</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Gina</td>
<td>Domestic</td>
<td>F</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Halil</td>
<td>International</td>
<td>M</td>
<td>Middle East</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Janna</td>
<td>Domestic</td>
<td>F</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Jatin</td>
<td>International</td>
<td>M</td>
<td>India</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Kavita</td>
<td>International</td>
<td>F</td>
<td>India</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Laura</td>
<td>Domestic</td>
<td>F</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Layla</td>
<td>Domestic</td>
<td>F</td>
<td>Asian American</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Lee</td>
<td>Domestic</td>
<td>M</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Luis</td>
<td>International</td>
<td>M</td>
<td>Latin America</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Mark</td>
<td>Domestic</td>
<td>M</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Ping</td>
<td>International</td>
<td>M</td>
<td>China</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Sergio</td>
<td>International</td>
<td>M</td>
<td>Latin America</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Tim</td>
<td>Domestic</td>
<td>M</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Trevor</td>
<td>Domestic</td>
<td>M</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

*Figure 5. Participants*
Data Collection

Interested students were asked to fill out the web-based background questionnaire. Potential participants were contacted by e-mail to schedule interviews. Each participant was interviewed once for 30 to 90 minutes. Eighteen interviews were conducted using the Skype voice-over-Internet service. This service allows users to make phone calls from their computer to landline or cellular phones. For the participants, the call was no different from a regular telephone call. Skype calls were recorded using an application called Pamela. The recording was stored as sound files in MP3 format. Two participants requested face to face interviews which were recorded using a digital recorder.

To ensure confidentiality participant identity was protected. Each participant was given a unique code and pseudonym. A list of the participants’ name and matching codes was kept in a password protected electronic file. Instruments and transcripts were identified by codes or pseudonyms only. Only de-identified data were shared with the peer reviewer.

Data Analysis

Analysis began as soon as each interview was finished. Interviews were transcribed and notable quotes highlighted (Saldaña, 2009). Atlas.ti was used to analyze the interviews and background information collected. The codebook, which included codes and their descriptions, was managed in Atlas.ti which has a feature that easily allows the user to list all quotes related to the code. In all, the codebook had a name for each code, comments, and data examples (Saldaña, 2009, p. 21).
The data analysis was organized around each of the research questions. Conceptions of learning and the basis for such conceptions were analyzed separately from conceptions of teaching. I first focused on the analysis of questions directly related to learning and later on conceptions of teaching. Although data analysis is presented here in a sequential manner, it actually occurred in a spiral process where at different points of the analysis I revisited and revised prior data interpretations and reports.

To facilitate the analysis, the first round of coding consisted of structural coding (p. 66). Segments were coded: ‘Str-Learn’, ‘Str-Teach’, ‘Str-Exp’ or ‘Str-Basis’ to indicate which of the major concepts and processes under study the segment related to: learning, teaching, experiences or basis for conceptions. These actions allowed the collection of segments for further analysis in each of these areas.

**Identifying conceptions of learning engineering.** After structural coding, the phenomenographic analysis of conceptions of learning began. The segments on learning from the first ten interviews were extracted. They constitute a ‘pool of meanings’ where the boundaries separating individuals are abandoned and which “contains all that the researcher can hope to find, and the researcher’s task is simply to find it” (Marton & Booth, 1997, p. 133).

Learning quotes from the first ten interviews were open coded. Then, the quotes on learning, along with their codes, were printed and re-read. At this point, the unit of analysis was all the participant’s quotes on learning. These were then sorted according first to the answer to the request for a definition of learning then on the rest of the answers to questions on learning. For participants that expressed multiple or conflicting conceptions of learning, the one perceived as the most prevalent throughout the interview
was selected. Four categories of conceptions of learning emerged in this initial analysis. The emerging conceptions of learning engineering are listed in Table 2.

Table 2

*Emerging Conceptions of Learning Engineering*

<table>
<thead>
<tr>
<th>Category</th>
<th>Conception of learning engineering as ….</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>gaining an understanding of a subject</td>
</tr>
<tr>
<td>B</td>
<td>gaining a understanding of how the world works</td>
</tr>
<tr>
<td>C</td>
<td>applying acquired knowledge and skills</td>
</tr>
<tr>
<td>D</td>
<td>practicing problem solving / design</td>
</tr>
</tbody>
</table>

Short descriptions of each category of conception of learning were written. All participants contributed to the pool of meaning that was analyzed to identify each category but only illustrative quotes were selected and reported in the findings. These preliminary categories of description of the conceptions of learning engineering were presented to the peer reviewer for discussion and feedback. The peer reviewer and I met to revise the categories as well as to discuss and revise coding of two participants’ quotes on learning.

Using the revised categories as a starting point, segments from the remaining ten interviews were added to the segments of the first ten interviews then all segments were resorted into piles of categories of conceptions. When a quote did not fit any existing category, a new pile was started. Again, the resulting categories were discussed with the peer reviewer. The final categories of conceptions of learning engineering are presented
in Table 3 and further described in Chapter 4.

Table 3

*Categories of Conceptions of Learning Engineering*

<table>
<thead>
<tr>
<th>Category</th>
<th>Conception of learning engineering as ....</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>acquiring knowledge</td>
</tr>
<tr>
<td>2</td>
<td>gaining an understanding</td>
</tr>
<tr>
<td>3</td>
<td>practicing problem solving</td>
</tr>
<tr>
<td>4</td>
<td>applying knowledge</td>
</tr>
<tr>
<td>5</td>
<td>developing an approach</td>
</tr>
<tr>
<td>6</td>
<td>maturing</td>
</tr>
</tbody>
</table>

As previously discussed in this chapter, each conception should have two aspects: the general meaning of the concept (referential) and the features that define it (structural). To clarify the features, one aspect of the phenomenon (such as the view of engineering or assessment) was selected at a time and inspected across all categories of conceptions (Marton & Booth, 1997).

Throughout the data analysis process, I wrote multiple analytic memos. The purpose of these memos was to document and reflect on the “coding process and code choices; how the process of inquiry was taking shape; and the emergent patterns, categories and subcategories, themes and concepts” (Saldaña, 2009, p. 32).

Thirty-two analytic memos were written about the analysis process. In addition,
research activities and decisions were documented in a researcher journal which contained fifty-two entries. What follows is an illustrative portion of an entry in an analytic memo that was written during the analysis of conceptions of learning.

Analytic Memo (Excerpt)

October 16, 2011

So what is the difference between practicing (engineering or problem solving) and developing an approach? The 'Practicing' conception emphasizes the process of doing engineering or problem solving. It involves more of the surface or (and/or?) procedural knowledge of doing engineering/design/problem solving.

Forming teams, breaking problems down, solving it (see i.e. Tim 232:232).

Developing an approach emphasizes the output of learning, a certain mindset or habits of mind, dealing with ambiguity, complexity, modeling, how to approach/figure out the unknowns. So practicing is the process of practicing, developing and approach emphasizes the final mindset. Now, I'll have to check quotes to verify this interpretation.

The categories identified were discussed with the peer reviewer once again. Revisions were made to the categories and the final conceptions of learning engineering identified are presented in Chapter 4.

Identifying conceptions of teaching engineering. Four categories of conceptions of teaching emerged from the analysis of the first ten interviews. The emerging conceptions of teaching engineering are listed in Table 4.
Table 4

*Emerging Conceptions of Teaching Engineering*

<table>
<thead>
<tr>
<th>Category</th>
<th>Conception of teaching engineering as ....</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>delivering knowledge to the student</td>
</tr>
<tr>
<td>B</td>
<td>helping students understand a subject</td>
</tr>
<tr>
<td>C</td>
<td>preparing students to have an impact on the world</td>
</tr>
<tr>
<td>D</td>
<td>inspiring interest in a subject</td>
</tr>
</tbody>
</table>

After discussing the emerging conceptions with the peer reviewer and analyzing the segments on learning from all twenty participants, five conceptions of teaching were identified. The final categories of conceptions of teaching engineering are presented in Table 5 and further described in Chapter 5.

Table 5

*Categories of Conceptions of Teaching Engineering*

<table>
<thead>
<tr>
<th>Category</th>
<th>Conception of teaching engineering as …</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>delivering knowledge</td>
</tr>
<tr>
<td>2</td>
<td>helping understand and apply concepts</td>
</tr>
<tr>
<td>3</td>
<td>motivating students</td>
</tr>
<tr>
<td>4</td>
<td>helping students learn how to approach problems</td>
</tr>
<tr>
<td>5</td>
<td>preparing students to make socially conscious decisions</td>
</tr>
</tbody>
</table>
Identifying basis for conceptions of learning and teaching. The analysis of what the participants described as the basis for their conceptions of learning and teaching was also separated in two stages. Segments where participants described experiences that influenced their conception of learning and teaching were analyzed. These included what participants revealed in their answers to the question: “What experiences, if any do you think have influenced your view on learning [or teaching]?” as well as the explanations participants gave for various aspects of their views of learning and teaching at other points in their interviews.

For example, segments from all interviews coded as ‘Str-Learn’, and either ‘Str-Exp’ or ‘Str-Basis’ were extracted for more detailed thematic analysis (Braun & Clarke, 2006). Common codes among those segments were identified and themes were reviewed. Descriptions of the themes were written and shared with the peer reviewer. After discussing the themes with the peer reviewer, descriptions of the basis for the conceptions of learning were revised.

Participants described the basis for their conceptions of learning engineering through four general themes: their own undergraduate student experience, their own research, their graduate school experience, and their prior teaching experiences. Each theme is described in Chapter 4.

A similar process was conducted for the analysis of the basis of conceptions of teaching. In this instance, ten themes were initially found. After eliminating themes that had just one or two quotes, merging codes and eliminating those that were not related to the research question, four themes emerged: observing professors, student experience,
talking about teaching, and teaching experience. Each theme is described in Chapter 5.

**Trustworthiness**

Collier-Reed, Ingerman and Berglund (2009) suggest researchers must consider trustworthiness throughout a phenomenographic study because it is not just something to be left for the reader to evaluate. With this in mind, the following strategies were used in this study to establish content-related credibility, credibility of method, and communicative credibility.

Content-related credibility (p. 347) is based on the researcher’s open understanding of the phenomenon under investigation. The value of research results could be questioned if the researcher was not familiar with the subject matter. On the other hand, research results could also be questioned if a researcher was known to have a predetermined interpretation of the phenomena. Therefore, the researcher has to “be open for ways of understanding it [the subject matter] which differ from those generally accepted” (Booth, 1992 as cited by Collier-Reed et al.).

To clarify possible biases, the researcher’s role, beliefs and values were articulated (Creswell & Miller, 2000). Reflections on how researcher background may shape interpretation of the findings were documented and reported. The peer reviewer was asked to challenge possible biases in the interpretation of data.

To establish credibility of method it is necessary to demonstrate that the design and execution of the study is appropriate to the stated research questions and goals. Earlier in this chapter, an attempt was made to explicitly state the rationale for decisions made in this study about the selection of participants and data analysis methods.
Communicative credibility depends on the researcher’s ability to argue persuasively for their particular interpretation of the data (Åkerlind, 2005) and to present the results in a way in which the study can be scrutinized (Collier-Reed et al., 2009). As described previously, at multiple stages in the data analysis process the preliminary findings of this study were presented and discussed with a peer-reviewer. In addition, preliminary findings were presented at engineering education (Torres-Ayala, 2010) and higher education (Torres-Ayala, 2011) research conferences. Feedback from those discussions helped shape the reporting and interpretation of findings.

Dependability is also to be considered in phenomenographic research because “it allows for consistency of data interpretation and thus consistency in the research findings of an investigation” (p. 348). Some of the procedures that were used in this study to ensure dependability included seeking accuracy in the transcription of interviews and seeking intersubjective agreement.

Interviews were transcribed either by me or by a professional. I verified each transcription in a process where I heard and corrected the transcription at least twice to ensure it did not contain mistakes. In addition, a copy of the transcript was sent to the interviewee as a courtesy. Participants were given an opportunity to correct any transcription errors. Ten participants made corrections or confirmed the correctness of the transcription.

Phenomenographic studies commonly use dialogic reliability “where agreement between researchers is reached through discussion and mutual critique of the data and of each researcher’s interpretive hypotheses” (Åkerlind, 2005, p. 331). A peer reviewer was asked to review and challenge the data and interpretations periodically. This person has a
doctorate in education and is familiar with qualitative methods because her dissertation also used these methods to study faculty. The peer reviewer served as a sounding board for ideas (Creswell & Miller, 2000) and helped revise and validate the categories of conceptions.

Chapter Summary

This study used qualitative research methods to analyze data obtained from interviews with doctoral engineering students who self-identified as potential engineering faculty. In this chapter, phenomenography and thematic analysis was discussed as well as the participants, data collection methods, and data analysis. Procedures used to ensure the trustworthiness of the study were also discussed.
Chapter 4: Conceptions of Learning

Introduction

One of the goals of this study is to explore future engineering professors’ conceptions of learning engineering. This chapter answers two questions:

Research Question 1: How do future engineering professors describe their conceptions of learning engineering?

Research Question 2: How do future engineering professors describe the basis of their conceptions of learning engineering?

The variations in conceptions of learning of future engineering faculty that emerged from interviews with 20 doctoral engineering students are described. In addition, the explanations given by participants as the basis for their conceptions of learning are presented in this chapter.

Outcome Space

This section provides a detailed description of the outcome space which consists of six ways in which future engineering professors conceptualize learning engineering. The participants themselves are not assigned to a specific category but their experiences and quotes are. Portions of the interviews are used to illustrate each category.

Each conception is described by the seven dimensions or features that emerged for the categories. The dimensions are: focus, nature of knowledge, view of engineering, strategies, assessments, interactions, and relational. The focus dimension describes what
is emphasized in the conception. The nature of knowledge dimension describes how knowledge is conceptualized. The view of engineering describes how engineering is defined within that conception. The strategies dimension describes how students learn. The assessment dimension describes how professors know students have learned. The interactions dimension indicates with who or what the learner interacts: other learners, teacher, context or content. The relational dimension describes whether learning is experienced as a communal or individual act.

The categories of conceptions of learning engineering are: 1) acquiring knowledge, 2) gaining an understanding, 3) practicing problem solving, 4) applying knowledge, 5) developing an approach, and 6) maturing. In the following sections, each category is described in detail.

**Category 1: Learning engineering as acquiring.** In this conception, learning engineering is described as acquiring knowledge. For example, Brent indicated "I really feel it is kind of -- almost mechanical, it is the acquisition of knowledge."

The focus of this conception is on the knowledge (i.e. content) being acquired or transmitted. The most extreme example of this notion comes from Kavita who equals learning with knowledge.

ATT: What is learning in your own opinion?

KAVITA: I think learning is knowledge.

The content that is learned includes both declarative (i.e. factual information, theories, rules, laws) and procedural knowledge (i.e. how to do things). See for example Janna:
To me learning engineering is learning how to write computer programs and learning how to manipulate computer programs because not that much is done by hand anymore and I am talking calculations and drafting in all of that so when I think of learning engineering, I think the thing that differentiate engineering from other fields is the technology that the computer compliments. (Janna)

This view of learning presumes knowledge as something concrete and external that must be taken in by the learner. This is illustrated by Ping when he states: “I think knowledge is out there. It’s like a circle. If you walk around, you’ll eventually get it.” This quantitative view of knowledge results in the notion that good learning means that more knowledge has been accumulated.

The engineering knowledge that is to be acquired is selected by experts (authorities) that make discoveries and make sense of them. Learners just need to internalize what is already there pre-determined by others. As Bill explains it: “… well I guess the majority of the people, they need to be told, in some way, how is this [material] understood by other people.”

Within this conception, engineering is mainly viewed as a field of study, a topic. To learn this topic, knowledge can be absorbed by reading a book, searching online, or listening to a lecture. Brent describes it this way:

If I'm curious about something or something inspires my curiosity and I go look for it and I think a lot of us had this with Wikipedia where we’re looking for something on Wikipedia and then well that looks interesting I’ll click on that and then we are just the rabbit hole of finding more and more things, deeper and
deeper in the subject. To me that is exactly what learning is, it's actually drilling down deeper into a subject based upon your own self motivated curiosity …

(Brent)

Asking questions from teachers is another possible learning strategy. Ping goes as far as saying that learning this way “is like stealing” knowledge from a teacher.

To determine whether students have learned teachers check student performance in tests. Tests afford a very concrete way of distinguishing whether a student knows something or not. Although tests are not the only assessment method used by future professors who hold this conception, it appears to be the preferred one:

ATT: How do you know your students have learned?

KAVITA: Test them.

ATT: Ok. [Pause]. Anything else?

KAVITA: No. I think testing them, asking them to make small projects or something like that, experimental projects to make sure they've learned anything.

Students can also demonstrate they have learned by expressing the knowledge they have gained in their own words. For example, Brent describes: “… if a student is able to write up a lab report and they very clearly articulate the ideas in their own words then it's obvious to me that they know what they are talking about.” This comment reveals an appreciation for the reproduction of knowledge.

Within this conception, learning is mostly experienced as an individual act. With the exception of interactions with teachers (learner-teacher), each engineering student learns alone by interacting with the content (learner-content). There appears to be very little that other students can contribute to the learning process.
In summary, future engineering professors who espoused this conception think of learning engineering as the individual process each student goes through to acquire engineering knowledge. Knowledge can be simply absorbed by reading or listening. This conception is further summarized in Table 6.

Table 6

*Category 1: Learning engineering as acquiring*

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus</td>
<td>Content</td>
</tr>
<tr>
<td>Nature of knowledge</td>
<td>Declarative and procedural, concrete, external, cumulative</td>
</tr>
<tr>
<td>View of engineering</td>
<td>Field of study</td>
</tr>
<tr>
<td>Strategies</td>
<td>Viewing a lecture, reading a book, searching online, asking teachers questions</td>
</tr>
<tr>
<td>Assessment</td>
<td>Tests, written reports</td>
</tr>
<tr>
<td>Interactions</td>
<td>Learner-content, learner-teacher</td>
</tr>
<tr>
<td>Relational</td>
<td>Individual</td>
</tr>
</tbody>
</table>

*Category 2: Learning engineering as understanding.* In this conception, learning engineering is described as gaining an understanding of things. Brenda describes learning as “gaining an understanding about what something is or how something works.” It was also described by Brandy as mastering new concepts. The word mastering implies the need to gain control over the material being learned.

Gaining an understanding of something requires comprehending the nature and
significance of what is being learned. This is a distinguishing feature of Category 2 and the focus of this conception. As students learn more material, they increase their level of understanding.

Learning is achieving a higher level of understanding on a given material. And so in the context of the student, what they’re going to see most with learning is it’s going to be okay, they’ve got this course material and they’ve got this curriculum and they start out at one level in the hierarchy. And they end off at another level of the hierarchy, and they finish the class, and they understand more because they have learned more... (Bill)

Like Category 1 before (learning engineering as acquiring), there is a sense that knowledge is external. Here knowledge needs to be acquired not only to be internalized but also to be understood. Both concepts and procedures are part of the knowledge that must be learned.

I think it’s from hundreds of years of people just gaining knowledge and being like, “Okay, to be an engineer, we have to understand how soils move and how they work when they get wet or how building materials work and how to utilize them. What happens when we put steel next to copper? Is anything going to happen in our piping? Is it going to corrode over time?” So, I think experience and also that just building up on itself over time. It’s a learning process for us, too. (Gina)

Similarly to Category 1 (learning as acquiring), participants who espoused this conception of learning viewed engineering as a field of study. To learn engineering, frequent exposure to and hands-on experience with the material is necessary. Brandy
explains the rationale for this strategy:

I would give them, hopefully, hands-on experiences where whatever we are learning in the book they could actually see it, touch it. I think you learn better when you use more of your senses, so doing some type of hands-on project. Maybe taking them on a plant trip or something like that could see what they’re learning in the textbook, and then --just pretty much helping them understand by doing... (Brandy)

The hands-on experiences help learners better understand the totality of the concepts they are studying.

Like Category 1 (learning as acquiring), tests are favored to assess student learning. In addition, participants who espoused this conception also considered discussions of course materials to assess student learning. Gina explains the reasons for adding this strategy and how it can benefit the students:

Obviously, there are testing mechanisms such as, yes, standardized testing and that works to a certain degree. But I also find that when students come to you with questions, you know they’re in the active process of learning because you can tell from their questions that there’s a thought process going on. They’re really curious. They’re wondering what’s happening. For the students that aren’t coming to you, maybe you happen to be by them at the end of class and you can go, “Hey, how are you taking this material? Do you understand the process behind fluid flow?” If you actually ask them that, they might stop and go, “Well, I don’t really understand that,” or they’ll say, “Oh, yeah, I get it - this, this and this.” (Gina)
Within this conception, learning is an individual act. There is very little to no mention of working with other learners among the future professors that espoused this conception. The engineering student mostly engages with the content (learner-content) and the teacher (learner-teacher) in order to learn.

In summary, future engineering professors who espoused this conception think of learning engineering as gaining an understanding of the knowledge they acquire. This conception, like Category 1, focuses on the content being learned but goes a step further by trying to comprehend its nature and significance. In addition to helping students accumulate knowledge, hands-on experiences are encouraged to help students understand that knowledge. This conception is further summarized in Table 7.

Table 7

*Category 2: Learning engineering as understanding*

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus</td>
<td>Comprehension</td>
</tr>
<tr>
<td>Nature of knowledge</td>
<td>Declarative and procedural, external, needs to be internalized</td>
</tr>
<tr>
<td>View of engineering</td>
<td>Field of study</td>
</tr>
<tr>
<td>Strategies</td>
<td>Frequent exposure to the material and hands-on experiences</td>
</tr>
<tr>
<td>Assessment</td>
<td>Tests and discussions</td>
</tr>
<tr>
<td>Interactions</td>
<td>Learner-content, learner-teacher</td>
</tr>
<tr>
<td>Relational</td>
<td>Individual</td>
</tr>
</tbody>
</table>
Category 3: Learning engineering as practicing. In this conception, learning engineering is described as practicing problem solving. The focus on this conception is on the behavior or skills engineers must demonstrate.

Solving closed ended and more undefined open ended problems also … I guess those are all defining engineering as opposed to defining learning. So let’s see, learning is practicing problem solving and doing so repeatedly, gaining expertise by doing. (Lee)

As Lee reveals, learning engineering is so related to the idea of doing engineering that they can be confused.

Within this conception of learning, procedural knowledge is emphasized as something internally created by the learner through practice. For example:

Learning engineering would be like learning how to form a group, attack a complex problem break it down to things that you can sort of understand, complete it and solve it that to me is like the basis of learning. (Tim)

Although much of what is learned in this conception has to do with the procedures and skills used to solve problems, they are not the only types of knowledge that must be learned. Sergio describes the necessary – though not exclusive - role of theory in learning engineering as well as discusses the needs for laboratories.

Obviously, you need to understand the theory before, because if you don’t understand what you’re going to do, you’re not going to be able to do it. But it’s like an explanation and then the hands-on experience is really what is going to teach you how to move forward. That is why we have so many labs - I think. (Sergio)
Engineering is viewed as a craft where problems are solved any which way, often by intuition or brute force (Shaw, 1990). The transmission of craft knowledge is slow among engineers partly because expert engineers “often do not recognize any special need to communicate” (p.16).

To learn engineering, students must practice extensively how to solve problems. [Students] “would learn by solving a question or solving an assignment or a project based on those topics” (Jatin). The rationale for this conception is very pragmatic and concrete. The only way to learn something is by doing it, as Sergio explains:

I think the best way to learn engineering is by practicing. It’s like, how did you learn to dance? You don’t learn dancing in a book. How did you learn riding a bicycle? I can give you the schematics and the AutoCAD drawings for a bicycle and explain all the physics involved but if you don’t get onto the bicycle and pedal, you are going to fail. So it has to be hands on experience most of the time.

(Sergio)

Projects, another common practice in engineering education, are used to learn engineering by practicing. They provide opportunities for hands-on experiences. Trevor’s discussion of the primary goals of teaching engineering reveal a preference for practicing engineering in projects and some of the things students would practice through this experience:

My ideal way to do it when I teach a class would be to have an entire … have one project that they would need to do through the entire semester and just have them work on that the whole time. That project would essentially require them to go out and research all these different ideas and topics and if they need some
thermodynamics or something, I would have them to actually design something that would require that, that would require them to find out the equations that they need to know themselves, figure out how to apply them, how to make it so that the device is safe, reliable and functional. By the end, they actually learn what they have to do because they actually did it for themselves. (Trevor)

Projects can afford students the opportunity to not only practice what they have already learned but also provoke new learning through self-directed exploration. They allow for interaction and closely resemble workplace or “real life” contexts.

... group based learning or projects at some point are very important that they interact with other students because in almost all positions … when they leave the university and they go on to the work force or some other similar avenue. They’re going with other people so the interactions are important that they know how to interact with other people and, and learn from them. So it’s not just important that you know everything, it’s important that you learn how -or what do you know or how do you work with someone else because they know it or can learn it. So I think it’s very important that they learn skills in how to interact with other people, work with other people. And also especially work with, how to recognize what they don’t know and find the person that does because that’s as important or more important than really knowing the answer. (Tim)

Within this conception it is thought that engineering students prove they have learned by demonstrating their ability to do something new. As Tim describes it learning engineering "... means that you now can do something that you could not do before you learned something." (Tim).
Tests and quizzes are still used to assess students’ ability to solve problems, level of understanding or to provide formative feedback but projects are the preferred medium by which students both practice engineering, calibrate their interpersonal skills and demonstrate they can solve problems.

In this conception, learning engineering is a communal experience. Practice occurs in a group environment were students work with others students (learner-learner), with professors (learner-teacher) and engage with the course material (learner-content) to solve problems (learner-context).

Table 8

*Category 3: Learning engineering as practicing*

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus</td>
<td>Behavior, skills</td>
</tr>
<tr>
<td>Nature of knowledge</td>
<td>Procedural</td>
</tr>
<tr>
<td>View of engineering</td>
<td>Craft</td>
</tr>
<tr>
<td>Strategies</td>
<td>Practice solving problems and doing projects in groups</td>
</tr>
<tr>
<td>Assessment</td>
<td>Demonstrate ability to do in tests, quizzes and projects</td>
</tr>
<tr>
<td>Interactions</td>
<td>Learner-learner, learner-context, learner-teacher, learner-content</td>
</tr>
<tr>
<td>Relational</td>
<td>Communal</td>
</tr>
</tbody>
</table>

In summary, future engineering professors who espoused this conception think of learning engineering as practicing problem solving. Students solve many problems, often within projects, in order to develop expertise. This conception is summarized in Table 8.
**Category 4: Learning engineering as applying.** In this conception, learning engineering is described as the process by which engineering students gain the ability to apply knowledge to solve problems. Laura described it as “having to understand the concepts and acquire the skill to apply that knowledge to real world problems.”

The focus of this conception is on acquiring *and* applying knowledge that is usable. As Janna describes it, “Learning is taking information, becoming familiar with it and then being able to use it to accomplish what you want to do with it.”

Like in the Category 1 conception (learning as acquiring), knowledge is declarative and procedural. Knowledge that is to be learned is also viewed as external. Jatin expresses this view of knowledge when he describes learning and what is learned: “Learning would be … understanding the work that has been done and trying to use that to either develop new ways of doing the previous work that has been done or using it for practical purposes.” (Jatin)

Future engineering professors who contributed to this conception view engineering as the application of scientific knowledge to problems. For them, engineering is another methodical process.

Therefore, learning engineering is viewed in this conception as a sequential process of acquiring knowledge and skills, and then figuring out how to apply it to solve problems. Bill explains:

... in terms of learning, I see a lot of images of towards the beginning, it’s very academic and it’s very book work driven and it’s very you’ve got to learn your calculus and then you’ve got to learn your physics. And then you start getting into what the traditional engineering classes are and you start learning about heat
transfer. And you start learning about fluids and you start learning about circuits. And then once you get from the basic math and science to those applications, then you see it applied and you start getting into design classes. (Bill)

Discussions, observations, and assignments are common assessment methods in this conception. Through these the professor tries to evaluate whether students can apply knowledge. Bill discusses the criteria he uses to determine whether his students have learned:

Getting back to assignments, in an ideal sense, you want to be able - I consider an ideal can you give them a homework assignment that really tests their understanding of a problem and given as much time and as much resources as they want, are they able to get the answer? (Bill)

It is interesting to note that individual student-teacher discussions seem to be preferred in this conception. The following exchange with Laura illustrates this:

ATT: How do you know your students have learned?
LAURA: Well, when you talk about it in conversation and they understand something it comes across in the conversation that they understand better than they used to. And then, other ways of telling would also be the results of a test, when they are solving problems, you know they don’t understand when they do crazy things with the numbers.
ATT: Now how would you facilitate that conversation, how would that happen in your classroom?
LAURA: Oh, I am talking about that conversation like office hours or maybe after
class or even in class though students don’t have that much conversation in class.

This reflects an experience and conception of learning engineering as an individual experience. Here learners interact mostly with faculty (learner-teacher) and the content (learner-content), not necessarily with other students.

In summary, future engineering professors who espoused this conception think of learning engineering as applying knowledge to solve problems. Learning is a sequential process of acquiring scientific knowledge and then using it to solve problems. This conception is further summarized in Table 9.

Table 9

Category 4: Learning engineering as applying

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus</td>
<td>Applied knowledge</td>
</tr>
<tr>
<td>Nature of knowledge</td>
<td>Usable, cumulative, external sources</td>
</tr>
<tr>
<td>View of engineering</td>
<td>Applied Science</td>
</tr>
<tr>
<td>Strategies</td>
<td>Sequential process. Acquire knowledge, memorize, then use knowledge</td>
</tr>
<tr>
<td>Assessment</td>
<td>Individual discussions, observations, assignments</td>
</tr>
<tr>
<td>Interactions</td>
<td>Learner-content, Learner-teacher</td>
</tr>
<tr>
<td>Relational</td>
<td>Individual</td>
</tr>
</tbody>
</table>

Category 5: Learning engineering as developing. In this conception, learning is described as developing an approach conducive to solving complex, unstructured
problems. This engineering approach is a certain mindset, or habits of mind, which include: dealing with ambiguity and complexity, and figuring out the unknowns among others. Brenda discusses the learning outcomes that help students develop an approach to solve problems:

I hope that they [my students] learn above all else how to think a way of problem solving, a way of approaching problems and also, what I don’t think that they learn but would like to see them learn, is how do you approach ambiguity, complex situations and break it down and be able to work through that. (Brenda)

Although future professors who express this conception think there is a need to understand fundamental science and engineering concepts, they appear to be more concerned about the challenge engineers face in keeping up with a vast and rapidly evolving body of knowledge.

The main purpose of engineering - teaching engineering is not the equations or the formulas or the numbers, but the engineering criteria or the creative thinking that you apply when a problem arises. ... you wont remember all the strength of materials formula, or you won’t remember solid mechanics in that point but at least you have to know there are certain things that you - you have to check first sequentially... you have to organize your mind in such a way that whenever you go and pick a book or ask for a colleague or another person for a question on how to solve the problem, you know how to approach the situation and not be lost. (Luis)

I summon /sic/ that college is not really about the material that’s covered. The
skills that I learned in college come from actually knowing how to find material myself. Having research skills and the ability to look things up and being able to find this information as opposed to writing down equations and memorizing them and things like that. (Trevor)

As a consequence of this concern, these future professors focus on developing in their students both self-directed learning and flexible thinking skills. They emphasize an engineering mindset that can adapt to solve complex problems in a changing world and helps engineers learn what they do not already know:

It’s not as important to memorize how to do every situation but as long as you know where you can start and what you might be able to do to accomplish the goal then that’s the important thing for learning. (Trevor)

For these future professors developing ways of thinking takes precedence over memorizing information. This emphasis is believed to be particular to engineering. Mark explains it this way:

I think it's just that there's - the proportion for what defines a discipline, there's some of it's the history, some of it's the approach, and some of it's the content. And the proportions in engineering are very different. And so it's much more the approach, and much less the content. Whereas with distinguishing between physics and biology, you can rely on the content more. So much more that you don't even really need to consider the difference in approach, unless you're interested in interdisciplinary collaboration, or really interested in the learning process or something. But for engineering, you can't distinguish it without trying to define the approach. (Mark)
Knowledge in this conception is tacit, which Sternberg (1999) defines as the “procedural knowledge that guides behavior but that is not readily available for introspection” (p. 231). This knowledge is acquired from experience in the environment where it will later be needed and is essential to achieving the goals established by the profession (solving problems). Acquiring and utilizing the engineering approach is very difficult because tacit knowledge in general is not easily verbalized or applied.

The engineering approach requires flexibility so it can take into consideration the complexities of the problems as they are but be able to model systems in a practical, solvable way.

When you get a problem, as I said, you think ‘ok, here is a system’ you define what parts you are going to analyze. Then for the actual solving the problem or the analysis of these parts, you need to know which rules to apply to it. How much you are going to simplify the system, or what kind of system you are going to take it as? Very basically, if are you going to take as a very idealized system with no complexities, is that going to be good enough? Or do you have to look at it in a very realistic, nuanced take and take into account very complex effects.

(Halil)

The engineering approach also involves taking into consideration the possibility of having multiple acceptable solutions to the same problem.

… there is more than one way to analyze a system or part of it. There are different approaches to solve the same problem. One crucial thing is that for each problem a different one will be more suitable and a challenging part of engineering is to gain the ability to recognize which one is suitable to a given situation and select
Engineering is viewed in this conception as a profession that requires specialized preparation to think as an engineer. It is assumed that this combination of specialized thinking (the engineering approach) and a highly scientific body of knowledge makes engineering a professional (e.g., exclusive, specialized) practice.

Developing this engineering approach, makes it is necessary for students to practice extensively how to solve problems and to gain experience on how to find information on their own.

You need to shape your way of thinking into the engineering approach to problems. You do that by using it over and over until you internalize it or engrain it in yourself. The main thing is to realize that you have to think in a certain way when you approach problems or when you approach how you are supposed to learn too because you are supposed to train yourself in how to find out information rather than putting information in your brain. (Halil)

This view of how learning occurs by practicing is similar to the one in Category 3 (learning engineering as practice) except here in addition to assignments, projects provide the context in which students practice solving problems. Projects are preferred because they give students the opportunity to practice design skills, inquiry and documentation; in essence they are an opportunity to do what engineers do in their professional practice.

My ideal way to do it when I teach a class would be to have an entire … have one project that they would need to do through the entire semester and just have them work on that the whole time. That project would essentially require them to go out and research all these different ideas and topics and if they need some
thermodynamics or something, I would have them to actually design something that would require that, that would require them to find out the equations that they need to know themselves, figure out how to apply them, how to make it so that the device is safe, reliable and functional. By the end, they actually learn what they have to do because they actually did it for themselves. (Trevor)

In spite of projects being the preferred strategy to learn engineering, these future professors perceived them as difficult to evaluate. Determining whether a student has developed an engineering approach is somewhat of a challenge in itself. Consequently, there is hesitation in the way these future professors express themselves about assessments of learning in general and more particularly of design projects. For example, Lee discusses his concerns about which criteria to use to evaluate designs:

For design is an interesting question of do you measure the amount of effort they have put into it or do you measure the quality of the end product. To me to balance those two and to figure out where are those students, where is their knowledge before and where is their knowledge after. For me, I think I err on the side of the amount of effort they put into it because I fear that applying the design process is something that is hard for most students to do because there is a lot of ambiguity in the activity. (Lee)

Presented with this challenge, some revert to more explicit forms of knowledge and assessment that can be more easily evaluated with certitude.

If you give them problems that are not mimicking the examples they have already seen solved. If you give them problems that they will need to really have to figure out and if they can actually figure it out. If you give them problems where they
need to find out the parts of the information from outside sources and they do that, then you can see that they have learned how to analyze a system and select an approach to come up with the solution or they have learned how to get the information they need related to that problem. (Halil)

Although future professors who contribute to this conception mentioned student groups, most had a tendency to see learning as an individual act or to not consider the roles of groups or student-student interaction in learning. The engineering approach is something that the student must develop by his or herself with guidance from professors (learner-teacher) and through engagement with course materials (learner-content). Learning from the quasi-context of projects (learner-context) is also very important in this conception as was previously discussed in this section.

Table 10

*Category 5 – Learning engineering as developing*

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus</td>
<td>Engineering approach</td>
</tr>
<tr>
<td>Nature of knowledge</td>
<td>Tacit</td>
</tr>
<tr>
<td>View of engineering</td>
<td>Profession</td>
</tr>
<tr>
<td>Strategies</td>
<td>Practice doing problems and projects</td>
</tr>
<tr>
<td>Assessment</td>
<td>(With hesitation) They can solve new unfamiliar problems. How to evaluate designs?</td>
</tr>
<tr>
<td>Interactions</td>
<td>Learner-context, learner-teacher, learner-content</td>
</tr>
<tr>
<td>Relational</td>
<td>Both</td>
</tr>
</tbody>
</table>
In summary, future engineering professors who espoused this conception think of learning engineering as developing an engineering approach, a mindset on how to solve engineering problems. To learn engineering, students must practice solving problems through design projects. Within this conception, the goal developing an engineering mindset presents challenges for how learning can be facilitated and assessed in practical ways. This conception is summarized in Table 10.

**Category 6: Learning engineering as maturing.** In this conception, learning is described as maturing. Although this conception encompasses the development of technical skills, it is more concerned about the development of student identity as well as gaining an understanding of the societal impact of engineering. Layla describes this:

> Maturing as an engineer, maturing in your technical understanding, maturing as in your ability to understand yourself and who you are in the context of your surroundings and the impact of the things that you do. Learning I guess would just be the process of maturing. (Layla)

With its emphasis on maturing, this conception focuses on the student and his or her development. It is a process of student development that helps them discover their internal and external world in order to make informed personal and professional decisions.

> I think that the job of education is to teach us ... how to grow into adults at an undergraduate level. It’s more about forming the kind of person we are going to be in our lives and in our careers ... than I think it actually should be about
learning the specific skills that we may or may not use. (Layla)

I think a lot of them [students], when they come up here, part of what they have to learn is what their responsibilities are. It’s not quite high school. They get to run around campus and if they want to skip class, there’s no one there to collect them and take them off to juvie or something. So, they have to learn the responsibility of being to class on time, getting up with their alarm clock all by themselves. […] So, it’s really just learning how to be a responsible citizen I think. (Gina)

Gaining the ability to make decisions, inside or outside the classroom, is part of the development process. Mark describes one form of decision making that facilitates the successful navigation of a university or engineering program:

I think there's a lot of learning that we do is learning about how to be successful at our university and I think for some students that they're aware of all that learning that they've done, and they're happy about it. By the time you're a senior, you know which instructors are good, you know their personal preferences, you know how their tests go, you know best how to study, and all of that feels like, I have learned some things, even if it's not engineering, or content. (Mark)

Implied here is also the notion that the knowledge that is learned is socially constructed through interactions with other students.

Within this conception, engineering is viewed as service for the purpose of contributing to society.

That’s great I know about the world around me and I can solve problems and I
can use tools that I’ve gain to solve problems but what does that mean about who I am in the community that I’m in and in the society that I’m in. How do I fit all of that together? How do I make decisions about what I’m doing and how that affects the people who might be using what I’m doing in more than just a technical way? So I think that is part of the learning side too. (Layla)

This is a view of engineering that takes into consideration the engineer’s individual identity and relationship with the community.

Future professors who contributed to this conception expressed hesitation as to how to help their own engineering students mature. Reflection was considered as one possible strategy:

I think that when you learn something, you should also be learning something about yourself. I’m not quite sure how I would enact that in the classroom maybe through some reflection or something … (Brenda)

… learning also comes from having experiences and making decisions based on them and being able to look back and evaluate them and being able to decide what to keep and what to change and what would you do differently next time. So learning, aside from just the classroom version, learning is also the ability to reflect and the ability to take the opportunity to grow and improve and progress in response to varying situations. (Bill)
Because learning is conceptualized as a complex long-term process, there is also hesitation as to how these future professors could determine whether their students had learned.

... well how am I going to know whether they have learned and because learning I’ve defined very broadly as maturing … sometimes you are not going to know, some of this is going to be, and this is how I feel with a lot of my students, I won’t know for twenty years … I may know, like kind of feed along the way, but really we won’t know. I think that is one of the hardest things about teaching. (Layla)

One possibility is to assess learning through dialogue, as Mark considers when he talks about student responsibilities:

MARK: I guess [students should] maintain their end of the dialogue. So starting at setting goals together. And I don't know if that needs to be with the teacher, or with the university, or what, that's I think kind of a politics question. So from that to the next stage would be sort of feedback on the process of teaching and learning.

ATT: Provide you with feedback?

MARK: Yeah. Or guidance. And then all the way through, I guess, to assessment, to honestly help people understand what they understand. So if the teachers are all enlisted to help them learn, then their role is to learn and to kind of constantly monitor this is working or it's not working.

The use of formative feedback, a type of assessment for learning, contributes to student learning and development (Shute, 2008).
As previously discussed, within this conception knowledge is socially constructed. Therefore, learning is viewed as a communal act in which teachers (learner-teacher interactions) and peers support the efforts of the learner (learner-learner interactions).

So I said that students have to come to the table wanting to learn and being committed to learn but a part of that wanting to learn and to continuing to want to learn even in the face of challenges is not something that can only come from within. For some people it can … and I think that I was probably one of those people but as I have grown and changed I’ve become someone who needs a nurturing community around me. It doesn’t mean that I don’t want challenges but I think that I learn better. I think we would all learn better if we had the support of the people around us. (Layla)

Interactions within this conception are not only between learners, but also between the learner and the context, as well as the learner and the content.

In summary, future engineering professors who espoused this conception think of learning engineering as a process of maturing which goes beyond the development of technical skills to include the development of student identity and understanding of the societal impact of engineering. This conception is further summarized in Table 11.
Table 11

*Category 6: Learning engineering as maturing*

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus</td>
<td>Student development, discovery</td>
</tr>
<tr>
<td>Nature of knowledge</td>
<td>Socially constructed</td>
</tr>
<tr>
<td>View of engineering</td>
<td>Service</td>
</tr>
<tr>
<td>Strategies</td>
<td>(With hesitation) How to help engineering students mature? Reflection?</td>
</tr>
<tr>
<td>Assessment</td>
<td>(With hesitation) Sometimes we won’t know for many years. Dialogue, formative feedback.</td>
</tr>
<tr>
<td>Interactions</td>
<td>Learner-context, learner-learner, learner-teacher, learner-content</td>
</tr>
<tr>
<td>Relational</td>
<td>Communal</td>
</tr>
</tbody>
</table>

**Progression through conceptions of learning.** The order of these conceptions does not necessarily represent a strict developmental path. There is no evidence to indicate that future professors’ conceptions evolve sequentially through each of the categories, from Category 1 to Category 6. However, upon analysis of the outcome space and the relationships amongst the conceptions of learning it is clear some of the higher numbered conceptions encompass elements of lower numbered conceptions. For example, the conception of *learning engineering as practicing problem solving* (Category 3) assumes, among other things, that students can understand fundamental engineering concepts. Higher numbered conceptions present more complex perspectives of learning.
Frequency of conceptions of learning engineering. Although participants expressed at times more than one conception of learning, a prevalent conception could be identified for each participant. Among participants in this study, the most frequent conception of learning was Category 5 – *learning engineering as developing an approach* (5 participants), followed by Category 4 – *learning engineering as applying knowledge* (4 participants). Categories 1, 3, and 6 – *learning engineering as acquiring knowledge*, *learning engineering as applying knowledge*; *learning engineering learning as practicing problem solving*, and *learning as maturing* – followed with 3 participants each. The least frequent conception was Category 2 – *learning engineering as gaining an understanding* with only two participants who presented this conception as their most dominant. These frequencies present a mixed landscape in which some future professors view learning engineering as a complex process in which students learn new ways of thinking how to solve problems while others view learning engineering as a simple process of acquiring and applying knowledge.

Basis for the Conceptions of Learning Engineering of Future Engineering Professors

In addition to identifying the different ways in which future engineering professors conceptualize learning, this study sought to explore what these future professors view as the basis for those conceptions. Participants described the basis for their conceptions of learning engineering through four general themes: undergraduate student experience, research, graduate school experience, and prior teaching experiences. Each theme is explained in this section.

**Undergraduate Student Experience.** The most often cited experience that
influences conception of learning was the undergraduate student experience the future engineering professor had. Eleven participants directly cited this experience as one that shaped their views on learning. It is worth also noting that participants often mentioned their own undergraduate experience when asked to further explain the reasons for their views of learning. For example, when Layla was asked how engineering students learn, she based her explanation on her own assumptions about how she learns:

Well, I think there are multiple ways and one way is to read about it, so I do think textbooks are very important. One way is to hear about it, learn about it from whoever your educators are. But I think that … and honestly that is probably how I did a lot of my learning but I think that the way that may have the most long lasting impact in terms of actually gaining that conceptual understanding is to learn it by observing it and testing it yourself. (Layla)

Like Layla, some of these future professors thought their undergraduate experience was influential because it helped them become aware of what they liked or perceived as helpful in learning engineering. Brenda, for example, liked interacting with faculty: “I really appreciated when the professor crashed in on a problem session or whatever because you get the opportunity to talk with your students and really listen to their thought processes.” In a similar way, Trevor spoke about having to learn where to start looking for information and getting emotionally involved in that process:

Once I’m forced to figure out something for myself, I get frustrated, I get depressed, I get angry then I dig around on the Internet or in textbooks or whatever I need to figure out …and when I finally found what I need I just feel a level of satisfaction and relief and that is how I actually learn that material.
Halil also expressed a belief in the importance of learning how to find necessary information. His belief was based on his undergraduate professors’ expectations in courses.

I would say it’s mainly my undergraduate education where the focus was always in practice. This was also preached a lot that we weren’t supposed to get information from the lesson, we were supposed to learn how to get the information. That was the number one skill set that they sought to give to us. We were always expected to show your work and work through the problems and show your approach as well as the nature of the problems you are trying to work it does shape you to think of problems in the engineering way of thinking that I mentioned before. So the subject matter itself and also the recognition on the part of the teacher in general is a way of learning that really shaped us. (Halil)

In Jatin’s case, his experience with projects in undergraduate classes led him to belief that engineering education should be more than just plugging numbers into formulas.

I would say there have been classes which had projects which were practical of using the things that I’ve learned, not just giving ‘solve this equation by’ or ‘solve this problem by putting values on the equation’ much rather than learning how to use it in a particular scenario because if you take a practical problem and you try to find a solution you don’t really understand which algorithm to use. So understanding not just an algorithm but understanding how to use that in a practical way is far better learning than just learning about the algorithm. That
also has influenced my teaching and learning. (Jatin)

For others, their conception of learning was colored by dissatisfaction with aspects of the undergraduate student experience. For example, Trevor contrasted the experience of sitting in boring classes with the experience of courses where more hands-on learning was expected.

I don’t want to say worthless, but [my undergrad experience] was really boring. I didn’t feel like I learned very much. The classes where I did learn a lot I feel were the computer science side of things where I did a lot of programming and a lot of hands-on things. Whereas the electrical engineering classes, I don’t remember essentially anything about those. (Trevor)

Throughout his interview, Trevor demonstrates a preference for learning through projects that involve more experiential (i.e., hands-on) learning. His predominant conception of learning (developing an engineering approach) seems to reflect this belief that experiential learning results in better learning outcomes. Hands-on learning was a frequent theme amongst this group of participants. Twelve of them mentioned hands-on learning at some point in their interviews.

Like Trevor, there were some participants who later became dissatisfied with their undergraduate student experience. After they graduated with their Bachelors’ degree, they felt that some things were missing from their engineering education that could have made the experience better. Layla, who had a very strong conception of learning as maturing, explains how discovering she had missed out on a liberal education experience influenced her view of learning in engineering.

So I think that affects my view on learning that I wish I had had more of a
learning experience where I had to figure out how the world around me works and do something with solving problems based on that learning. I also think that the maturity aspect of what I said, that for me has … I’ve just seen it happen to myself. I’ve changed from someone who … I did really well as an undergraduate like academically I did really well but I didn’t necessarily think about what was I going to do with these things that I was learning in the book and what was the kind of impact I was going to have and who am I in the context of the people around me, who do I wanna be in it. All the things that I think you get as part of a good liberal arts education, I really missed that I didn’t have that and I think I got it myself in a lot of ways because I learned it through other experiences that I’ve given to myself … (Layla)

Layla’s questions about what her own impact was going to be and her identity as an engineer led her to think about engineering education as a different process than the one she experienced. In her view, learning should help engineering students to answer those same identity and impact questions for themselves.

Observing classmates also influenced what future professors thought about learning engineering. Both examples of successful and not so successful learning strategies influence their personal theories of how learning occurs:

I think whatever I've learned, like me being a student, whatever I have learned in class that's what has developed my ideas about it or looking at some of the other bright students in my class, I can say that because they are used to asking a lot of questions or do things by their hands and things like that, that's why they'll be able to learn more things. (Kavita)
I’ve sat in a class before and sometimes you can just see students zoning out and still be writing down the information and taking notes. Maybe they’ll be able to memorize it for the next quiz, that’s fine, get a passing grade. But they’ll never remember it after that and they’ll never be able to utilize any of that information because if they don’t remember it, they didn’t care. Therefore, if nothing was learned, they didn’t gain anything from it. (Gina)

For these future engineering professors, their own undergraduate experience provides a wealth of first hand knowledge that informs how they conceptualize learning. They consider both positive and negative examples of learning strategies into their views of how learning should occur.

Research Experience. Participants also mentioned their own research experience as a basis for their conception of learning. Several participants had conducted research on engineering education, including a few for which this was their primary research area even though they were enrolled in traditional engineering programs.

Specifically, three of the participants indicated that their experience of doing research in engineering education had influenced their views on teaching and learning. Brenda is an example:

Well, I have to say that I think that I’m biased because engineering education is my research area and I’ve thought about it so much more than I ever did before specially since now this is part of my research design […] I think that just the fact that there is an engineering education field out there … and I’ve been made aware of it, has helped me in thinking about teaching and learning and how things are
and how things should be. (Brenda)

The research they conducted on teaching and learning engineering appears to have been an opportunity for them to reflect more deeply than they would have done otherwise about existing research on learning and how engineering students learn.

**Graduate School Experience.** The experience of going to graduate school was also discussed by participants as an influence on their conception of learning. It appears to have changed their ideas of what engineering education can be. Brent, for example, describes graduate school coursework as an empowering experience:

> Again, I’m just going to go back to my graduate school education just because I mean it really -- when I got to that point I didn’t realize, things became interesting. I learned that you could do all this thing -- that for example by reading journal articles you could learn something yourself … I realized that like wait a minute I can be teaching myself anything that I have the curiosity about engineering if I want to solve a problem, I can figure this out on my own. And as soon as I was kind of empowered to do that and maybe that’s really what it comes to do as some sort of empowering moment that said, I can do this, this isn’t difficult, I have the ability to learn this and not only do I have the ability, the resources are there. (Brent)

The independence that is inherent in graduate school appears to have helped the participants become more self-directed and even changed their motivation for learning. For Brenda, graduate school changed her motivation for learning from being achievement/grade oriented to a more intrinsic motivation.
When I was an undergrad and before that, I was achievement-oriented. I worked my butt off to get straight As. Did everything I had to, stayed up late, crammed, office hours… I think I was very focused on the grades but do I have the As and do I have what I need to get to the next job, grad school, whatever. I admit to myself that as an undergrad in the Mechanical Engineering curriculum, I was not learning-oriented. I didn’t know it at the time, I always thought that I was getting the straight As so I must know it, right? [...] Now I kind of see learning more as … learn stuff because you are interested in it, learn it to know it. Learn it because you want to understand what is going on and you are interested and if you didn’t find out how it worked it would bother you. I guess I’m very much more motivated now by the interest rather than just doing something for the sake of doing it. So I find learning and the things I’m learning now much more fulfilling.

(Brenda)

Brenda’s experience in graduate school led her to re-think what learning means in engineering, the value of grades, and what the motivation for learning should be.

Perceptions of institutional climate in graduate school can also have an effect on future engineering professors’ conception of learning. Ping, an international student from Asia, explained that the climate at the school where he is conducting his doctoral studies inspired him to encourage his students to not be afraid of showing vulnerabilities or of seeking help.

… it’s like at least in the college and university, everybody is here to help you. So don’t be shy. Don’t be hesitating to tell us your problems. It’s okay to show weakness. Because you are here to learn. You’re not here to show, right? (Ping)
The helping attitude of other people at the school he is attending in the U.S. made Ping feel that difficulties do not need to be hidden because they are part of the learning process and are even expected.

In summary, the graduate school experience exposed these future engineering professors to other ways of thinking about learning. It brought to their attention other alternatives for what should be emphasized, different strategies for learning engineering, and even other attitudes towards students and the learning process.

**Teaching Experience.** Two students mentioned their prior teaching experience as something that influenced their views on learning. Not surprisingly, it appears that as these future educators interact with students and see their outcomes they reflect on which strategies their most successful students employ. Feng, who taught a senior design class, explained:

... I know what are [my students] final jobs. And I saw some people who are passionate and actual do the senior design best got a job offer. And other people who are not so active, their job offer is not so good. So it’s an actual learning process. […] but for the people that’s actually doing the project, they often try to resolve the problems by themselves and I just, sometimes I just need to be with them looking and that they were actually find it out by themselves. So that’s the major difference. And that causes the different, I think, different results for their job.” (Feng)

Future engineering professors also talked about their teaching assistant experiences when explaining their views on multiple aspects of learning. It appears that
reflecting on their teaching and teaching assistant experiences informs their views on how learning occurs.

**Chapter Summary**

This chapter presented findings about the conceptions of learning of future engineering professors based on interviews with doctoral engineering students interested in academic careers. Six categories of conceptions of learning engineering emerged. These include conceptions of learning engineering as: 1) acquiring knowledge, 2) gaining an understanding, 3) practicing problem solving, 4) applying knowledge, 5) developing an approach, and 6) maturing. Among the participants of this study, the most frequent prevalent conception was Category 5 – *learning engineering as developing an approach*. The least prevalent conception was Category 2 – *learning engineering as gaining an understanding*. Each conception can be described by seven dimensions, including: focus, nature of knowledge, view of engineering, strategies, assessments, interactions, and relational. The variations the conceptions of learning engineering identified in this study can be compared in Table 12.
Table 12

*Outcome Space for Future Engineering Professors’ Conceptions of Learning*

**Engineering**

<table>
<thead>
<tr>
<th>Learning engineering as...</th>
<th>(1) acquiring</th>
<th>(2) understanding</th>
<th>(3) practicing</th>
<th>(4) applying</th>
<th>(5) developing</th>
<th>(6) maturing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Focus</strong></td>
<td>Content</td>
<td>Comprehension</td>
<td>Behavior, skills</td>
<td>Applied knowledge</td>
<td>Engineering approach</td>
<td>Student development, discovery</td>
</tr>
<tr>
<td><strong>Nature of knowledge</strong></td>
<td>Declarative and procedural, concrete, external, cumulative</td>
<td>Declarative and procedural, external, needs to be internalized</td>
<td>Procedural</td>
<td>Usable, cumulative, external sources</td>
<td>Tacit</td>
<td>Socially constructed</td>
</tr>
<tr>
<td><strong>View of engineering</strong></td>
<td>Field of study</td>
<td>Field of study</td>
<td>Craft</td>
<td>Applied Science</td>
<td>Profession</td>
<td>Service</td>
</tr>
<tr>
<td><strong>Strategies</strong></td>
<td>Viewing a lecture, reading a book, searching online, asking teachers questions</td>
<td>Frequent exposure to the material and hands-on experiences</td>
<td>Practice solving problems and doing projects in groups</td>
<td>Sequential process. Acquire knowledge, memorize, then use knowledge</td>
<td>Practice doing problems and projects</td>
<td>(With hesitation) How to help engineering students mature? Reflection?</td>
</tr>
<tr>
<td><strong>Assessment</strong></td>
<td>Tests, written reports</td>
<td>Tests and discussions</td>
<td>Demonstrate ability to do in tests, quizzes and projects</td>
<td>Individual discussions, observations, assignments</td>
<td>(With hesitation) They can solve new unfamiliar problems. How to evaluate designs?</td>
<td>(With hesitation) Sometimes we won’t know for many years. Dialogue, formative feedback.</td>
</tr>
<tr>
<td><strong>Interactions</strong></td>
<td>Learner-content, learner-teacher</td>
<td>Learner-content, learner-teacher, learner-context</td>
<td>Learner-content, Learner-teacher</td>
<td>Learner-context, learner-teacher, learner-content</td>
<td>Learner-context, learner-teacher, learner-content</td>
<td>Learner-context, learner-learner, learner-teacher, learner-content</td>
</tr>
<tr>
<td><strong>Relational</strong></td>
<td>Individual</td>
<td>Individual</td>
<td>Communal</td>
<td>Individual</td>
<td>Both</td>
<td>Communal</td>
</tr>
</tbody>
</table>
In addition, the explanations given by participants as the basis for their conceptions of learning are presented. Four experiences emerged as the most influential on their conceptions of learning engineering: their own undergraduate student experience, their own research, their graduate school experience, and their prior teaching experiences.
Chapter 5: Conceptions of Teaching Engineering

Introduction

To explore future engineering professors’ conceptions of teaching engineering, this study sought to answer these two questions:

Research Question 3: How do future engineering professors describe their conceptions of teaching engineering?

Research Question 4: How do future engineering professors describe the basis of their conceptions of teaching engineering?

In this chapter, the variations in conceptions of teaching held by 20 future engineering faculty are described. In addition, the explanations given by participants as the basis for their conceptions of teaching are described.

Outcome Space

This section provides a detailed description of the five ways in which future engineering professors conceptualize teaching engineering. As in the prior analysis of conceptions of learning, the participants themselves are not assigned to a specific category but their experiences and quotes are. Similarly to the conceptions of learning, the order of these conceptions does not represent a strictly developmental path. However, high numbered conceptions encompass some elements of lower conceptions.

Each conception is described by the five dimensions or features that emerged for the categories. The dimensions are: focus, strategies, student prior knowledge, faculty-
student interaction, conception of learning, and projects. The focus dimension describes what is emphasized in the conception. The strategies dimension describes pedagogies the participants already used or planned to use in their teaching. The student prior knowledge dimension describes the role, if any, of student prior knowledge in teaching. The conception of learning dimension describes which conception of learning is related to this conception of teaching. Finally, the role of projects is described in the projects dimension.

The categories of conceptions are teaching engineering as 1) delivering knowledge, 2) helping understand and apply concepts, 3) motivating students, 4) helping students learn how to approach problems, and 5) preparing students to make socially conscious decisions. In the following sections, each category is described in detail.

**Category 1: Teaching engineering as delivering engineering knowledge.** In this conception, teaching engineering is described as delivering engineering knowledge to students. For future professors who hold this conception, teaching is the process by which engineering knowledge, both declarative and procedural, flows from professors to students. Gina describes teaching simply as “... just trying to figure out the best way to communicate your knowledge and the knowledge of others to these students so they can later utilize it themselves.”

The focus of this conception is the actions professors take to present knowledge. This includes the presentation of fundamental engineering knowledge, also known as “the basics”, as well as teacher experiences. Within this conception, professors are viewed as source or authority on knowledge as Janna expresses:
Teaching is being able to take your life experiences and teach them to somebody else who is coming from a completely different background with a completely different outlook on life and different skills and learning styles and successfully being able to communicate that information. (Janna)

The primary strategy future professors who espouse this conception plan to use is delivering well organized and interesting lectures of course content. Gina describes good teaching this way:

... teachers have to be able to get the ideas across and make sure the students are learning and understanding it. Maybe their professors aren’t getting the idea clearly enough across. Maybe it’s very jumbled and confusing for the students. And when they get feedback on that, they have to adapt the way of their teaching to make it more acceptable to the students so the students are learning the material. (Gina)

Consequently, bad teaching is characterized by disorganized presentations. Gina exposes this assumption when she spoke about student evaluations of teaching: “We actually get to grade the professors at the end, and I think that’s really valuable because say I didn’t like the PowerPoint, how it was presented, because they were very confusing, at that time, I get to write it down.” Implied in both Gina’s and Janna’s comments is the notion that professors bear the most responsibility for organizing knowledge and making it understandable.

Future professors who hold this conception assume their students have no prior knowledge on the course topic. Janna reveals this assumption when she talks about considering the student’ point of view:
… you have to be able to remember what it was like not to know anything when you walked into a classroom and being able to bring things down to the basics where a student gets learning pretty much from scratch. (Janna)

Within this conception, most of the communication flows one way: from faculty to student. It is initiated by faculty who lecture to their classes. As Gina explains: “... it’s just trying to figure out the best way to communicate your knowledge and the knowledge of others to these students so they can later utilize it themselves.” However, students occasionally need to initiate communication with faculty to ask questions. Even in those occasions when students go to the office hours, these future professors appear to take a teaching-centered approach:

And then the real challenge also comes into those people you don’t capture with that lecture, somehow you have to entice them and make them want to come to your office hours so that you can do the one-on-one that people need and then you have to try and teach it from a different approach … (Janna)

Although concerns about establishing their credibility with students was expressed by many of this study’s participants regardless of their conception of teaching, this group of future professors appeared to be particularly concerned with convincing students of their credibility as an expert in the topic they would teach. This may be due in part to their own need to develop their teaching identity or to their assumptions about the nature of knowledge and the power expert authorities hold.

This conception of teaching shares many assumptions about the nature of knowledge with the conception of learning engineering as acquiring knowledge (Category 1 of Conceptions of Learning). There is a difference though in that knowledge
is more applied in this conception of teaching than it is in the acquiring conception of learning. In this conception of teaching, knowledge is acquired with one purpose: to be applied. As Janna explains:

… some people say that’s kind of old school but there is just some foundation information that you got to pound into the students you know in painful classes that are you know memorizing and regurgitating kind of thing. But once you have all that basic information in there then you own it, that information, and then you can take it and use it to solve problems. (Janna)

Similarly to the conception of learning as acquiring, how experts -teachers in this case - are authoritative, almost exclusive, sources of knowledge.

Projects or other hands on experiences did not appear to be factors in this conception of teaching. In fact, projects were not mentioned at all by two of the future professors who contributed to this conception.

In summary, future engineering professors who espoused this conception think of teaching engineering as delivering knowledge. Good teaching depends on the teacher’s ability to organize and present material in a logical manner. This conception is summarized in Table 13.
Table 13

Category 1: Teaching engineering as delivering knowledge

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus</td>
<td>The actions professors take to present knowledge</td>
</tr>
<tr>
<td>Strategies</td>
<td>Organized lectures</td>
</tr>
<tr>
<td>Conception of learning</td>
<td>Learning as acquiring knowledge (Category 1 of Conceptions of Learning)</td>
</tr>
<tr>
<td>Student prior knowledge</td>
<td>None assumed</td>
</tr>
<tr>
<td>Faculty-student interaction</td>
<td>Mostly one-way, from faculty to student</td>
</tr>
<tr>
<td>Projects</td>
<td>Not considered</td>
</tr>
</tbody>
</table>

Category 2: Teaching engineering as helping understand and apply concepts.

Future engineering professors who hold this conception view teaching as helping students understand new engineering concepts so they can be used in solving problems. According to Laura: “[Teaching] is facilitating student learning so they can really understand the deep concepts of what they are trying to know how to do.” Brandy describes the primary goal of teaching engineering as: “giving [students] a foundation to solve real world problems.”

Similar to Category 1 of Conceptions of Teaching (teaching as delivering
knowledge), presentation of knowledge is still a concern in this conception. For me teaching would be … giving information about a particular area so that the student can understand and work through … try to implement those ideas or information to do something in practical areas of their own lives. One of the main things about teaching is [pause] in engineering they can’t fake it, they can use that information in their own lives or use it for practical purposes. […] They have to use that information in practical areas as well. They have to know how they can use it in real life as well. (Jatin)

However, Jatin and other participants revealed that the focus of this conception is on both the understanding and the application of engineering knowledge. Tim explains it this way: “… the goal [of teaching] should be an ability to have an understanding of concepts and an ability to apply them.” Students are expected to master core engineering ideas. Feng explains teaching as “… how to efficiently let the students master the core ideas and how to cultivate their problem solving abilities.”

Therefore, this conception goes further than the category 1 (teaching as delivering knowledge) in trying to ensure that students understand course material and that they somehow use that knowledge in a practical way.

... for me there is a varied umbrella of what teaching can be and I think its probably, for me it maps to what is the appropriate level of information that is being conveyed and how best to do that. So there is this figuring out the underlying information or vocabulary for something and learning that and then there is trying to practice and apply that knowledge to addressing some problem. Then there is trying to map and transfer that knowledge to other spaces. So for
me, the role of teaching is conveying information, you can help students deal with that information and you can help students transfer that information to some other circumstance. (Lee)

This conception of teaching as helping understand and apply is related to not only one but three of the previously discussed conceptions of learning. Future engineering professors who espoused this conception share some of the assumptions about the nature of knowledge and the strategies planned by these conceptions of learning: learning engineering as understanding (Category 2 of Conceptions of Learning), learning engineering as practicing (Category 3 of Conceptions of Learning), and learning engineering as applying (Category 4 of Conceptions of Learning).

In this conception, presentations of knowledge take the form of problem solving sessions. In this exchange, Alan explains his aversion for using PowerPoint presentations for his Digital Logic course.

ALAN: […] Logic, there’s no way I can do those algorithms, and work them out. If I do them by PowerPoint they’re all just going to glass over. So it slows me down enough for them to see what’s going on, and also can work with them on it. The rate at which I’m writing is a good speech rate to talk with them about it.

ATT: So you do the diagrams on the board?

ALAN: Absolutely, I work on the board.

The need to create an environment where students feel comfortable asking questions also influenced participants who chose to slow down their presentations and encourage in class discussions.

Other strategies considered in this conception include presenting multiple real
world applications of knowledge and providing problems or projects to practice application of what is being learned.

So I’ve created in that course these fake chips that are very simple, easy for them to understand, they don’t actually exist though. But if they did exist, here’s the application they would have, how wonderful it would be in the world, the things they understand. Like create a chip that is basically a neural network chip. Now, it doesn’t exist, but here’s the simple task of what it could do, and it’s easy for them to grasp and understand how it works. (Alan)

Students’ prior knowledge is somewhat taken into consideration in this conception of teaching engineering. These future professors believe that previous material affects how students understand what is being taught and their ability to use knowledge in the future:

... communication is important because you want to get the right messages across so that [students] are pulling from previous material in the right ways and that the stuff that you are teaching them, they’re able to apply to the future material in the right way. (Bill)

Students’ existing abilities are also taken into consideration in this conception. Feng, for example, considers students’ abilities when assigning tasks:

When I’m guiding the senior design -- because some students are really good at the software parts and some students are good at the hardware parts. So I sort of found that their abilities -- I mean found their strengths, and assigned the tasks with some focus by the students which are good at programming, I assign them the projects for the software development. Yeah. Because really, different
students have different strengths for their future job. I think to make the best of their strengths, you should try to accommodate them on the parts they are good at.

(Feng)

This conception of teaching still holds the teacher as a source of the truth and in a position of greater power. Bill’s comments reveal that replication is one of his intents: “Good communication is going to make sure that what gets said also gets interpreted in the way that it’s intended.”

However, the emphasis on understanding requires that the professor listens to students in order to know if understanding is occurring. According to Bill, a more cooperative relationship must occur.

…it’s the shared responsibility of the student and the teacher to pass along information so that learning can occur. And I know that the teacher is in a much more responsible position, like a much more authoritative position. But I do believe that it is a shared responsibility. It does need some cooperation on both sides. (Bill)

Future professors who hold this conception are concerned for students who can demonstrate learning within the class context (in exams and homework) but cannot transfer that knowledge to other contexts.

I have seen many undergraduate students who do the coursework but they solve the problems but they can’t use the algorithm when they are asked to do some other works. For example, they don’t know the relationship between the work they learned and how they can use it. So, when I did my Operating Systems class, I asked them to make projects like that - they would know how the algorithms
have been used. So I asked them to write programs so they can implement the
algorithms, know what the problems are and they can implement it and so on. So,
using them in real life is different than just learning it. So that is one of the things
I tried to achieve. (Jatin)

Partly in response to this concern, these future professors plan to use projects.
Projects help reinforce what students learn in class. They are the context in which
students transfer and practice what was learned.

Because if I just teach the contents on the textbook, [students] may not fully
master it. So I need to design some projects just to let them know how this
knowledge in the textbook can be used in the real life. (Feng)

In summary, future engineering professors who espoused this conception think of
teaching engineering as helping students understand new concepts so they can apply them
to solve problems. To teach engineering, multiple examples of application of engineering
knowledge must be presented to students and opportunities to practice what is being
learned must be provided. Greater interaction between professors and students is
necessary to gauge how well students understand the material. This conception is
summarized in Table 14.
Table 14

*Category 2: Teaching engineering as helping understand engineering knowledge*

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus</td>
<td>Both the understanding and the application of engineering knowledge</td>
</tr>
<tr>
<td>Strategies</td>
<td>Greater in class faculty-student interaction. Present multiple real world applications of knowledge. Provide problems or projects to practice application.</td>
</tr>
<tr>
<td>Conception of learning</td>
<td>Learning engineering as understanding (Category 2 of Conceptions of Learning)</td>
</tr>
<tr>
<td></td>
<td>Learning engineering as practicing (Category 3 of Conceptions of Learning)</td>
</tr>
<tr>
<td></td>
<td>Learning engineering as applying (Category 4 of Conceptions of Learning)</td>
</tr>
<tr>
<td>Student prior knowledge</td>
<td>Somewhat taken into consideration</td>
</tr>
<tr>
<td>Faculty-student interaction</td>
<td>Some two-way communication</td>
</tr>
<tr>
<td>Projects</td>
<td>Used to reinforce learning</td>
</tr>
</tbody>
</table>

*Category 3: Teaching engineering as motivating students.* Future professors who hold this conception view teaching engineering as motivating students. They take into consideration time constraints, students’ affect, and the complexity of the material to
conclude that motivation is central to helping students learn and therefore to their teaching jobs.

I think your main responsibility [as a teacher] is to motivate your student to learn. Because with the numbers of hours that you’re supposed to teach some of these complicated topics, it’s impossible that you are able to teach that in the classroom. But if you motivate your student right, then they’re going to be able to go by themselves, and look at that material and practice, and improve themselves.

(Sergio)

The need for professors to present course content and facilitate learning is not disregarded in this conception but the focus is motivating students to learn engineering. Brent elaborates: “apart from just the conveying and the assumed absorption of knowledge by students, I think teaching is also about trying to inspire or trying to invoke or to bring up within the students interest in the subject.”

For future professors who hold this conception, motivation is essential to their teaching role. Kavita describes how important motivating students is for her job satisfaction this way: “If I’m able to interest and motivate even one student out of the whole class for that day and that subject, whatever I taught that day, I’ll be satisfied.”

The main strategy in this conception is the use and discussion of real world examples or experiences. This conception assumes that these experiences increase student interest in engineering which can result in more time spent on self-directed learning activities.

… your aim is not to concentrate on precise students in a class of 5 students who know it already, but to be able to motivate the other 45 students to at least go on
the Internet and try to look for things that are new. Like discussing with them some global issue which can be built with the help of engineering or something like that. (Kavita)

Appealing to student interest is a common concern for these future engineering professors. Interest is assumed to help students persevere in their studies. Kavita explains:

… what you teach to undergrads basically pretty much wouldn’t change at all over the years. But what we need to do as young teachers or young people, who want people to get motivated to do something nice, like maybe carry onto graduate studies or promote or motivate them to carry on research, is that you give them glimpses of the wonders of engineering. What engineering can do for you. (Kavita)

Students’ prior knowledge does not play a major role in this conception but their attitudes do. These future professors consider how student attitudes and feelings affect their willingness to learn and be taught.

I think there are two very important things in teaching engineering stuff. The first is logic, the second is mathematics. These two are the most important things in understanding the engineering stuff, especially computer science. […] So while I teach, I always focus on these two parts. But during the teaching, students always feel bored with the contents, so you have to have some jokes […] None of them too funny, but you know, you have got some jokes to change the mood of the class. (Ping)

Ping believes that improving the mood of students is important in teaching engineering. Therefore, ignoring student’s feelings is expected to have a negative impact
on classroom environment and learning outcomes.

In this conception, projects are the context in which the knowledge and skills learned are reinforced. Projects are used to give students a chance to apply what they learn in an interesting, real world context. The future utility or relevance of what is being learned in class is also highlighted by these projects. Sergio, for example, involved his students in a community service project which actually allowed them to practice what they were learning in his class.

So I say in class one day, okay, we have this project. We are going to assemble five thousand backpacks for poor kids in the area. And they were like, yeah, sure. No, no, I’m talking for real, we’re going to do that. So basically, we divided the class into departments like logistics, public relations, inventory, layout design, and each one was to achieve … a person in charge, and they have responsibilities and they have deadlines. So basically we’re simulating a whole project, and we’re performing the whole project. […] The objective is that we submit a successful project by the end of the semester, and these people are going to be able to accomplish their goal. So when they start looking at things like that, then their job is not only because I want an A, and if I copy it’s okay. It’s like, okay, if I don’t do my job right, the system isn’t going to work as a whole, and then those kids are not going to receive their backpack at the end. So eventually there was some friction, and discussion, but they were able to manage that, and to work in a real environment. And at the very end they were excited because their project was accepted. (Sergio)

From the analysis of these interviews, it is not clear which, if any, conception of
learning is related to this conception of teaching as motivating students. The emphasis on using examples and projects to appeal to students’ interest makes the conception of learning engineering as practicing problem solving (Category 3 of Conception of Learning) the most likely candidate. However, there is not enough evidence that this conception of teaching shares the assumptions about the nature of knowledge or the social aspect of learning of learning engineering as practicing problem solving. An analysis of the conceptions of learning of future professors who contribute to this conception of teaching did not result in any logical association. Therefore, the relationship of this category of conception of teaching to conceptions of learning remains unclear.

The interaction between these future professors and their students is easier to characterize. The nature of the relationship appears to be one of collegiality where students are treated as future professional colleagues. At the same time, these participants felt the need to both encourage and challenge students to greater performance.

In summary, future engineering professors who espoused this conception think of teaching as motivating students to learn engineering. To teach engineering, these future engineering professors plan to use real world examples that appeal to student interest and assign projects where students can see the relevance of what they are learning. This conception is summarized in Table 15.
Table 15

Category 3: Teaching engineering as motivating students

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus</td>
<td>Motivating students to learn engineering</td>
</tr>
<tr>
<td>Strategies</td>
<td>Use and discussion of real world examples.</td>
</tr>
<tr>
<td>Conception of learning</td>
<td>-</td>
</tr>
<tr>
<td>Student prior knowledge</td>
<td>No significant role but their attitudes are considered</td>
</tr>
<tr>
<td>Faculty-student interaction</td>
<td>Collegial, encouraging but challenging</td>
</tr>
<tr>
<td>Projects</td>
<td>Used to reinforce learning and motivate students</td>
</tr>
</tbody>
</table>

Note. Dash (-) indicates dimension could not be determined from data.

Category 4: Teaching engineering as helping students learn how to approach problems. Future faculty members who hold this conception think of teaching as helping students learn how to approach engineering problems. This encompasses: teaching students how to learn, and how to define and analyze systems. Students need to be taught self-directed learning skills like assessing what is known, what needs to be learned, and finding information. Learning engineering is viewed in this conception as developing an approach (Category 5 of Conceptions of Learning) conducive to solving complex, unstructured problems.

... the first thing anyone who is in engineering education is going to tell you is that it should teach you a way of approaching problems, of analyzing things in
terms of defining it as a system and defining what parts of it there are. (Halil)

In this conception developing self-directed learning and problem solving skills is emphasized over acquiring information. These future professors believe it is impossible for engineers to learn all the information they will need to solve any given problem.

... there is so much information that you will not be able to learn at all plus some piece of information you get you may never again use in your life and yet the thing is there is a lot of information … (Halil)

Therefore, it is better for these students to learn how to find information and how to learn new things. In other words, for future engineers to become better problem solvers it will be important for them to know which books or other sources to search for missing equations or parameters. Although participants recognized that knowing some basic common information is necessary, having these adaptable problem solving skills, including information seeking, is more important for students than memorizing information.

The main purpose of teaching engineering is not the equations or the formulas or the numbers but the engineering criteria or the creative thinking that you apply when a problem arises. Like […] what should you know to go first check or – you won’t remember all the strength of materials formula, or you won’t remember solid mechanics in that point but at least you have to know there are certain things that you have to check first sequentially. Or if you - you have to organize your mind. In such a way that whenever you go and pick a book or ask for a colleague or another person for a question on how to solve the problem, you know how to approach the situation and not be lost. (Luis)
Future engineering professors who hold this conception plan to encourage students to learn how to learn on their own. To facilitate this, they would not give students all the information needed to solve a problem so they are forced to search for additional data. This strategy is perceived by future professors as more practical and enduring.

... I would essentially have my students [find information] rather than just telling them what they need to know, have them find out what they need to know by themselves, that way they actually learn it as opposed to just memorizing it briefly… long enough to take the test and then just forget about it as soon as they leave the room. (Trevor)

Developing problem solving skills is also encouraged. Working in teams to solve problems is one of the skills these participants considered particularly important for their students. Future engineering professors in this category plan to encourage peer interaction in order for students to learn how to work in teams.

Work in groups. That is another skill they need to have as engineers. I would encourage them to seek help from each other more than myself as a teacher but if they need it or if I feel it is important I may step in and give them some hints and tips. (Trevor)

In this conception, projects are one of the main strategies used to teach engineering. In their view, projects help facilitate the development of self-directed learning, problem solving, and communication skills.

I think you would maybe do a project where you have to do experiments so you gain skills related to the lab environment or if you have a project that has to use a
new software packages so you will be getting those skill sets as well as a lot of problem solving in other projects and exercises which would just practice the different aspects of how engineers approach problems and get information, solve problems, and so on. (Halil)

… I like to take a hands-off approach to things like I would just give the students an assignment and say “That’s it. Go do it.” I like to have them figure things out on their own because that is how they learn. (Trevor)

Student prior knowledge is taken into consideration by these future engineering professors. Students are encouraged to figure out what they know so that they can determine what information or skills are needed.

… I never want to impose anything – any ideology from my side. … when I teach, I try to hear mostly from students why they are thinking about how to solve the problem. And then I try to get the same solution, I mean I try to use their point of view, their idea and use that as a solving tool, not my idea. (Luis)

Both Luis’ and Trevor’s comments suggest a view of professors as a guide – or consultant - on the side of students as they work in their projects. They listen to students, assess their current knowledge and work with them to help them solve problems.

Trevor’s own definition of teaching exemplifies this view of student faculty interaction: “it’s your job to assist them [students] on their path [to learn for themselves], help them with things, be given a starting point, or help them with some roadblocks along the way.” This reveals how important it is to assist students in their learning.

As Halil previously suggested, projects in this conception are viewed as the context in which learning occurs. Projects not only reinforce learning but help cause learning. Trevor
elaborates how projects can help students develop their own engineering approach:

Teaching engineering, I believe, give students a more technical background but just don’t tell them how to solve equations, just don’t tell them things make them learn it on their own again. Make it more project-based. My ideal way to do it when I teach a class would be to have one project that they would need to do through the entire semester and just have them work on that the whole time. That project would essentially require them to go out and research all these different ideas and topics and if they need some thermodynamics or something, I would have them to actually design something that would require that, that would require them to find out the equations that they need to know themselves, figure out how to apply them, how to make it so that the device is safe, reliable and functional. By the end, they actually learn what they have to do because they actually did it for themselves. (Trevor)

In summary, future engineering professors who espoused this conception think of teaching engineering as helping students learn how to approach problems. To teach engineering, these future professors plan to use projects to encourage students to develop self-directed learning, problem solving, and teamwork skills. This conception is summarized in Table 16.
Table 16

Category 4: Teaching engineering as helping students learn how to approach problems

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus</td>
<td>Developing self-directed learning, problem solving, and teamwork skills</td>
</tr>
<tr>
<td>Strategies</td>
<td>Withhold some information so students have to search for missing data on their own. Encourage students to collaborate in assignments, including projects.</td>
</tr>
<tr>
<td>Conception of learning</td>
<td>Learning engineering as developing an approach (Category 5 of Conception of Learning)</td>
</tr>
<tr>
<td>Student prior knowledge</td>
<td>Considered. Students are encouraged to figure out what they know so that they can determine what information or skills are needed</td>
</tr>
<tr>
<td>Faculty-student interaction</td>
<td>Faculty as guide or consultant, assisting student learning</td>
</tr>
<tr>
<td>Projects</td>
<td>Project-based learning</td>
</tr>
</tbody>
</table>

Category 5: Teaching engineering as preparing students to make socially conscious decisions. Future professors who hold this conception, view teaching as preparing students to have an impact in the world by being conscious of how their decisions affect others.

… to equip people to make decisions about things whether or not it’s a big
decision or a small decision … and also give the students the prerequisites skills in order to be productive members of society. (Brenda)

The focus of this conception is to help students make informed decisions that not only take into consideration technical issues but also consider the broad (social) impact of engineering work. Mark describes the purpose of teaching as “having each graduate formulate their own reasoned position, I guess, between technology, knowledge, scientific research inquiry, and societal problems and goals.”

These future professors are concerned with helping their students think and make sense of how what they are learning and their future work fits into the real world. Layla defines teaching as “helping someone else understand the world around them and how they can have an impact on the world around them.”

To understand the world around them, students are encouraged to make their own interpretations of what they learn based on the context in which they work:

... how do we understand what we are doing, our problem solving, our discovery of the way things work in the context of the society and the community in which we are working? That is going to include things like the ethical decisions we make as engineers and I understand that is very broad but I think that is probably the third principle. How do we think about the works that we are doing within the community and the society that is being done and the impact that it’s going to have. What are the responsibilities that we have, that go along with that? (Layla)

Interest in helping students gain an understanding of the societal impact of engineering and what their role in the world is provides some clues as to which conception of learning relates to this conception of teaching. Learning engineering as
maturing (Category 6 of Conceptions of Learning) encompasses some of these same concerns.

Both Sergio and Kavita mention making a difference in the world or having a sense of social responsibility. Kavita indicates “I think teaching is a profession that you inspire a generation to live their life in a way that is inspiring to others.” She elaborates:

I think you are not just supposed to make their basics strong but you are also supposed to ensure that they get a glimpse of what is going on the real world so they feel motivated to go into the real world and do something awesome. (Kavita)

Future professors who contributed to this conception did not address the strategies they would use to achieve their goals or any of the other features that characterize the other conceptions of teaching. From their discussions of teaching and learning it is unclear how they would interact with students, how student prior knowledge factors into their teaching or whether they would use projects as part of their teaching.

Future engineering professors’ interest but lack of preparation to teach students to consider the social impact of engineering contrasts against two trends that are bringing social issues to light in engineering education. The first trend relates to changes in accreditation criteria for engineering programs. In the early 2000s, ABET included a new student outcome to its criteria that called for students to have “the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context” (ABET, 2011). Due to that change in criteria, engineering programs have sought out ways of incorporating the broad impact of engineering into their curricula.

The second trend relates to the recruitment of underrepresented groups in
engineering. Women and other students from underrepresented groups tend to gravitate towards engineering subdisciplines, such as biomedical and environmental engineering, which more directly address social and community issues (Chubin, Donaldson, Olds & Fleming, 2008; Schreuders, Mannon, & Ruthersford, 2009). Inclusion of applications that highlight the social benefits of engineering in curricula and recruitment materials has been touted as having the potential to improve the retention of female engineering students (Schreuders, et al., 2009, p. 110).

These two trends indicate an emerging need to incorporate social issues in engineering education. Participants in this study who conceptualized teaching engineering as preparing students to make socially conscious decisions may be reflecting these trends. Their concerns highlight some clear gaps in the preparation of future engineering faculty in order to fulfill this teaching goal.

In summary, future engineering professors who espoused this conception think of teaching engineering as preparing students to make socially conscious decisions. Although their purpose for teaching is clearly articulated, it is unclear how these future engineering professors plan to achieve their teaching goals. This conception is summarized in Table 17.
Table 17

Category 5: Teaching engineering as preparing students to make socially conscious decisions

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus</td>
<td>Helping students think and make sense of how what they learn and create impacts society</td>
</tr>
<tr>
<td>Strategies</td>
<td>-</td>
</tr>
<tr>
<td>Conception of learning</td>
<td>Learning engineering as maturing (Category 6 of Conceptions of Learning)</td>
</tr>
<tr>
<td>Student prior knowledge</td>
<td>-</td>
</tr>
<tr>
<td>Faculty-student interaction</td>
<td>-</td>
</tr>
<tr>
<td>Projects</td>
<td>-</td>
</tr>
</tbody>
</table>

*Note.* Dashes (-) indicate dimension could not be determined from data.

**Progression through conceptions of teaching.** Similarly to the findings of the conceptions of learning, the order of the conceptions of teaching does not necessarily represent a strict developmental path. However, it is clear some of the higher numbered conceptions of teaching encompass elements of lower numbered conceptions of teaching.

**Frequency of conceptions of teaching.** Among participants in this study, the most frequent prevalent conception of teaching was Category 2 – *teaching engineering as helping understand and apply concepts* with 8 participants who expressed this view of teaching. Category 3 – *teaching engineering and motivating students* followed with four
participants. Category 4 – *teaching engineering as helping students learn how to approach problems* and Category 5 – *teaching engineering as preparing students to make socially conscious decisions* were expressed by three participants each. Category 1 – *teaching engineering as delivering knowledge* only had two participants express this as their prevalent conception.

**Basis for the Conceptions of Teaching Engineering of Future Engineering Professors**

In addition to identifying the different ways in which future engineering professors conceptualize teaching, this study also sought to explore which experiences future professors view as the basis for those conceptions. Participants described the basis for their conceptions of learning engineering through four general themes: observing professors, student experience, talking about teaching, and teaching experience.

**Observing professors.** The majority of participants mentioned lessons about teaching learned from observing and reflecting on what engineering professors did. This includes observations of what participants saw their own professors do in their classes, how their advisors dealt with their students in and outside of class, and also what they saw other engineering professors do.

I have to say that the majority of instructors that I have had that were average, I don’t remember. When I look back I remember the really good ones and the really bad ones. So those are the ones that I need to learn from. I need to look at – Why did that person do such a good job with me in that class? I mean what, how
did they communicate, what did they do that made everything click? and that’s
what I wanted to take with me and use and develop and then the ones that I hated
– Why did I hate them, what was it about that and how can I avoid that in my
teaching? (Janna)

Participants discussed what they perceived as successful teaching techniques.

Talking directly about which experiences influenced his views on teaching, Jatin
reflected on what professors did in the classes he thought worked.

The first thing was the professors or the instructors made sure that students are
involved …. They asked questions … like they also use practical, current,
everyday projects or anything like this. For example, one of my operating systems
professor had similarities between algorithms he used and the algorithms in the
textbook and see how they are different … (Jatin)

Participants talked about what they learned about teaching engineering by observing what
ing engineering professors and TAs do and reflecting on how effective their efforts were.

… I also look at what did my professors do? Now that I’m a lot more interested
in how professors teach and which types of tactics they use in their classrooms
and stuff like that. But even TAs, what I think is a good TA and what I think is a
bad TA for example. (Brenda)

Participants also considered the challenges faculty face to balance their work/life
given the myriad needs of students.

Probably a really big influence would have to be previous professors that not only
I’ve learned from but also that I’ve worked with. You see these individuals just
take these tremendous challenges every single day, not only teaching the kids
what they have to learn but also, some of the students will absolutely go to these professors and all of a sudden break down crying because they’re so stressed out. And I find often, they have to be part psychologist, too. So, I think that’s really inspiring that they’re able to balance not only work life but also a personal life with the students and their own personal lives and still be so upbeat and positive and ready to keep going. (Gina)

Participants were aware of the challenges of balancing research and teaching responsibilities and take those into consideration when making instructional decisions. Lee for example, believes helping students during office hours is a part of professors’ responsibilities but wants to make sure office hours are enforced.

So, I think that there are other opportunities [for engagement] probably before and after class. I’m probably thinking about my own -- how I would do things and my own expectations, that there is balancing research, teaching and other responsibilities to have the engagement with students in a class, constrained to either class time or office hours. Maybe I have some concern that leaving things completely open ended might leave me open to having an imbalance of time spent on those issues. (Lee)

Several participants also discussed what they learned not to do from observing and reflecting on what bad professors did. Tim learned about the importance of having a syllabus and honoring it.

… I see things they [professors] do in the classroom and the way they manage the board or mange things that I really imitate. And then there are a few professors that I see things like not having a syllabus -- or changing things so much, what I
recognize as a student it’s something that I like to avoid because I see how that affects students. (Tim)

Based on her observations and experiences, Janna decided it was important to simplify course material to help students understand and maintain interest in the course. … some of the calculus professors that I had that were so theoretical, they couldn’t teach the basics and I realize when you are a high level researcher that you are really working way out here. [...] And so when I was in classes and you know they just didn’t explain it in a way that I could understand or they taught the class from a higher level than where I was that, I just lost all interest in the class and that just really kind of drove home to me that when I am teaching you know I don’t want to be that way, I want to be the person that can simplify it and turn on light bulbs in kids’ minds. (Janna)

From his observation of terrible professors, Alan concluded that professors’ passion for a subject is very important for their students.

ALAN: I had some terrible professors.

ATT: Okay, tell me more about that.

ALAN: I don’t know, I’ve had some professors that - I had one professor that was so boring he fell asleep in his own class. It was a math class, he fell asleep repeatedly.

ATT: While he was doing math?

ALAN: Oh, yeah, while he was teaching. He would sit on the desk, and be talking and pointing and he would drift. And it was fantastic. We’d sit there in class going, do we leave? Do we not leave? Should we wake him? We don’t
wake him … don’t wake him. And I’ve had some amazing professors. Guys that I’ve idolized, this is amazing, the passion they have for it. Because when a professor’s passionate about a topic, it’s infectious. It makes the class passionate. It doesn’t matter how boring of a class it is, how boring the topic is. If the professor’s passionate, that’s amazing.

Many participants observed and reflected on the effectiveness and fairness of how engineering was taught to them and how it was taught to other students. Regardless of their conclusion, participants’ reflections on how engineering is taught were highly influential in shaping their own conceptions of teaching engineering.

**Student experience.** Participants’ own student experiences shaped their conception of teaching engineering. These were not just observations of what professors did in their classes but how they lived those experiences as students.

In my experience, I really always appreciated when the professor came up to the session and not just the TA or the professor tried to be there as much as possible. It is something that I would like to try to do if I ever have something like that to do. (Brenda)

I know, in part, what to teach because I have been a student and it's not that I kind of – I am a student at the moment, right? It really comes from being a student and knowing what works and what doesn't and you know what has always worked for me is when I'm able to understand what is really interesting about something when I can understand that passion and like for example problem solving which is the key to engineering when you get that a “aha!” in solving a problem that is
something that it can be kind of addictive, it's something you want to do again.

(Brent)

Like Brenda and Brent, participants’ own preferences and assumptions about what worked for them in engineering courses influenced what they though professors should do and how they plan to teach in the future. For Sergio, it was the experience of working many hours on classwork by himself at the request of a professor that led him to conclude how important it is for teachers to motivate students to practice.

I had a calculus professor that we were doing some very complicated integrals at some point in the university, and I went to him and went like in two seconds here is the solution, you just had to divide and stuff like that. I say, whoa, how do you do that? It’s easy. After 400 integrals, 401 is easy. So the secret is practice, practice, and practice. So I remember when I was an engineering student, I woke up every Sunday, 8 a.m., put a little music, take my calculus textbook, and start solving integrals until lunchtime. Eventually that increases your proficiency. But if you’re not motivated, you’re not going to do that. (Sergio)

On the other hand, participants also reflected on the influence of unmet expectations. Lee’s disappointment with professors and their class structure led him to conclude that as a future professor he should let his student know the reasons for how his class will be structured and what will be taught.

I think I’ve been in a number of classes and experiences where I had this innate trust in the structure of the class and the capabilities of the professor and have been disappointed in that … what I thought was going to be useful, or what I
thought was going to be what I would take away from the class wasn’t there. So for me, I think I have mentioned setting and managing expectations a number of times but I think my own experiences having been in a class or a situation where those expectations are not met have colored my view on trying to make things in the classroom more transparent: like what’s the motivation, or the learning objective, or why things are setup in the way they are. (Lee)

Similarly to what was previously discussed regarding the basis for conceptions of learning, the countless hours spent in engineering courses and interacting with faculty and peers, influence what future professors assume works in teaching engineering.

**Talking about teaching.** Talking about teaching also shaped participants’ views on teaching. Several of them recalled discussing issues they had as TA with their advisors. Participants who had relatives who were educators, at the university or K-12 levels, also appear to have been influenced by their discussions about teaching. Their relatives’ experiences teaching in other contexts also expanded their understanding of what teaching can be.

The teaching approaches of advisors can influence their doctoral students’ own conceptions of teaching. Alan’s advisor had strong beliefs about what were the right things to do for students. Although he did not think his advisor was basing his recommendations on theory, Alan trusts and shares in his advisor’s teaching approach.

… [my advisor and I] never really talked about his approach, we just talk in sort of examples about what's okay to do, and if we disagree, we'll talk about the principles behind it. So whatever his view is has, I think, strongly influenced me too. [...] … if he [my advisor] has a theory or pedagogy behind it, he doesn't say
it that way at first. But for him, it's usually what's - I can picture him saying that it's just not right - you just don't do that. So for him, I think kind of the essential challenge is balancing, doing everything you can for every student and I guess that's it. (Mark)

Beyond the actual teaching techniques employed in the classroom, participants also discussed other factors that influence professors teaching decisions. Talking about the challenge to maintain a balance between student needs and other responsibilities gave Alan an opportunity to think about an aspect of teaching that is often more reactionary than purposeful: the relationship between professors and their students.

So then that means that if somebody is asking more than you could - if someone's asking so much that you need to limit what you do for other students, then you have to say “no.” And how do those situations work out? And when students don't understand that relationship, how do you deal with it. How do you try to get them to understand? And if they just refuse, then how do you protect yourself, and protect them, and still be fair to them. Make sure that they can know that something is going wrong, but still be fair to them. (Mark)

Although several participants mentioned talking about teaching with family members who taught, the most salient case was Janna. She came from a family of educators which included her mother who taught kindergarten, her sister who teaches lower elementary grades, and her uncle who although retired from a prestigious university was still an active education scholar.

My sister is actually a proponent of developing the critical thinking skills at an early age and I think that there has to be a balance. I think that at some point you
have to just learn the basics before you can develop critical thinking skills. You
got to have information to work with and so having the discussions between my
sister who is the critical thinking skill at an early age, me who said yeah but when
I get them they still don’t know some of the basics and then my uncle […] and
that’s been a really, really valuable resource for me. (Janna)

Janna had the opportunity to informally discuss different education paradigms
with people whose judgment she trusted. These conversations allowed her reflect and
make sense of her own teaching experiences. From those reflections, Janna was able to
take well-articulated positions on her own philosophy of education. Her experiences with
the educators in her family also appear to have influenced her belief that professors need
to learn more about educational psychology.

I am a firm believer that to be a professor it takes more than just being a student
and doing research. I think that doctoral students nowadays need to have, if they
plan on going into education they need to have more educational psychology than
they do […] If they are going to be in an academic setting where teaching is
critical I think they need to take classes on how to teach or workshop or some sort
of training. (Janna)

Talking about teaching after a critical incident also influenced conceptions of
teaching. After Sergio began a class with most seats empty, he gave a pop quiz to the few
students who arrived on time to class. Later, a colleague challenged his rationale for
doing this pop quiz.

At some point, I remember one day, I have only have like 20% of my students in
my class, and everyone coming late, so I said, okay, take a piece of paper. We are
going to have a quiz right now. And they took a piece of paper, they have a quiz, every student that was late, they were not able to take the quiz. I took the quiz, and I grade it, and those that are late, they miss that quiz. And then this guy came to me, and say, okay, tell me something, what was the objective of the quiz? Teaching them that they have to be punctual. Do you know how the students look at the quiz? […] And how you feel when you get punished, how you feel about the other person that’s punishing you? And then I learned that those students came late because they have another class, and they were running late because of another professor. So it was not even their fault. […] And he mentioned something very special at the end of that conversation. You are a teacher, because you have to love your students. If you don’t love your students, you’re in the wrong profession. You have to love them, and you want them to be the best professional, and the best person they can be. That’s your job. (Sergio)

That conversation made Sergio reconsider his strategy with that class and furthermore influenced his philosophy of teaching to be more collaborative with his students.

**Teaching experience.** Four participants spoke about how their own experience teaching engineering or assisting in teaching influenced their conception of teaching. For some, the experience challenged their assumptions about teaching engineering and engineering students. Most of those who discussed their teaching experiences reflected on what they had learned from revising their courses and procedures in response to issues that occurred in their classes.

The experience of teaching and interacting with students led future professors to
reconsider assumptions about the academic and emotional development of undergraduates.

In a university situation, I expected the students to be a little more prepared than they were and I had of eighty-four students I had a significant portion that had little to no computer experience. And I think if you are a student that’s going into engineering and you are not even that familiar with computers then you really are not very well educated as to what an engineer does, because computers are such a big component of that now. (Janna)

Some of the participants adjusted their teaching in response to the situation and abilities of their students. As instructors and TAs they experimented with different ways of helping students to learn. For example, Sergio taught a class in which half the students performed badly in the midterm exam. He reflected on the situation:

So, okay, if I continue playing by the book, those students are not going to get even a C, because the midterm was just awful. So if you just say, okay, first class I say this and I have to stay with my syllabus and with the percentiles. So those guys are going to fail, and they are never become engineers, and they’re going to drop out of the program. So the question is, this happened because those guys don’t want to learn? because those guys don’t have the skills? or because those guys were really, really lazy? So, you need to find a way to push them, and challenge them, and to say, okay, I’m going to make you a deal: If you get more than 80% in your next three quizzes, and in your final one, you are going to pass this class, and I’m going to forget about the midterm. Because of the nature of my class, everything from now on is cumulative. So if you show me that you are able
to perform this quiz, and perform the final, then you get back into track. (Sergio)

By the end of the semester, only one student was failing Sergio’s class and the others were working hard to improve. The experience reinforced Sergio’s belief that as a teacher “you’re not here to fail a student, you’re here to teach them and to motivate them.”

Not all changes in conceptions occurred as a result of a major issue or incident. Even the normal process of making minor incremental revisions to a course can shape future professors views on teaching because they provide opportunities to make low risk experiments. For example, Alan gained new insights into students’ preferences after making modifications to test questions.

We try again, we revised - because the course, when I came out, it still had a horrible failure rate. I mean it was still 20%, where it was bad. We tried it my way, and it got a little bit better. We then did some other little tweaks to it. We tried it again, a stupid, simple exam, and the feedback from the students was they didn’t like it. […] Their mind was at a point of, “don’t spoon feed this to me”. I want actually the problem. How did you get this? What does this mean? (Alan)

Students apparently resented an exam that oversimplified problems. This led Alan to conclude that students need better contextualized background information about a problem.

What these participants reveal is that the process of making instructional decisions and reflecting about their consequences can provoke new developments in conceptions of teaching.

Others. There were other experiences mentioned by participants that were
relevant but did not emerge as a theme because just one or two participants mentioned them. These included for example education courses, institutional influence, industry experience, and their own research experiences.

**Chapter Summary**

This chapter presented findings about the conceptions of teaching of future engineering professors based on interviews with doctoral engineering students interested in academic careers. Five categories of conceptions of teaching engineering emerged. These include conceptions of teaching engineering as: 1) delivering knowledge, 2) helping understand and apply concepts, 3) motivating students, 4) helping students learn how to approach problems, and 5) preparing students to make socially conscious decisions. Among participants in this study, the most frequent prevalent conception was Category 2 – *teaching engineering as helping understand and apply concepts*. The least frequent prevalent conception among participants was Category 1 – *teaching engineering as delivering knowledge*.

Each conception is described by the five dimensions or features that emerged for the categories. The dimensions are: focus, strategies, student prior knowledge, faculty-student interaction, conception of learning, and projects.

The variations in conceptions of teaching engineering identified in this study can be compared in Table 18.
Table 18

*Outcome Space for Future Engineering Professors’ Conceptions of Teaching*

**Engineering**

<table>
<thead>
<tr>
<th>Teaching engineering as</th>
<th>(1) delivering knowledge</th>
<th>(2) helping understand engineering knowledge</th>
<th>(3) motivating students</th>
<th>(4) helping students learn how to approach problems</th>
<th>(5) preparing students to make socially conscious decisions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus</td>
<td>Actions professors take to present knowledge</td>
<td>Both the understanding and the application of engineering knowledge</td>
<td>Motivating students to learn engineering</td>
<td>Developing self-directed learning, problem solving, and teamwork skills</td>
<td>Helping students think and make sense of how what they learn and create impacts society</td>
</tr>
<tr>
<td>Strategies</td>
<td>Organized lectures</td>
<td>Greater in class faculty-student interaction. Present multiple real world applications of knowledge. Provide problems or projects to practice application.</td>
<td>Use and discussion of real world examples.</td>
<td>Withhold some information so students have to search for missing data on their own. Encourage students to collaborate in assignments, including projects.</td>
<td>-</td>
</tr>
<tr>
<td>Conception of learning</td>
<td>Learning as acquiring knowledge (Category 1 of Conceptions of Learning)</td>
<td>Learning engineering as understanding (Category 2 of Conceptions of Learning) Learning engineering as practicing (Category 3 of Conceptions of Learning) Learning engineering as applying (Category 4 of Conceptions of Learning)</td>
<td>Learning engineering as developing an approach (Category 5 of Conception of Learning)</td>
<td>Learning engineering as maturing (Category 6 of Conceptions of Learning)</td>
<td>Learning engineering as maturing (Category 6 of Conceptions of Learning)</td>
</tr>
<tr>
<td>Students’ prior knowledge</td>
<td>None assumed</td>
<td>Somewhat taken into consideration</td>
<td>No significant role but their attitudes are considered</td>
<td>Considered. Students are encouraged to figure out what they know so that they can determine what information or skills are needed</td>
<td>-</td>
</tr>
</tbody>
</table>
Table 18 (Continued)

<table>
<thead>
<tr>
<th>Faculty-student interaction</th>
<th>Mostly one-way, from faculty to student</th>
<th>Some two-way communication</th>
<th>Collegial, encouraging but challenging</th>
<th>Faculty as guide or consultant, assisting student learning</th>
<th>-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Projects</td>
<td>Not considered</td>
<td>Used to reinforce learning</td>
<td>Used to reinforce learning and motivate students</td>
<td>Project-based learning</td>
<td>-</td>
</tr>
</tbody>
</table>

*Note.* Dash (-) indicates dimension could not be determined from data.

Four experiences emerged as the most influential on future engineering professors’ conceptions of teaching engineering. These experiences are: observing professors, their own student experience, talking about teaching, and their own teaching experience.
Chapter 6: Conclusion

Introduction

This study was informed by a review of literature on educational research, psychology and engineering education (Chapter 2). Major topics explored included epistemological beliefs, learning in engineering, conceptions of problem solving, conceptions of learning, conceptions of teaching in higher education, and the development of those conceptions. The review revealed that there is abundant research exploring conceptions of teaching of university faculty and conceptions of learning of students but the exploration of the conceptions of learning and teaching of doctoral students who are training to become faculty was previously scarce.

This study explored variations in future engineering professors’ conceptions of learning and teaching engineering. The research questions that guided the study were:

1. How do future engineering professors describe their conceptions of learning engineering?
2. How do future engineering professors describe the basis of their conceptions of learning engineering?
3. How do future engineering professors describe their conceptions of teaching engineering?
4. How do future engineering professors describe the basis of their conceptions of teaching engineering?
Qualitative research methods were used to answer these research questions. Specifically, a phenomenographic approach was used to analyze data obtained from interviews with twenty doctoral engineering students who self-identified as potential engineering faculty. The phenomenographic approach was discussed in Chapter 3 as well as the sample, data collection methods, and data analysis.

The outcome space resulting from this study on the ways future engineering professors think about learning engineering was presented on Chapter 4. How participants described the basis for their conceptions of learning was also described in that chapter. Chapter 5 describes the variations in how future engineering professors conceptualize teaching engineering and how they describe the basis for those conceptions. The following sections provide a discussion of the outcome space, the implications of the study for the preparation of future and new engineering faculty, suggestions for future research, and conclusions.

**Discussion**

**Conceptions of Learning Engineering.** In this study, six categories of conceptions of learning engineering emerged from the analysis of interviews with doctoral engineering students interested in academic careers. The conceptions of learning engineering were learning as: 1) acquiring knowledge, 2) gaining an understanding, 3) practicing problem solving, 4) applying knowledge, 5) developing an approach, and 6) maturing. Each conception was described by seven dimensions: focus, nature of knowledge, view of engineering, strategies, assessments, interactions, and relational.
From the analysis of conceptions of learning, it is evident that future engineering professors are concerned about their students learning declarative knowledge (knowing what) and many are concerned about helping students learn procedural knowledge (knowing how). What was not apparent was concern for helping students develop structural knowledge which is knowledge about how concepts are interrelated and which can help facilitate the translation from declarative knowledge to procedural knowledge to the application of such knowledge (Jonassen, Beissner, & Yacci, 1993). According to Jonassen and colleagues, the explicit awareness of the interrelationships between conceptions is essential for higher order, procedural knowledge (p. 4).

In spite of calls for engineering educators to consider not only content and topics but also how students engage with these materials (Smith, Sheppard, Johnson, & Johnson, 2005), content was the main focus of the learning engineering as acquiring knowledge (Category 1 of Conceptions of Learning). This is a result of what some call the tyranny of content (Wankat & Oreovicz, 1998), the need to cover material rather than to encourage student learning. An emphasis on content suggests engineering educators are very concerned about keeping up with rapidly emerging new knowledge and this is reflected in the norms of their academic culture. As Sheppard, Macatangay, Colby, and Sullivan (2008) argue, a consequence of this tendency is an education that “allow[s] little opportunity for students to have the kind of deep learning experiences that mirror professional practice and problem solving” (pg. xxii).

Future professors who espoused the learning engineering as practicing conception (Category 3 of Conceptions of Learning) and particularly those who espoused learning engineering as developing an approach conception (Category 5 of Conceptions
of Learning) have the potential to provide students with those deep learning experiences. However, in their descriptions of strategies and assessment methods there appears to be little guidance or formative feedback from the professor to help students learn deeply from problem solving or project experiences.

The conceptions of learning found also reveal how important it is for some future engineering professors the development of an engineering approach. In fact, it is the most prevalent conception of learning among the future engineering professors in this study. As discussed in Chapter 4, this approach is a form of tacit professional knowledge that is not often well articulated by doctoral students. For future engineering professors, and even for some new and existing faculty, it is not very clear how this approach is learned by engineering students or how to assess such learning.

Problem solving and design skills are an essential part of what engineering students must learn (Donald, 2002; ABET 2011) but remain part of the tacit professional knowledge that future engineering professors who participated in this study sometimes mentioned but rarely articulated in an operational manner. The vast majority of participants either did not discuss any aspect of design or if they did it was addressed in very general terms. For example, participants who contributed to the learning engineering as developing an approach conception (Category 5 of Conceptions of Learning) came closest to discussing design yet they had difficulty articulating how it would be learned or assessed. This impacts future professors’ ability to teach engineering design or problem solving as was found in Chapter 5. Their apparent lack of awareness of one of the most important aspects of engineering practice should be of concern.

Among participants who contributed to the learning engineering as maturing
conception (Category 6 of Conceptions of Learning), there was little understanding of how students develop. How that sort of learning could be assessed in an engineering course was not clear either.

The findings of this study reveal similar patterns as prior conceptions of learning engineering identified by Marshall et al. (1999) such as the view of learning as memorization (acquiring knowledge), learning as applying, learning as understanding, learning as changing as a person (maturing). What is new in this study is the addition of conceptions of learning as practicing and as developing an engineering approach. These are two conceptions that are very much in accordance with engineers’ interest in hands on learning and pragmatism.

Conceptions of Teaching Engineering. In the analysis of conceptions of teaching engineering, five categories emerged. Participants thought about teaching engineering as: 1) delivering knowledge, 2) helping understand and apply concepts, 3) motivating students, 4) helping students learn how to approach problems, and 5) preparing students to make socially conscious decisions. In describing conceptions of teaching, five dimensions or features were identified: focus, strategies, use of students’ prior knowledge, faculty-student interaction, conception of learning, and projects.

The findings of this study are consistent with categorizations of conceptions of teaching of university professors found by prior studies (Kember, 1997). Like the conceptions found by those studies, the conceptions of teaching engineering espoused by future professors in this study could be arranged along a continuum from teacher-centered/content-oriented views to student-centered/learning-oriented views. More specifically, three of the conceptions of teaching engineering are similar to Pratt’s (1998)
perspectives of teaching in higher education. *Teaching engineering as delivering knowledge* shares the emphasis on content of the Pratt’s transmission perspective. *Teaching engineering as motivating students* shares with the nurturing perspective an emphasis on helping students feel they can learn the material and that learning the material is useful and relevant. Although *teaching engineering as preparing students to make socially conscious decisions* is not based on a particular world view, like the social reform perspective it assumes that both teachers and students are responsible for how their future actions will affect society at large.

In addition to supporting what is already known about variations in general conceptions of teaching in higher education, the findings of this study reveal which discipline specific aspects of teaching and learning are emphasized by future engineering faculty members. They also reveal deficiencies in the teaching strategies future professors intend to use. Additional tensions between future professors’ teaching goals and the schema they have of teaching techniques can be also be ascertained from these findings.

One of those tensions is related to the use of students’ prior knowledge. Although it is well known that students’ prior knowledge can help or hinder learning (Ambrose et al., 2010), few conceptions of teaching or for that fact few participants considered students’ prior knowledge. Prior knowledge was barely addressed by participants except for those that espoused views about teaching that contributed to the conception of *teaching engineering as helping students learn how to approach problems* (Category 4 of Conceptions of Learning).

This study confirms the challenges in educating professional engineers. As Sheppard et al. (2008) argue “although engineering education is strong on imparting
some kinds of knowledge, it is not very effective in preparing students to integrate their knowledge, skills, and identity as developing professionals.” This is evidenced by the absence of well-articulated strategies in the conception of teaching held by future professors most concerned about integrating professional identity, *teaching engineering as preparing students to make socially conscious decisions* (Category 6 of Conceptions of Teaching). While their focus and teaching goals were very clear, it was difficult to interpret how they would achieve them or evaluate whether students have reached those goals.

Projects are one of the contexts in which this integration of knowledge, skill and identity could occur but their full potential may not be achieved through future engineering professors’ intended teaching strategies. In three of the five categories of conceptions of teaching, projects - were design experiences usually occur – are either not considered or used just as reinforcement of learning. Used in this manner, projects will not necessarily be the context in which deep, integrative learning can occur. Another concern future professors expressed in relation to projects is how learning is assessed in design or project assignments.

**Basis of the conceptions of learning and teaching engineering.** The explanations given by participants as the basis for their conceptions of learning were presented in Chapter 4. Four experiences emerged as the most influential on their conceptions of learning engineering: the participants’ undergraduate student experience, their own research, their graduate school experience, and their prior teaching experiences. In Chapter 5, the experiences that emerged as the most influential on future engineering professors’ conceptions of teaching engineering were very similar to those that
influenced conceptions of learning: participant’s own student experience and their own teaching experience. Additionally, participants talked about observing professors and talking about teaching as experiences that influenced their views on teaching.

Findings of what future engineering professors describe as the basis for their conceptions of learning and teaching support the notion that teaching conceptions and strategies are based on a person’s student experiences (McKenna et al., 2009). They also support Bieber and Worley's (2006) findings that graduate students’ view of faculty life is rooted in their undergraduate experience. The participants of this study repeatedly referred to their own preferences, experiences and observations as a student to justify their views on learning and teaching engineering.

Contrary to popular belief, the participants of this study demonstrated that future engineering professors do not simply teach as they were taught. Although participants indicated that observing their professors influenced how they thought about teaching, this did not mean they immediately adopted the teaching techniques they saw. Future engineering professors reflected on their observations and experiences of teaching. Sometimes those reflections resulted in the adoption of similar teaching approaches but at other times they resulted in a rejection of observed teaching practices and a search for better alternatives.

Even though this study revealed some experiences future engineering professors thought influenced the development of their conceptions of learning and teaching, it was not possible to characterize how these experiences or others such as industry or teaching experience, influenced conceptions. In other words, it was not possible to identify whether certain experiences helped facilitate more complex conceptions of teaching.
Implications

The implications for both doctoral education in engineering and faculty developers involved in the preparation of future, new, and current engineering faculty are discussed in this section.

**Doctoral education.** The findings of this study highlight doctoral engineering students’ often unaddressed needs as they prepare for academic careers. These needs include helping them make knowledge related to problem solving skills and the engineering approach more explicit. In particular, it is necessary for doctoral students to better articulate, facilitate, and evaluate the design process and its resulting solutions. Doctoral students in engineering could use more help in becoming more aware of structural knowledge (Jonassen et al., 1993) in engineering.

As expressed by participants in this study, the teaching assistant experience shapes future professors’ views on learning and teaching engineering. Doctoral students who intend to become professors need to be given opportunities to assist and then teach at least one course during their own studies.

**Faculty development.** This study can inform the design and evaluation of programs to prepare future engineering faculty. The first thing to consider is that just like students’ prior knowledge can affect learning (Ambrose et al., 2010), new professors preconceptions of learning and teaching can help or hinder how they learn to teach. Faculty developers must keep in mind that new faculty may hold a variety of preconceptions of learning and teaching which may be incompatible with the assumptions made when designing programs or providing services. This may contribute to new faculty resistance to suggested teaching practices. Understanding future
professors’ conceptions of learning and teaching can help faculty developers in supporting new professors’ professional learning. One possibility is to first assess new professors’ underlying assumptions about learning engineering before discussing with them teaching methods.

Faculty developers may also use the findings of this study to aim to increase future engineering professors’ awareness of variations in thinking about learning engineering. Contrasting different ways of thinking about the same phenomenon can help highlight key features of the phenomenon (Åkerlind, 2008, p. 636). For example, future professors could be asked to reflect on their own views on learning. Comparing and contrasting their own conceptions with those identified by this study could help future professors become more aware of various aspects of learning engineering such as acquiring knowledge (Category 1 of Conceptions of Learning), understanding engineering concepts and procedures (Category 2), development of problem solving skills (Category 3), application of knowledge to different contexts (Category 4), developing an engineering approach (Category 5), discovering the societal impact of engineering, and developing a professional identity (Category 6).

As previously discussed, most future engineering professors who participated in this study either did not mention or barely mentioned design when talking about teaching and learning. Design is a significant part of what professional engineers do. Faculty development programs should assume new faculty need help facilitating and assessing design learning. They should provide opportunities for faculty to explore and discuss this aspect of their teaching.

Findings also reveal areas of teaching that are a priority to future engineering
professors but are not typically addressed by faculty development programs. These areas include motivating students, helping students mature, helping students become effective decision makers, and helping students become more aware of the social context and impact of engineering.

Future engineering professors who view teaching as motivating students do not have the benefit of a deep understanding of motivation theories to inform their teaching practices. Faculty developers should include the goal of helping professors and teaching assistants better understand the theories of motivation and how motivation affects learning.

Future engineering professors who were interested in how they could help students mature were not sure how to facilitate this or how this type of learning could be assessed. One possibility would be to help new faculty learn about theories of intellectual student development, metacognition, motivation, reflection and formative feedback. Evaluation of outcomes in these more complex conceptions of learning is even more of a challenge that needs to be addressed.

Considering that participants thought talking about teaching was very influential on their conceptions, faculty developers should consider longer term interactive development program models such as faculty learning communities (FLCs) (Layne, Froyd, Morgan & Kenimer, 2002; Cox, 2004). FLCs provide faculty members with opportunities to talk, reflect about teaching, and collaborate on teaching projects over a longer period of time.

The use of guided instructional consultations, such as Small Group Instructional Diagnosis (SGID), (Finelli, Ott, Gottfried, Hershock, O’Neal & Kaplan, 2008) should
also be considered. SGIDs help facilitate discussion and reflection about teaching practices and student learning. This type of discussions with a knowledgeable consultant can positively influence professors’ conceptions of teaching and learning.

Both FLCs and SGIDs reflect a more holistic view of faculty development were faculty members not only participate in one-time events but engage in activities that promote lifelong professional learning (Webster-Wright, 2009).

Suggestions for Future Research

In addition to the implications discussed, the findings of this study also open up new questions for future research on future engineering professors and the preparation of engineering faculty. These questions include:

- How do conceptions of learning and teaching of future engineering professors compare with the conceptions of new engineering professors? How do conceptions of learning and teaching of future engineering professors compare with the conceptions of established engineering professors? How do conceptions of learning and teaching of future engineering professors compare with the conceptions of expert engineering professors?
- How do the conceptions of learning engineering espoused by future professors compare with the intended ways of thinking in engineering?
- How do future engineering professors conceptualize learning engineering design? How do future engineering professors conceptualize teaching engineering design?
What is the relationship between the conceptions of teaching of new engineering professors and their teaching practices?

What are future engineering professors’ conception of student motivation?

As previously discussed, this study could not identify which experiences helped future engineering professors develop more complex conceptions of learning and teaching. Future researchers should seek to explore this area by conducting studies that explore particular experiences. They could explore:

- What is the relationship between industry experience and the development of conceptions of learning and teaching engineering?
- Does the type or location of future engineering professors’ undergraduate studies influence their conceptions of learning and teaching?

As future professors in this study discussed, their teaching assistant and teaching experiences shaped their views on learning and teaching. From the results of this study it is unclear whether those experiences help challenge or reinforce preconceptions of teaching. Although it could be theorized that more teaching experience results in more complex conceptions of teaching, the data in this study is insufficient to support this assumption. Future researchers should consider the following questions to help explore these theories:
How do the conceptions of learning held by future engineering professors who had teaching assistant experience compare to those held by future engineering professors who had no teaching assistant experience? How do the conceptions of teaching held by future engineering professors who had teaching assistant experience compare to those held by future engineering professors who had no teaching assistant experience?

How does the type of prior teaching context influences the conceptions of learning held by future engineering professors? How does the type of prior teaching context influences the conceptions of teaching held by future engineering professors?

This study and others like it also highlight the need to explore the values and beliefs of future faculty. Such research can help increase our understanding of the instructional culture and epistemology of engineering educators (The Steering Committee of the National Engineering Education Research Colloquies, 2006).

Suggestions for research methods. This study was based on future engineering professors recollections of which experiences influenced them as expressed in retrospective interviews. It is a look back at how they recall their thinking about teaching and learning changed. These recollections may or may not be the reasons for changes in their conceptions.

In hindsight, it would have been preferable to conduct a second interview with each participant. It would have provided an opportunity to clarify and confirm emerging findings. Future researchers exploring questions similar to those in this study should
consider analyzing interview data to identify conceptions before conducting a second more in-depth interview with participants about the basis of their conceptions.

As previously indicated, conceptions are not easily measured or self-reported. The analysis of just what future professors say about teaching and learning and not how they teach tells just half the story of how future professors think about teaching (Kane et al., 2002). To address these challenges, future research should study the evolution of conceptions from multiple perspectives and at different times in professors’ careers. Some alternative data gathering strategies to study these phenomena could be to look at: statements of teaching philosophies, multiple interviews, critical incidents, reflective journals, instructional materials, and classroom observations. Multiple data sources could provide a richer data set from which to triangulate conceptions and further seek to explicate future professors’ conceptions.

Conclusions

The findings of this study are consistent with previous categorizations of university professors’ conceptions of teaching from teacher-centered/content-oriented to student-centered/learning-oriented (Kember, 1997). However, this study contributes to the literature of engineering education and faculty development by contextualizing the conceptions of learning and teaching of future engineering professors. Furthermore, this study provides much richer descriptions of variations in other aspects of teaching and learning engineering such as future professors views on interactions, student development, assessment, motivation, problem solving, assumptions about knowledge,
teaching and learning strategies. Participants in this study revealed areas of engineering education, such as motivating students and teaching about the societal impact of engineering, that are of interest to future engineering professors but for which they are not formally prepared.

In addition, this study contributes to our understanding of how professors learn about teaching. In particular, the exploration of the basis for the conceptions of learning and teaching opens new avenues to explore how conceptions of teaching and learning evolve over time. The fact that future engineering professors indicated their own learning experiences and their observations of teaching were very influential on their conceptions of teaching and learning should remind us that people are, whether consciously or unconsciously, constantly engaging in professional learning.

An aim of this study was to contribute to and challenge future researchers to seek a better understanding of how engineering professors and those that aspire to become professors, learn about teaching and learning, and how their conceptualizations and practices change during their professional lives. In this regard, this paper supports others’ call to reframe faculty development and research on faculty development from an atomistic perspective (i.e. training episodes or development programs) to a more holistic perspective where faculty engage in lifelong professional learning (Webster-Wright, 2009). A better understanding of professional learning in engineering faculty has the potential to more effectively support how they learn to teach and consequently improve how engineers are educated.
References


Graduate Programs - School of Engineering Education, Purdue University (2009). Retrieved from https://engineering.purdue.edu/ENE/Academics/Graduate/


Neumann, R., Parry, S., & Becher, T. (2002). Teaching and learning in their disciplinary

Pajares, F. (1992). Teachers' beliefs and educational research: Cleaning up a messy


FL: Krieger Publishing


Prosser, M., Ramsden, P., Trigwell, K., & Martin, E. (2003). Dissonance in experience of
teaching and its relation to the quality of student learning. Studies in Higher

Quinlan, K. (2002). Scholarly dimensions of academics beliefs about engineering
education. Teachers and Teaching, 8(1), 41-64.

Directions for Teaching and Learning, 1991(45), 7-14.


Appendixes

Appendix A: Research Recruitment Information Letter for Faculty

Dear [Professor],

I am the outgoing Information Chair for the ASEE Student Constituent Committee. I am also a PhD candidate in Higher Education at the University of South Florida and for my dissertation I am conducting a study of how doctoral students in engineering conceptualize learning and teaching engineering. Please note that this study has been approved by the University of South Florida’s Institutional Review Board (Study ID: Pro00000290).

The goal of this study is to increase our understanding of how future engineering professors think about learning and teaching and what these conceptions are based on.

One potential benefit for students participating in this study is that talking and reflecting on these concepts aids their preparation for faculty job interviews.

Your help is being solicited in the recruitment of students to participate in this study.

You are being asked to simply do the following:

1. Select five (5) students at your institution who meet the following criteria:
   a) Completed at least one (1) year of doctoral studies in an engineering program, AND
   b) Are interested in becoming a professor, AND
   c) Have been involved in at least one (1) of the following activities preparing them for a career in academia:
      1. Involvement in ASEE at the local, regional, or national level, OR
      2. Taken teaching or TA workshops, OR
      3. Taken credited coursework on teaching, OR
      4. Have been an Instructor or Teaching Assistant for at least one(1) semester.
2. A diverse group of students is sought in both experience, country of origin, ethnicity, and gender.
3. To nominate, please forward the invitation at the end of this e-mail to the students you wish to nominate. Copy me (attorres@mail.usf.edu) on invitations sent to students.
I believe that students are more likely to read an e-mail and respond to it if they receive this e-mail from a name they recognize. In the invitation letter students will be asked to respond directly to me.

No further action will be asked of you beyond the initial e-mail. I will share with you the results of this study.

If you have any questions about the nature of this study or the process, please contact me at (xxx) xxx-xxxx or attorres@mail.usf.edu.

I appreciate your thoughtful consideration of my request and look forward to hearing from you.

Sincerely,
Ana T. Torres-Ayala, MEng
Doctoral Candidate, Higher Education
University of South Florida
Appendix B: Research Recruitment Information Letter for Students

Dear Future Engineering Professor,

I am a PhD candidate in Higher Education at the University of South Florida and I am conducting a study of how doctoral students in engineering conceptualize learning and teaching engineering. The goal of this study is to increase our understanding of how future engineering professors think about learning and teaching and what these conceptions are based on.

You are invited to participate in this study if you meet the following criteria:
   a) Completed at least one year of doctoral studies in an engineering program, AND
   b) Are interested in becoming a professor, AND
   c) Have been involved in at least one of the following activities preparing you for a career in academia:
      1. Involvement in ASEE at the local, regional, or national level, OR
      2. Taken teaching or TA workshops, OR
      3. Taken credited coursework on teaching, OR
      4. Have been an Instructor or Teaching Assistant for at least one semester.

If you participate, I would schedule a one and a half hour interview at your convenience. The interview will be conducted by phone. With your permission, the call will be recorded and transcribed. In the interview, I would ask you general questions about your understanding of the learning and teaching processes in engineering, and how you developed that understanding. You may find that talking about and reflecting on these concepts is beneficial for your preparation for faculty job interviews. There is no right or wrong answer to these questions as I am only interested in your views. I will also ask for some basic background information such as demographic information and prior academic and professional experiences.

Any information that is obtained in connection with this study and that can be identified with you will remain confidential. If I refer to any of your responses in any publication, I will use a pseudonym and will omit anything that could potentially identify you.

There are no known risks to your participation in this study which has been approved by the University of South Florida’s Institutional Review Board (StudyID: Pro00000290).

What do you do if you wish to participate?
To be considered for participation in the study, please read the Informed Consent Statement attached to be aware of your rights as a volunteer in the study.

Fill out this short Web questionnaire: "http://survey.acomp.usf.edu/survey/entry.jsp?id=1268416620225". By completing the questionnaire you acknowledge that you read the Informed Consent Statement and give your consent to participate in this study.

If you are selected to participate in this study I will contact you to schedule the interview. After we complete the interview, I will transcribe it and send you a copy of the transcript. If you wish to, you will have the opportunity to correct any transcription errors.

As a token of appreciation for your participation, a $10 iTunes or Amazon.com gift card will be given to you after the completion of the interview.

If you have any questions about this study or the process, please contact me at (xxx) xxx-xxxx or attorres@mail.usf.edu.

I appreciate your thoughtful consideration of my request. I look forward to your participation in the study.

Sincerely,
Ana T. Torres-Ayala, MEng
Doctoral Candidate, Higher Education
University of South Florida
Appendix C: Informed Consent to Participate in Research

You are invited to participate in a research study conducted by Ana T. Torres-Ayala, PhD candidate in Higher Education at the University of South Florida. The research is a study of how doctoral students in engineering conceptualize learning and teaching engineering. The goal of this study is to increase understanding of how future engineering professors think about learning and teaching and what these conceptions are based on.

Study Procedures
If you decide to take part in this study, I will ask you to complete a short web survey asking for some basic background information such as demographic information and prior academic and professional experiences. Completion of the survey should take about 5 minutes. If you are selected to participate in the study, you will be asked to schedule a one and a half hour interview at your convenience. The interview will be conducted by phone. With your permission, the call will be recorded and transcribed. In the interview I will ask you general questions about your understanding of the learning and teaching processes in engineering, and how you developed that understanding.

Risks
There are no known risks to your participation in this study which has been approved by the University of South Florida’s Institutional Review Board (# ).

Benefits
You may find that talking and reflecting on these concepts is beneficial for your preparation for faculty job interviews. I will share with you the interview transcript which may help you prepare a teaching philosophy statement or teaching portfolio.

Confidentiality
Any information that is obtained in connection with this study and that can be identified with you will remain confidential. If I refer to any of your responses in any publication, I will use a pseudonym and will omit anything that could potentially indentify you.

Recording and transcriptions will be electronically stored under password. All identifying information will be removed and stored separately.

Voluntary Participation / Withdrawal
You should only take part in this study if you want to volunteer. You should not feel that there is any pressure to take part in the study, to please the investigator or the research staff. You are free to participate in this research or withdraw at any time. There will be no penalty or loss of benefits you are entitled to receive if you stop taking part in this study.
Questions, concerns, or complaints

If you have any questions, concerns or complaints about this study, contact Ana T. Torres-Ayala at xxx-xxx-xxxx or attorres@mail.usf.edu.

If you have questions about your rights, general questions, complaints, or issues as a person taking part in this study, call the Division of Research Integrity and Compliance of the University of South Florida at (813) 974-9343.

If you experience an adverse event or unanticipated problem contact Ana T. Torres-Ayala at xxx-xxx-xxxx or attorres@mail.usf.edu.
Appendix D: Future Engineering Faculty Background and Demographic Questionnaire

Informed Consent to Participate in Research

You are invited to participate in a research study conducted by Ana T. Torres-Ayala, PhD candidate in Higher Education at the University of South Florida. The research is a study of how doctoral students in engineering conceptualize learning and teaching engineering. The goal of this study is to increase understanding of how future engineering professors think about learning and teaching and what these conceptions are based on.

Study Procedures
If you decide to take part in this study, I will ask you to complete a short web survey asking for some basic background information such as demographic information and prior academic and professional experiences. Completion of the survey should take about 5 minutes. If you are selected to participate in the study, you will be asked to schedule a one and a half hour interview at your convenience. The interview will be conducted by phone. With your permission, the call will be recorded and transcribed. In the interview I will ask you general questions about your understanding of the learning and teaching processes in engineering, and how you developed that understanding.

Risks
There are no known risks to your participation in this study which has been approved by the University of South Florida’s Institutional Review Board (# ).

Benefits
You may find that talking and reflecting on these concepts is beneficial for your preparation for faculty job interviews. I will share with you the interview transcript which may help you prepare a teaching philosophy statement or teaching portfolio.

Confidentiality
Any information that is obtained in connection with this study and that can be identified with you will remain confidential. If I refer to any of your responses in any publication, I will use a pseudonym and will omit anything that could potentially indentify you.

Recording and transcriptions will be electronically stored under password. All identifying information will be removed and stored separately.

Voluntary Participation / Withdrawal
You should only take part in this study if you want to volunteer. You should not feel that there is any pressure to take part in the study, to please the investigator or the research staff. You are free to participate in this research or withdraw at any time. There will be
Questions, concerns, or complaints
If you have any questions, concerns or complaints about this study, contact Ana T. Torres-Ayala at xxx-xxx-xxxx or attorres@mail.usf.edu.
If you have questions about your rights, general questions, complaints, or issues as a person taking part in this study, call the Division of Research Integrity and Compliance of the University of South Florida at (813) 974-9343.
If you experience an adverse event or unanticipated problem contact Ana T. Torres-Ayala at xxx-xxx-xxxx or attorres@mail.usf.edu.

Consent to Take Part in this Research Study
It is up to you to decide whether you want to take part in this study. If you want to take part, proceed with this questionnaire and confirm if each of the following statements are true.

☐ I freely give my consent to take part in this study.
☐ I understand that by proceeding with this questionnaire I acknowledge that I received a copy of the Informed Consent form.
☐ I am agreeing to take part in research.

Full Name: _____________________________
Telephone Number: _______________________
E-mail Address: __________________________

How many years have you completed in an engineering PhD program?
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 or more

Do you have industry experience?  ☐ Yes  ☐ No

Where did you work? _______________________
How long did you work in industry? ________________

Do you have any teaching experience (not TA)?  ☐ Yes  ☐ No

What did you teach? _______________________
How long did you teach? _____________________
Do you have any teacher assistant experience?  □ Yes  □ No

If Yes, which course(s) you assisted? ______________________________
How long did you TA? ______________________________
What were your TA responsibilities in those courses?
  □ Grading  □ Laboratory
  □ Breakout sessions  □ Other __________

Are you involved in any activities sponsored by the American Society of Engineering Education (ASEE) at the local, regional or national level?  □ Yes  □ No

Have you taken any courses or workshops on teaching?  □ Yes  □ No

If Yes, which one(s)? ______________________________

Other than your doctoral studies, are any other ways in which you are preparing yourself for an academic career?

__________________________________________________________

__________________________________________________________

__________________________________________________________

Gender: □ Female  □ Male

Are you an international student?  □ Yes  □ No

Ethnicity or Country of Origin _______________________________

Thanks for your willingness to participate in this study! If you are selected, I will contact you soon to schedule the interview.
Appendix E: Interview Guide

Participant Code: ______________________
Date: ______________________
Time: ______________________

Possible follow up prompts/questions:
• Tell me more ...
• Why do you think that is?
• How do you know this?
• How is that achieved?
• Why do you think this is important?

Introduction:

☐ As I mentioned in my introductory letter, I am interested in understanding how you, as a future engineering professor, think about learning and teaching and what these conceptions are based on. Therefore, there is no right or wrong answer to any of these questions. I’m just interested in your personal perspective and experiences.

☐ Please also consider that since the majority of engineering students are undergraduate students, I am interested in your thoughts about undergraduate education. So please keep this in mind as we talk.

☐ Any questions before we begin?

Background

☐ Please tell me a bit more about your background, for example where did you grow up and went to school?

☐ Please tell me a bit about your academic background.

☐ Tell me briefly about your prior teaching experience

☐ Tell me briefly about your Teaching Assistance experience
Possible follow up prompts/questions:

- Tell me more ...
- Why do you think that is?
- How do you know this?
- How is that achieved?
- Why do you think this is important?

☐ Can you also describe briefly your professional background?

☐ Why are you interested in an academic career?

☐ Tell me briefly about how you are preparing for an academic career.

☐ Tell me more about the courses/training on teaching you completed.

Teaching

☐ Imagine yourself as a professor of engineering. Then imagine yourself teaching Engineering, what images come to mind? [Alternative: What will you do in a typical class period? In a typical week?] Any other images that come to mind?

☐ What is teaching? [Alternative: How do you define teaching?]

☐ What do you think are the primary purposes or goals of teaching engineering?

[Alternative: What should be achieved through teaching engineering?]

☐ Tell me more about the roles and responsibilities of engineering teachers.

☐ What experiences, if any, do you think have influenced your view on teaching?

Learning

☐ When I say the phrase “Learning Engineering”, what images come to mind? Any other images that come to mind?

☐ What is learning? [Alternative: How would you define learning?]
How do you think students learn?

Possible follow up prompts/questions:
- Tell me more ...
- Why do you think that is?
- How do you know this?
- How is that achieved?
- Why do you think this is important?

What is it that engineering students learn? [Alternatives: What are engineering students taught? What types of thinking do engineering students learn?]

How do (will) you know your students have learned?

How do students know that they have learned?

Tell me more about the roles and responsibilities of engineering students.

What experiences, if any, do you think have influenced your view on learning?

Wrap-up

What other experiences, if any, do you think have influenced your views on teaching and learning?

Is there anything else that you would like to add about teaching or learning engineering?

Thank you!

Amazon or iTunes card?
Appendix F: Peer Review Form

I, Dr. Marilyn Armstrong, have served as a peer reviewer for “Future Engineering Professors’ Conceptions of Learning and Teaching Engineering” by Ana T. Torres-Ayala. In this role, I worked with the researcher throughout data analysis process to validate or challenge the interpretation of data, develop the presentation of data, and assist in related emerging issues.

Signed: _______ (Signature on file) __________________________________________

Date: _______ June 27, 2012 ______________________________
About the Author

Ana T. Torres-Ayala holds a B.S. degree in Computer Engineering from the University of Puerto Rico, Mayagüez, and a M.Eng. degree in Computer and Systems Engineering from Rensselaer Polytechnic Institute. She has experience in the telecommunications industry where she worked for Lucent Technologies. In other past roles, Ana taught information technology courses and researched statewide education policies. She currently serves as Instructional Resource Consultant at the University of South Florida’s Academy for Teaching and Learning Excellence (ATLE). Her research interests include engineering education, faculty development, scholarship of teaching and learning, graduate education, and underrepresented groups in science, engineering, technology, and math (STEM).