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ANALYSIS OF ENGINEERING FACULTY MEMBERS' REFLECTIONS ON PLANNING FOR INSTRUCTION

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ABSTRACT

The purpose of this study was to begin development of a method to better describe the instructional planning processes of post-secondary teachers. Long term, it is hoped this work might have constructive implications for faculty development by providing a few case studies demonstrating how instructors with a strong interest in teaching think about what is important to them in planning their courses and how this relates to planning for the instruction of specific topics. Four engineering faculty members from a large research university were interviewed about influences on how they plan to teach a self-selected topic and related concepts and procedures in a course. The resulting transcripts of the interviews were analyzed to identify common themes and differences in planning. Strengths of association between influences on planning were created. The reports of these influences revealed that all participants focused on how to encourage their students to improve their abilities to transfer knowledge learned in the classroom to novel situations, though the planning decisions they made to achieve this goal varied significantly among them. The reports also confirmed the assumption that asking the participants to reflect on planning for instruction at the topic level would generate more detailed and nuanced discussions of planning influences than asking them to reflect solely on their course planning activities. Comparisons of the findings to those in the research on course planning and suggestions for future research were made.

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Chapter 1

Introduction

I was enrolled in a course on curricula in higher education in the spring of 2011 when I developed the idea for the study that constitutes this dissertation. Through my staff position as an institutional researcher at a large research university, I had developed an understanding of how certain administrative decisions related to teaching were made in colleges and universities, but I was interested in knowing more about the thinking that drove the kind of decisions that were made directly by faculty members regarding instruction. Through my studies as a graduate student and experiences as a student in college classrooms, it had become clear that most college and university faculty members received little training in pedagogical concepts and methods, at least compared to those teaching the primary or secondary grades. Over time, this repeated observation made me curious about what motivated planning decisions in the classroom for these individuals with well-developed subject knowledge but significantly less pedagogical knowledge. The objective of the aforementioned course was to familiarize students with how curricula at colleges and universities are developed and how the history of education, various philosophies of education, and political pressures on higher education institutions inform that process. The class reviewed several topics, such as the content of different curricula, strategic alignment of curricula with university and college missions, assessment and evaluation, and more. Of particular interest was the section on how higher education faculty members plan to teach their courses.

The main text and articles for this section of the course described the major studies on the topic of instructional planning in higher education. In each of the studies presented, the researchers used interviews and surveys to ask faculty members about what they considered to be the influences (intellectual, material, and otherwise) on how they plan and conduct their courses. The researchers wanted to know why the instructors chose to prioritize certain topics over others, assigned the kind of homework they did, arranged the seating in the classroom as they did, and more. Most of the researchers used semi-structured questions to prompt answers to these questions. In other studies, researchers provided participants with a list of influencing factors, such as past classroom experiences or availability of instructional resources, and asked them to rank them in order of importance. The results of this research generally indicated that faculty members often taught in the same ways they were taught by their instructors, were focused on teaching their students about the basics of their discipline through strong content coverage, considered student characteristics to a mild and more rarely moderate degree in their planning, rarely consulted research on effective pedagogy, and did not often take advantage of professional development opportunities for teaching (e.g., Anderson et. al., 1985; Powell & Shanker, 1982; Stark et. al., 2000; Thielens, 1987).

While the studies reviewed were generally of high quality in that they demonstrated effective designs for their goals and did not draw conclusions unsupported by the results, I found the scope and results of the research unsatisfying. The studies did provide some evidence of factors that influence the course planning behavior of faculty members, but they did little to describe how those influences were specifically considered during the planning or implementation of instruction. The studies did not describe how faculty members determined what constituted the basis of their disciplines they were so interested in representing through content coverage, what student characteristics they generally considered important and how that influenced the selection of content and activities, and why they did not usually consult pedagogical resources when creating their courses. In other words, none of the studies represented a significant investigation into the deeper thinking that higher education faculty members engage in as they plan courses.

Shortly after completing this course, I started reading through resources on primary school teacher preparation in an effort to better understand the instructional planning process, this time among those who had received strong training in pedagogy. It was during this search that I discovered several references to the construct of Pedagogical Content Knowledge (Shulman, 1986), or PCK, situated in the work on the knowledge, pedagogical and otherwise, teachers bring to the classroom. The construct of PCK was initially proposed as a way to better describe the unique knowledge of teachers as compared to persons with similar levels of content knowledge, but without teaching responsibilities. For example, an anatomy and physiology teacher possesses a kind of knowledge comprised of a combination of general pedagogical knowledge and content knowledge a medical doctor does not possess, even though they possess similar levels of content knowledge. The teacher has had to determine how to teach anatomy and physiology facts and concepts in ways students can understand, whereas there is no such expectation of the doctor. That amalgamation of knowledge types, general pedagogical and content, with the goal of teaching less knowledgeable persons, was generally described as PCK.

Though PCK has been defined in somewhat different ways since its introduction in the mid-1980s, the consistently defined part of the construct demands that PCK represents content knowledge that a teacher transforms using his other types of knowledge, such as general pedagogical knowledge and knowledge of student characteristics, to render the original content more approachable by students. In other words, instead of a physics teacher explaining Newton's Laws of Motion with all the inherent richness and complexity as she understands it, she would create or use modifications of her understanding that she believes her students will have a better chance of learning, even if the resultant instruction is shallow or inaccurate in some ways. For example, she might ask her students to imagine working with a frictionless surface when solving certain motion problems, which would not reflect reality, because experience or training has taught her that students at this level often have trouble accounting for the effects of friction until they gain more experience with the topic.

What I found interesting about the construct of PCK was the way it motivated highly analytical studies of teachers planning instruction. Researchers working with the construct often asked their teacher participants to identify all the different types of knowledge and resources they brought to bear on content when planning for the instruction of particular topics and related concepts and procedures within a lesson. The teachers needed to identify not only what they were doing, but why they were making the decisions they did. This represented a different approach than the one used in the research on the planning activities of post-secondary education teachers. Those participants were asked to describe what they did, but they were not prompted to provide significant justification for those decisions – justifications that might have better represented the complexity of the planning process at the post-secondary level.

I was encouraged by the work on PCK to consider using a similar approach to study instructional planning in higher education. The current course planning literature provides useful information about general influences on planning behavior, but does not provide as rich an understanding of the decision-making involved in the planning and teaching of college course topics as some of the work done using PCK in K-12 settings. It occurred to me that perhaps a more accurate description of what is involved in the process of faculty members creating instruction can be created by asking them to talk more in depth about smaller units of instructional planning in a way similar to that demonstrated in many of the PCK studies.

I knew that post-secondary teachers differed from primary and secondary teachers in meaningful ways. They often possess terminal degrees in their disciplines and exhibit very strong content knowledge of their disciplines. They often understand what it means to contribute to the knowledge-base in their disciplines and possess the skills to do so. These teachers usually work at institutions with broader missions than primary and secondary schools, with a demand for research and outreach in addition to teaching. They typically receive less supervision and have more freedom in structuring their time, and they may not have the same opportunities to get to know their students as well as primary and secondary school teachers. They also have little to no formal training in pedagogy.

Despite these differences, it seemed safe to assume that post-secondary teachers could reflect on their teaching in the same way as those primary and secondary educators who participated in the PCK studies. Apart from developing a strong understanding of their disciplines, post-secondary teachers must routinely engage in the practice of planning for instruction like those who teach primary and secondary grades. While post-secondary teachers may not be able to speak about their decision-making to the same degree given their usual lack of general pedagogical knowledge, all teachers are responsible for creating and implementing effective instruction and should be able to describe those experiences in varying levels of detail.

The study described in these pages represents my effort to extend the previous research on the planning activities of post-secondary teachers, while being guided by the same kind of focus on discovering what influences specific teaching decisions demonstrated in some of the research on PCK. A review of the *Journal of Engineering Education* indicated a growing interest in scholarly work on engineering education and research on teacher activities in the larger field of engineering (e.g., Shulman, 2005; Turns et. al., 2007). Through my staff position I became aware that there were several faculty members in the engineering college who expressed a strong interest in teaching. I assumed then that engineering would be a good discipline in which to start this work, so I recruited four faculty members to participate in the study. I then interviewed each of them several times over the course of an academic semester using semi-structured questions motivated by the work on course planning in higher education and the depth of analysis often employed in studies on PCK. The desire was to begin development of a method to better describe the instructional planning processes of post-secondary teachers. Long term, it is hoped this work might have constructive implications for faculty development in engineering by providing a few case studies demonstrating how instructors with a strong interest in teaching think about what is important to them in planning their courses and how this relates to planning for the instruction of specific topics.

Overall, my time with the participants was well spent. Each participant freely offered detailed accounts of their instructional decision-making, and most of the time, they needed little encouragement to talk in depth about specific decisions. In the cases where some encouragement was required to get them to further discuss particular points, they responded with enthusiasm. The findings were revealing as well. While some of what they said echoed the findings in the research on higher education course planning, especially regarding the importance of discipline coverage, it was clear that each participant considered multiple, nuanced influences on each instructional decision, despite possessing limited pedagogical training. By the end of the interviews, I learned a great deal about how some teachers can approach similar goals in different ways, and I became convinced that encouraging post-secondary teachers to talk about specific instructional topics could generate more detailed representations of their teaching philosophies, knowledge, beliefs, and practices than asking them to talk about their course planning activities generally.

Personally, this study represented an opportunity to conduct research using novel perspectives and methods. Most of my training and work had been in the development of assessment tools and the quantitative analyses of data generated through experimental or quasi-experimental designs. This study required the use of methods typically associated with qualitative work (interviews and observations) and a desire to tell a rich, non-reductive story about how these educators thought about their teaching. I did end up employing some reductive methods in my analysis, but this was done to elucidate the larger points and provide the reader with a guide to better understand the details, not elevate aggregated data above any individual reports. I consider this a qualitative work that made use of some basic quantitative methods purely to assist in the organization of a large amount of information.

Before this study, I had developed an understanding of what the lives of faculty members at a university were like, but only in a broad sense. I knew something about how they typically spent their time and the kind of workloads they carried. In addition to creating new knowledge about the planning activities of faculty members that may be of use to those interested in teaching, either in a practical or academic sense, at the post-secondary level, this research helped to further my appreciation for the people I serve. Even if I did not have a good story to tell about new ways to understand instructional planning in higher education, the research still would have been worth the effort to better understand “how the other half lives.”

In Chapter 2, I review the research on course planning in higher education generally and engineering specifically, as well as the major research on PCK and its use in studying instructional planning. I describe the design of this study in Chapter 3. In Chapter 4, I review the logistical considerations of this study and provide a detailed look at the participants. In Chapter 5, I analyze the results of the interviews with the participants about their focused instructional planning. I conduct a review of the study and offer suggestions for future research in Chapter 6.

Chapter 2

Basis

While planning for instruction in higher education in general and engineering education in particular has received some attention in the existing research literature, most work on the topic has focused on investigating larger issues of course planning, such as deciding on the basic content to be covered, kinds of assignments to use, and general structure of the course regarding content delivery (Lattuca & Stark, 2009; Stark, 1988; and Stark et. al., 2000). Researchers have examined individual and organizational influences on the course planning process, but they have not studied how this decision-making expresses itself in the instruction of particular topics and their related concepts and procedures, a more finely grained level of decision-making. It may be that the influences previously identified at the course level manifest differently when looking at the planning of more specific instruction, or that influences not identified at the course level express themselves when looking at the instruction of specific topics. If we are to better understand what it means for a college faculty member to prepare for a course, it is necessary to develop a more detailed description of post-secondary faculty instructional activities than currently exists. This may require the creation of new language and methods appropriate to the task.

In this chapter, I review the literature on how higher education faculty plan for instruction, as it represents what is currently known about what post-secondary faculty members consider important when planning their courses. While none of these studies are representative of the kind of research being proposed in this study, they describe some of the considerations faculty members make when thinking about their courses. As such, they provide a point of comparison for the current work. Following that, I examine the research using PCK to study planning for instruction at the primary and secondary school level, as the construct specifically focuses on how teachers integrate their knowledge bases and work with affordances and constraints to create instruction at the topic level. The review also describes changes in the field of engineering education that demonstrate a need for such fine grained analysis of instruction and concludes by examining the few studies that have been done on planning for instruction in engineering.

Planning for Instruction in Higher Education

Research on planning for instruction at the post-secondary level is sparse. Most of it has been conducted using interviews, surveys, and case studies to ask faculty members to identify influences on how they plan and conduct their courses (Lattuca & Stark, 2009). These influences are spoken of generally. For example, most commonly, faculty members are focused on covering a certain amount of content, satisfying the interests of students, or achieving the goals of the program that includes the course or courses being discussed when planning their courses.

Despite these goals however, the research also suggests that faculty members tend to spend relatively little time in systematic planning activities prior to teaching an existing course, but are planful when preparing to teach new courses (Lattuca & Stark, 2009; Young & Irving, 2005). Regarding existing courses, they seem to make changes when obvious problems arise, such as students vocalizing their disappointment about the presentation of specific material. Often the goal of faculty, however, seems to be to create a fairly stable instructional sequence that can be maintained from semester to semester that requires little revision (Cross, 1993). Most of the time then, faculty members are most focused on covering a specific amount of content in a course and work toward creating a consistent presentation rather than being more reactive to say student needs (among other possible contextual factors).

As one of the first studies on course planning in higher education, Powell and Shanker followed the course planning and monitoring activities of a university teacher throughout a semester as he taught a graduate level course on hospital administration (1982). The researchers were concerned that staff development programs, course review procedures, and attempts at educational innovation were severely hampered by a lack of information about the ways in which teachers conceive their task and reflect upon the execution of it. They interviewed the participating teacher once a week shortly after each class. The interviews were unstructured, and as such the participant was asked to simply talk freely and reflect on how he felt the classes were going. The scholars conducted a content analysis on the frequency of topics mentioned in the interviews.

Findings indicated that the teacher focused primarily on course coverage and student participation. He did not write objectives or have a well-developed evaluation plan. He did not do much to alter content based on student responses. He further indicated a general lack of knowledge about his students. It seemed to the authors that the practices of this teacher differed significantly from what they knew about how primary and secondary grade teachers plan their courses. Given the differences in training though, this raised the question of whether or not what is known about the planning practices of those teachers can be generalized to higher education faculty members. The authors concluded their study with a call for more research on course planning in higher education.

As a follow up study with increased sample size, Andresen, along with Powell and others, interviewed seven university lecturers about the weekly progress of one of their courses for one semester (1985). The lecturers were asked to reflect on their planning and monitoring concerns using the same method described by Powell and Shanker (1982). With the exception of the first interview to gather background and general course information, all the interviews were unstructured reflections based on the opening question of, "How did it go this week?" Participants were encouraged to talk more about their teaching of the content rather than the content itself. The researchers checked continually with the instructors to ground their interpretations.

The overall results from this study revealed general consistency in the teachers' primary concerns, which included communication of theoretical material to students and the quality of responses and discussions in class. The researchers reported that the participants seemed to conceive of planning with a more reactive stance to include changing tactics when they were not getting the kind of responses they wanted. Twelve thematic categories were created from the data, demonstrating a more rigorous approach to data analysis than used in the foundational Powell and Shanker study. A profile was created for each teacher based upon the frequency with which his interview responses fell into one or more of these categories over time. The researchers identified three primary categories: communication with students; such as questions being asked inside and outside of class; ongoing course planning activities, such as the kind of administrative work all teachers do to maintain a class; and processes in class, such as the way in which material is presented by the teacher and engaged by the students. The other nine categories were more idiosyncratic and included categories like teaching methods, intellectual development, and external events (p. 310).

Despite the creation of the thematic categories, the researchers demonstrated that the participants were not much different in behavior than the single participant in the original study. Again, the teachers seemed to be very concerned about content coverage without much thought for student characteristics. The researchers called for work that explored planning activities prior to the commencement of courses. This would include examining the effects of different variables on planning, such as the instructional setting, length of teaching experience, and the nature of the material being taught. The goal would be to determine whether or not there was more complexity to the decision-making of the participants than had been revealed in the two studies.

Several researchers (Stark et. al., 1988; Stark, 2000; Tadashi Hora, 2012; and Thielens, 1987) conducted more comprehensive studies of course planning using interviews. For example, Stark and her colleagues interviewed 89 faculty members of various ranks, including those who were unranked, in four different types of colleges across eight fields of study (sociology, history, biology, English composition, Literature, mathematics, nursing, business) about the different factors that influenced how they plan their courses (1988). The researchers were concerned that the then current calls for curricular reform in higher education failed to identify the need for more research on how faculty members plan and teach their courses. The researchers used open questions as well as structured questions and activities to collect information about the course planning activities of post-secondary faculty members. While acknowledging that little research existed to provide insight to these questions, they wondered if, “faculty members have clearly focused academic intentions and plans for their courses” and argued that the foundation for this question and related questions must be laid by examining intentions of faculty when they design courses (p. 220).

The participants were asked to respond to two probes: “Tell me about what you do as you plan this introductory course,” and “What things do you believe influence you as you plan? (p. 226)” A related task asked them to assign a total of 100 points across various planning influences to determine how strongly each affected their planning for instruction. To explore each participant’s beliefs about teaching, the researchers also asked them to read short paragraphs that demonstrated different beliefs about the purpose of teaching, such as to create effective thinkers or to instill the desire for social change, and to rank the beliefs in order of importance. In the analysis of the responses, researchers reported that characteristics of the faculty member’s discipline, personal educational beliefs, students’ characteristics, and personal background were stronger influences on course planning than the goals of the college, available resources and facilities, and the views of instructional experts. The participants rarely mentioned making choices among alternative instructional strategies. In some specific situations, program goals, college goals, and the expectations of stakeholders did play a role in decision making, but the participants’ focus was primarily on selecting content that they considered to be representative of their discipline.

Building from this initial work, Stark and her colleagues followed the interviews with a survey of 2,311 faculty members across 267 colleges about their teaching of introductory courses in twelve fields: English composition, literature, history, psychology, sociology, biology, mathematics, fine arts, romance languages, educational psychology, nursing, and business (2000). Participants were asked to complete the *Course Planning Exploration* survey, an 11 section survey comprised primarily of multiple-choice items, which posed questions about teachers’ perspectives on the nature and content of their academic field, beliefs about the purpose of education, preferred ways of arranging course content, program and college context for course planning, and typical course planning activities over the course of a semester.

The results of this study supported their previous findings. They found that most participants agreed that while there are various purposes to education, conveying the skills and concepts of their discipline was most important. The faculty members selected content and considered certain student characteristics such as typical majors and grade levels, as well as their own backgrounds, in planning a course. They did not typically reference reports about findings in educational research or take advantage of professional development offerings at their schools. Gender, age, academic rank, tenure status, and teaching experience were essentially unrelated to their beliefs about education, the way they viewed their disciplines, or their course planning activities. Less than one-third reported that pedagogical training had an influence on their teaching practices.

While most of these results were consistent with previous research, some of them conflicted with the findings in Tadashi Hora's later study of how organizational factors affect instructional decision-making (2012). Interviewing 22 faculty members from mathematics, life science, and education departments at a research university, he specifically asked them about organizational factors salient to their teaching practices. Framing the investigation this way, they reported how structural features of their organizations constrained and afforded practice in three primary ways: (a) as exerting normative practices on teaching decisions as in what is typically expected, (b) as imposing logistical constraints on behavior, such as work on research demanding time that could be used to improve teaching, and (c) as encouraging autonomous teaching practices, or in other words, enabling those who want to focus on their teaching to do so since they enjoy a certain level of freedom as a faculty member (especially for those with tenure status). The rest of the reported findings were similar to those found in the work of Stark and her colleagues (1988, 2000), but organizational factors had not shown up as significant influences on planning for instruction in those studies. A difference though is that Hora's participants were asked directly about possible organizational factors on their planning. This may have had an effect on the kind of responses received.

While there has been some interest in the possible effects of academic discipline on the planning of faculty members, the topic has not been subject to much focused study. Interested in the effects disciplinary preparation may have on the planning of lectures, Thielens surveyed 1,041 university teachers across 83 universities and all available disciplines about their instructional practices, receiving 820 usable responses (1987). Eighty-one of these respondents were contacted to participate in 10 to 45 minute interviews about their teaching. Almost all respondents were full, associate, or assistant professors.

Thielens found that the vast majority of these teachers relied heavily on lectures in their instruction. Some of the responses suggested that this might have been due to organizational characteristics like instructional budget or student teacher ratio. Discussion was the only other instructional method used by those interviewed with any frequency, and this was more common in the humanities. It seemed that decisions to use lectures and discussions were driven mostly by how the teachers viewed their disciplines, and what they believed was needed to introduce students to the basics of those disciplines, which almost always meant covering a certain amount of content. Responses indicated that selection of content was the most important part of their course planning efforts, and that attempts to use other teaching techniques, such as self-directed group activities, were reported by most of the participants to be failures.

Though limited in coverage, the research on course planning in higher education suggests that faculty members often rely on their experiences and beliefs about teaching to orient students to the foundational knowledge that comprises the taught disciplines (Anderson et. al., 1985; Lattuca & Stark, 2009; Powell & Shanker, 1982; Stark, 2000; Young & Irving, 2005). As far as organizational factors, resources and facilities seem to be a weaker influence on planning than teachers' perceptions of what is expected of them for retention, promotion, and tenure (Stark et. al., 1988; Stark 2000; Tadashi Hora, 2012; Thielens, 1987). The availability of education literature or teaching support services seems not to play much of a role in planning efforts. None of these findings seem to vary much by discipline or rank

(Stark et. al., 1988; Stark 2000). These conclusions are tentative given the small number of studies conducted on this topic, but do represent a starting point for additional research on how and why faculty members plan for instruction at the smaller scale, that of particular topics and their related concepts and procedures.

Planning for Instruction in Primary and Secondary Education

There are many differences between post-secondary education teachers and primary or secondary education teachers, especially with regard to content knowledge and pedagogical training. Post-secondary teachers often possess more of the former than the latter, and with primary and secondary education teachers, the reverse is often true – primary education teachers likely possess less content knowledge than secondary education teachers. Faculty members in these two groups, post-secondary and primary/secondary, usually have different responsibilities and levels of autonomy.

The instructional planning work of primary and secondary teachers was subjected to a fair degree of inquiry starting in the early 1970s (e.g., Bishop & Whitfield, 1972; Shavelson, 1973; Shavelson, 1976; Shulman & Elstein, 1975), dropping off somewhat in mid-1980s (Warren, 2000). Despite the differences between primary/secondary teachers and post-secondary teachers, the results from this research on the planning activities of primary and secondary education teachers can provide insights that may be useful in an investigation of how post-secondary education teachers plan for the instruction of specific topics.

Most of the more recent research on the course and lesson planning activities of K-12 teachers exists as part of larger bodies of research concerned with teachers' instructional thought processes (Lachance Wolcott, 1994; Warren 2000) including decision making both when planning a lesson and when responding to students during instruction (Borko, Roberts, & Shavelson, 2008). As such, studies of course and lesson planning are often indirectly nested in investigations of topics like instructional design (Gange et. al., 2004), pedagogical reasoning (Howey & Zimpher, 1994; Shulman, 1987), and Pedagogical Content Knowledge (Van Dijk, 2009), among others. The findings from some of the research in these areas are fairly consistent, and in some ways echo the findings from the research on course planning in higher education. For example, with both primary/secondary teachers and post-secondary teachers, there is a focus on covering a certain amount of content in a course or lesson, suggesting that certain instructional planning concerns are universal, regardless of training, background, or responsibilities.

Reviews of this research indicate that experienced teachers seem to rely heavily on their reflections of what has worked with their students in the past when planning, while less experienced teachers rely more on their training when developing instruction (Lachance Wolcott, 1994; Rentel, 1994; Warren 2000). (Of course, past experience for experienced teachers often includes the implementation of methods learned during their training.) Experienced teachers tend to prepare broad scripts or general outlines of what they will teach and tailor this to the interests and abilities of their students. Less experienced teachers are not as proficient at developing these scripts and especially have a difficult time improvising in the classroom, though they often still try to take the needs and abilities of their students into account. The availability of certain instructional materials also necessarily influences teachers' planning activities. For example, a teacher may be required to only teach from a specific textbook or may want to conduct an experiment using equipment the school cannot provide.

Pedagogical Content Knowledge. While instructional planning can be studied from historical, sociological, and psychological perspectives, this investigation was inspired by psychological research on teacher decision making as central to teaching, work that began in the early 1970s with studies from three separate groups of researchers (Bishop & Whitfield, 1972; Shavelson, 1973; Shulman & Elstein, 1975). The work of Bishop and Whitfield was driven by a desire to develop ways to help teachers-in-training develop strategies for resolving problematic incidents as they occur in the classroom and not specifically focused on issues of course or lesson planning. Shavelson and Shulman and Elstein separately developed larger decision making perspectives that were influenced by the emerging field of cognitive psychology (Borko, Roberts, & Shavelson, 2008), while Bishop and his colleagues demonstrated a practical focus on what constitutes good decision making in the moment. Shavelson and Shulman and their respective colleagues were more concerned with accurately portraying teachers' decision making process through the application of instructional schemas as well as how teachers go about developing and applying schemas in preparing for the classroom. Shulman, in particular, was focused on how teachers work with their different kinds of knowledge to make instructional planning decisions, work that eventually led to the creation of Pedagogical Content Knowledge (PCK).

Shulman first proposed the PCK construct in 1986 with a call for content specific pedagogical research that did a better job of studying the interactions among content, teacher, and students. Shulman had found it curious that in the research on teaching, no one asked how subject matter was transformed from the knowledge of the teacher into the content for instruction. Looking at the research on teacher cognition regarding planning and decision making at the time, subject matter knowledge was treated more often as a control variable than something meaningful to be investigated (Hashweh, 2005). In other words, there was a strong interest in trying to describe planning for teaching apart from the subject-matter being taught in an attempt to identify universal pedagogical principles. While those efforts were important, Shulman thought there was value in studying how and why teachers combine old and new knowledge in their work. He felt making these processes explicit could be instructive to current and new teachers, much like Shavelson and Stern (1981). He also thought such research could help demonstrate the unique practice of those in the teaching profession, a profession he believed needed a boost in status (Shulman, 1987).

PCK is generally defined as knowledge either created, or learned, by the teacher which goes beyond the knowledge of content per se to the dimension of content knowledge for teaching. (It should be noted that Shulman used the terms subject-matter knowledge and content knowledge interchangeably across several early articles on PCK, but later used the term content knowledge exclusively.) Informed by general pedagogical knowledge, curricular knowledge, the availability of resources, knowledge of students, and anything else that can influence the instructional process, PCK represents a teacher's collection of transformed content knowledge into forms more suitable to the students receiving the instruction (van Driel & Berry, 2012; Shulman, 1986; 1987). PCK represents a teacher's knowledge store of appropriately transformed definitions, analogies, illustrations, examples, demonstrations, and more, is meant to be sensitive to the particular needs of an instructional situation.

Upon introduction, PCK quickly became part of the secondary education research lexicon, and it still appears to enjoy widespread use among those researchers who study the knowledge bases of primary and secondary teachers (Van Dijk, 2009). PCK has been useful in the study of planning for instruction in science, mathematics, and English (Kind, 2009) and for demonstrating to student teachers how subject matter knowledge is modified in preparing instruction (Abell, 2008). PCK if often used to organize the responses of primary and secondary teachers talking about how they plan for instruction through the identification of different knowledge, belief, and resource influences on instructional decision-making for specific topics at a fine level of detail.

However, PCK is not consistently defined in the literature, and has been revised by different authors for various reasons (a few examples follow). Grossman stressed the importance of including how teachers consider horizontal and vertical curricular integration when generating PCK (1990). Veal highlighted how beliefs about teaching affect the planning of teachers (1999). Reconceptualizations, such as those by Hashweh (2005) and Park and Oliver (2008) put more emphasis on the teacher as the creator of PCK as opposed to someone who simply implements the subject matter knowledge transformations of others. Regardless of the permutations, previous scholars have found the concept useful in clarifying the knowledge bases and actions of participants in investigations of teacher knowledge and planning in English, mathematics, and science (Cochran et. al., 1993; Geddis et. al., 1993; Grossman, 1990; Koballa et. al., 1999; Lee et. al., 2007; Magnusson et. al., 1999; van Driel et. al., 1998).

Regardless of definitional variances, the application of PCK requires users to identify and analyze different knowledge-bases, resources, beliefs, constraints, and anything else that can have an effect on the instructional planning process. The goal is to better understand this core act of teacher decision making. The PCK construct is popular among those interested in how teachers plan instruction, even though it was poorly defined when first proposed, because its inception encouraged researchers to focus on studying part of the teaching process that had not previously received much attention. In other words, the application of PCK motivated researchers to take more care in defining and separating different knowledge-bases, resources, and actions of teachers that come together during the planning and implementation of instruction, and further made the case that therein rested one of the activities that makes teaching a unique practice.

As an example, if a teacher wanted to teach his students about the use of fuel by engines and decided to use human digestion as an analogy, the thinking that lead to that decision could be studied and the results organized using some version of PCK. The teacher could be asked about how he relied on his knowledge of the subject matter, general pedagogical knowledge, and student characteristics to create that instructive piece, which some researchers (e.g., Hasweh, 2005) would refer to as a pedagogical construction, a construction that would from then on be considered part of that teacher's PCK. The creation of the human digestion analogy and plan for demonstrating it in class may have been influenced in other ways besides those knowledge bases, such as resources, program goals, and educational beliefs - anything that played a role in making instructional decisions would be of interest. Even deciding to implement a "ready-made" construction, such as a set of examples and demonstrations from a textbook, would involve a similar process of thinking that would lead the teacher to determine that relying on a previously created construction made the most sense given the context, and such thinking would be worthy of study.

The application of any of the variations of PCK requires nothing more than eliciting the appropriate information from the teachers participating in the study. The researcher has to understand what each teacher is trying to create as a piece of instruction, how the teacher's knowledge of content and pedagogy come together in that creation, and what other knowledge bases, resources, and constraints play a role. There are no established standards for how this should be represented or how the strength of the different influences should be measured. Perhaps the value in the PCK construct is not in proscribing a set of research actions, but in regularly reminding the researcher to pay attention to how the teacher integrates various factors in the creation and implementation of instruction, and that this activity is one of the most important qualities that separates teachers from others who possess similar content knowledge. The application of PCK variants can help researchers move beyond general discussions of teachers' work so that the complexity of the instructional experience can be more accurately represented when talking about the instruction of specific topics and related concepts and procedures as opposed to broader course planning activities. As such, it may prove useful in an investigation of how post-secondary faculty members plan and implement instruction for specific topics and related concepts and procedures.

Engineering Education

While all academic disciplines could benefit from scholarly research on teaching specific to their knowledge and practices, educators both inside and outside the discipline of engineering have expressed an interest in advancing the scholarship of engineering education over the last decade (Shulman, 2005; Turns et. al., 2007). Whether it is because of the variety of instructional situations available for study, the recognition by instructors that they do not possess formal teaching training and want to know what it takes to improve their teaching, pressures from outside agencies to improve teaching quality (Volkwein et. al., 2004), or the call from some engineers to treat the improvement of engineering education as a design problem (Watson, 2009), there is a willingness to determine how the study of engineering education can improve teaching practice as well as enrich general pedagogical knowledge, and vice-versa (Fink et. al., 2005). There also exists a perception that though increased access to engineering study by students over the last decade or so has been beneficial, they are less prepared than past students and traditional forms of teaching are no longer sufficient especially given the wealth of instructional technology available (Felder et. al., 2005). Instructional improvements may be needed to correct this imbalance.

A special report in the October 2006 issue of *Journal of Engineering Education*, the leading journal in the field of engineering education, proposed a research agenda for the newly emerging discipline of engineering education that encompassed five broad areas: engineering epistemologies, engineering learning mechanisms, engineering learning systems, engineering diversity and inclusiveness, and engineering assessment. This proposal was a response to the requests of business, academic, and government leaders' for a more systematic study of engineering education to address concerns about not only what is taught, but also how it is taught, so that instructional improvements could be made with more efficiency. The proposal offered several examples of the kinds of questions that can be asked in reference to each research area. Of particular interest, however, was a question under Engineering Learning Systems; "How can we characterize the engineering teaching culture (i.e., social interactions, beliefs about teaching and learning, and the growth of communities of educators) in order to inform the development of current and future engineering educators for teaching practice (p. 260)?" This served to remind researchers that the focus should not solely be on the learners and the specific challenges they face in trying to become engineers, but also on teachers and the challenges they face in trying to engage their students (Chen et. al., 2008).

Many of the articles in the *Journal of Engineering Education* focus on the application or development of instructional methods and learner characteristics, but relatively few investigate why and how engineering instructors make the instructional decisions they do at both the course planning level and the more specific topic level. Besides the fact that an important part of the described agenda may not be receiving adequate attention, it raises the question of whether or not the implementation of new instructional methods can be informed and ultimately improved by understanding why instructors in engineering practice the way they do. It might be the case that we should be asking engineering educators to approach their education work with the same kind of analytic sense they bring to their professional research work (Fink et. al., 2005). This would create a need for basic research at all levels, including the aforementioned, and would require moving beyond classroom research (Borrego & Bernhard, 2011), off of ad-hoc paths that fail to demonstrate a systematic understanding of how learning occurs (Johri & Olds, 2011), and toward educational engineering theories that are as well-developed, in terms of establishing causal links, as possible (Johri, 2010).

An increased focus on the scholarship of teaching and learning can improve instruction, help faculty members align their duties, and better satisfy the missions of the universities at which they work, but the goal cannot be to just develop instructional methods to prescribe to engineering faculty members (Brawner et. al., 2002; Felder et. al., 2011). Beside the potential for this to generate resistance by those who might otherwise be open to improving their practice, it does little to empower faculty members in their own classrooms (Felder et. al., 2011). The creation of broader frameworks that can help solve classes of teaching problems needs to be the focus instead, and this requires understanding current practice so it can be refined and extended with the help of those already doing the teaching.

Planning for Instruction in Engineering

Aside from the current work, there are not any studies on planning for the instruction of specific topics and related concepts and procedures in engineering education. However, a few scholars examined the teaching concerns and general decision-making processes of engineering educators. Some of that work included discussion about the participants' teaching practices. In a few ways, these studies mimic the designs, methods, and findings of the broader higher education studies on planning previously reviewed, but there are some notable differences.

Motivated by the belief that "there are benefits to understanding the decision-making processes that your colleagues make because you will then be able to better recognize and prepare for similar decision-making situations," Huang and his colleagues (2006) investigated how some engineering faculty members make instructional decisions by examining ten transcripts of interactions the faculty members had with instructional consultants they had asked for help. Teaching decisions were defined as those made during the execution of the professional responsibilities of the teacher, a broad criterion for sure. The researchers focused on classifying the decisions according to impact, immediacy, and whether the decisions were active (planned without motivation by an incident) or proactive (in reaction to something that happened in the class being discussed).

Overall the researchers identified and examined 77 decision points across the ten transcripts and found that seventy percent of decisions focused on affecting large groups of students, such as those that would affect the department and college, rather than individual students in a course of subgroups of students. Regarding immediacy, 66% of the decision points involved activities that had a direct impact on students: classroom management, such as determining seating arrangements and policies for attendance (16%); curriculum design, or what content and skills should be taught (32%); and teaching development, or the use of teaching techniques novel to the instructor (18%). The rest were dispersed among other responsibilities of their positions and represented activities indirectly related to teaching, such as networking and grant-writing. Sixty-three percent of the decisions made were classified as being proactive; most of the rest were classified as reactive to issues in the classroom (a small percentage was undetermined). The results were similar to findings indicated by Lattuca and Stark (2009), and suggest that these teachers were planful when focused on the preparation of full courses.

Huang and others followed up on this study by interviewing 20 faculty members across all ranks who said they possessed a strong interest in teaching and learning. The protocol asked faculty to reflect on decision-making that went into a self-selected pre-active preparation, and reflect on an instance of a self-selected interactive decision-making – a decision made during class to address an emergent situation (2007). For these two exercises, participants were asked to describe the context for these decisions, the factors they considered in making these decisions, their level of satisfaction with the outcome of each decision, and whether they would make different decisions if faced with the same situation again. In reporting the findings, the researchers selected a subset of 10 responses for analysis (no justifications were given for how the 10 were selected or why only 10 were selected). The researchers identified the availability of time for working on teaching activities as a factor that heavily influenced the instructional decision-making of the participating faculty members, a finding also uncovered by Turns and her colleagues (2007, 2008). Even though many of the participants wanted to make improvements to their teaching, they felt that they often did not have enough time to enact such improvements given all their responsibilities. It was not clear why the researchers only identified time as a factor. One would expect that the participants mentioned other factors that affected their instructional decision-making.

Interested in the concerns engineering faculty have about their teaching, Turns and her colleagues collected 63 narrative accounts of teaching consultations between engineering educators and an instructional consultant for analysis (2007). The accounts were coded for individual teaching concerns, which numbered 376, with 120 of these concerns directly related to core teaching responsibilities. They then analyzed the content of the discrete concerns and aggregated them into themes.

The data revealed that these engineering educators were interested in improving their teaching, but were concerned about their ability to do so given that they did not receive significant formal teacher training. They expressed that while they recognized their autonomy to make changes, and were generally open to doing so, they were concerned about adopting new methods for fear of the negative consequences that might result for themselves and students if they were not able to implement them properly or the methods did not turn out to be more effective than their typical methods. Effectively, these educators were unsure how to integrate new teaching knowledge with their existing knowledge, even though they possessed the desire to do so.

Similar results were found when Turns and her colleagues (2008) asked 33 faculty members across ranks with varying amounts of teaching experience to identify a planning decision and an interactive decision and talk about how these decisions were made, a method similar to that used by Huang and others (2007). Participants talked generally about how they planned, their educational beliefs, and how they considered their relationships with students. They also frequently mentioned time as a strong influence on achievement of their instructional goals. In terms of resources used in their planning, campus teaching resources such as classroom facilities and literature on education research were at the bottom of the list. As it was clear that the participants took students into account when making teaching decisions, the authors suggested that future research should move away from asking whether educators take learners into account, and instead move toward asking how exactly they do so.

Although only a few studies on planning for instruction have been conducted with engineering faculty, the participants generally expressed much of the same thoughts about their teaching as reported in the broader higher education course planning studies reviewed. A lot of what instructors do in the classroom is driven by their educational beliefs, including the desire to orient students to the discipline; who their students are in a general sense (year in school, academic preparedness, and more); and how much time they can afford to spend on teaching given other obligations, notably research, even when the desire to make improvements to their teaching is present. What is not clear is exactly how these concerns are reflected in specific units of instruction.

Conclusion

The research on course planning and instructional decision-making by higher education faculty members identifies some of the factors that influence how they approach their courses, but in a general sense. These teachers plan, but more when the course is new or when there is trouble and something needs to be changed. They care about covering content, which they identify as the best way to orient their students to their disciplines. They consider their students when planning and teaching, more so when planning than during instruction; but do not necessarily know much about who their students are or what they know at any given point during a course. They tend not to consult literature on effective educational methods or consult with those who possess expertise in pedagogy. They often feel tension when trying to decide how to allocate their time across all their responsibilities, and their teaching sometimes suffers for it.

What none of the researchers in the reviewed studies did, however, was examine how these influencing factors express themselves when planning lessons on specific concepts or procedures within a topic or offer a methodology that could be useful in achieving such an aim. As a result, not much is known regarding how faculty members think about orienting students to the basics of a discipline, for example, or how to engage with faculty in ways that would reveal this kind of decision making. Despite limitations in definitional and conceptual consistency, the literature on PCK suggests some ways to think about what this process could look like so that more detailed representations of how faculty members in higher education plan to teach can be created. More detailed descriptions of how faculty members think about their instruction, along with effective ways to elicit them, may facilitate better communication with faculty about pedagogy by enabling those in faculty development to take faculty members' prior knowledge into account when delivering instruction.

Given research agendas in engineering education, the needs of instructors, and the conclusions shared by those who have conducted research to address teacher decision-making and concerns, there is a need for research that seeks to develop a stronger understanding of what the experience of instructional planning is like for faculty members in engineering education. The ways in which skilled instructors make sense of their teaching may provide clues for how others can frame their own work (Major & Palmer, 2006; Morris & Usher, 2011). Huang and his colleagues (2007) and Turns and her colleagues (2008) initiated this research, but the scope of their work stopped short of exploring the influences of different knowledge-bases, beliefs, resources, and more on the transformation of engineering instructors' subject matter knowledge for teaching. The development and application of a more finely grained approach, like that sometimes found in the application of PCK in the study of teacher decision making in planning lessons of topics, may be useful to those working with faculty members to improve their teaching skills.

The term "planning for instruction" was used throughout this review to emphasis the difference between the terms "course planning", used in the reviewed higher education research, and "teacher decision-making and concerns", used in the reviewed engineering education research. Planning for instruction is meant to refer to describing the what, how, and why of specific decisions made for the teaching of concepts and procedures within particular topics and lessons. Course planning seems to be used in the study of general influences on the planning of whole courses. Teacher decision-making and concerns is used in the study of general influences on the planning of whole courses, but also in the study of decisions made about specific instructional instances. Extending this line of thinking, the term "planning for instruction" represents not only what happens in a specific instructional instance, but also why it happens, and is therefore used throughout this work.

Chapter 3

Design and Other Considerations

The purpose of this study was to begin development of a method to better describe the instructional planning processes of post-secondary teachers. Long term, it is hoped this work might have constructive implications for faculty development by providing a few case studies demonstrating how instructors with a strong interest in teaching think about what is important to them in planning their courses and how this relates to planning for the instruction of specific topics. If faculty members are to be instructed on how to improve their teaching, it is necessary to be able to accurately describe their knowledge and application of instructional practices in ways specific to their disciplines so they can be engaged in high quality discussion about effective instruction and learning. Understanding the schemas, or organizing structures for connecting knowledge elements into coherent structures (Mayer, 2011, p. 35), faculty members use to teach should better equip those working in faculty development to provide teaching advice tailored to current concerns, an approach advocated by Fink et. al. (2005) and Felder et. al. (2011) for engineering faculty.

As a promising area of study for engineering educators for the reasons described in Chapter 2, I chose to work with four faculty members from a college of engineering in a large Mid-Atlantic public research university who were teaching introductory engineering courses as test cases. The goal was to determine if interviewing faculty members about planning for the instruction of topics within a course would enhance discussions of general course planning. It was hoped this would be achieved by not only identifying a desire by a participant to “orient students to the basics of the discipline,” for example, but also by demonstrating how said participant seeks to achieve this aim with specific instructional planning decisions.

Though informed by related research, this study was also exploratory as this particular context and situation had not been subjected to rigorous research previously. This study did not test hypotheses, but instead gathered information relevant to answering the question of how to best work with faculty members to generate reliable and valid reports of planning for the instruction of specific topics with the hope that it would help elucidate their planning goals and practices at the course level. Previous research on course planning suggested interesting questions that might be answered using this approach, and previous research on PCK suggested ways to think about how to implement the approach, but the process was not constrained by previous conceptions, only informed and aided by them when they proved useful in generating discussion during the interviews or making better sense of the data. The questions I tried to answer with this study included:

1. What do the participants identify as specific influences on their planning for the instruction of their courses in general (including goals, knowledge-bases, resources, constraints, and more)?
2. What do the participants identify as specific influences on their planning for the instruction of self-selected topics and related concepts and procedures (including goals, knowledge-bases, resources, constraints, and more)?
3. How do the reports of the participants generally compare to those in previous research on planning for instruction in higher education?
4. Are conceptions of PCK useful in prompting discussion or organizing and understanding descriptions of instructional planning?

This being a qualitative study where personal perceptions are embedded and in fact essential to the work, it is necessary to be clear about my perspective on the research as before and after the fact. As in any study, the research context should dictate the methods used to explore it, and this context changes as the work progresses. This chapter describes my thinking about the research design before any data were collected to enable the reader to fully assess my thinking on the study throughout each phase. As such, the next few sections detail the methods chosen for this study before I entered the field, the justifications for selecting them, and the implications for implementation in a presentation format similar to that described by Creswell (1998).

Assumptions and Rationale for Design

Given the purpose of this study, several different techniques could have been used in trying to develop a method to better describe the instructional planning processes of post-secondary teachers. The participants could have been surveyed about their practices. They could have been asked to participate in a simulation where they engaged in the activity and reflected on the activity out loud for the purpose of protocol analysis. Their course documents for the past several years could have been reviewed to uncover evidence of planning decisions. The point being, every research question has to be focused through a specific methodology guided by the purpose of the inquiry (Giorgi, 2009).

The participants in this study were asked to reflect on previous, concurrent, and future real practice through semi-structured interviews. Thus a qualitative methodology was used, but it is necessary to be clear about exactly what that entailed and why it was considered the best approach given the goals of the study, as there is danger in assuming too much given a label like “quantitative” or “qualitative” (Ercikan & Roth, 2006). Confusion abounds about the differences between quantitative and qualitative methodologies and the related, but not equivalent concepts of qualitative and quantitative data.

Quantitative and Qualitative. The terms quantitative and qualitative are used in reference to social science research generally and educational research specifically. The usage of these terms is not always consistent across disciplines or even within disciplines, which made choosing an approach for this study difficult. Some methodologists treat the different terms as synonymous with specific epistemological assumptions about the nature of scientific knowledge, such as Gall et. al. in their popular textbook on basic education research methods (2003). Within this text, the authors equate the use of quantitative methods with the positivistic philosophical perspective and the use of qualitative methods with the post-positivistic perspective or interpretivist perspective (pp. 23-24). This is bizarre as positivism as a philosophy limits itself to the study of sensory data, which disqualifies a swatch of education research, and does not demand mathematical treatment of data, only logical (which may express itself mathematically of course), a requirement which is not limited to the application of quantitative methods.

Post-positivism requires accepting that unlike positivism, the researcher's perspective cannot be separated from the observations made, which says nothing about whether or not the data collected should be in, say, counts or descriptive text.

Other methodologists argue that every object of study, physical or psychological, exhibits a particular kind of internal structure, and that it is this structure that should determine whether the research requires a quantitative or qualitative approach (Mitchell, 2005). For example, measures of weight can exhibit quantitative structure due to the fact that ratios of weights can be readily determined, while measures of anxiety or sadness cannot satisfy the rules of true ratio that are used to determine numeracy in the natural sciences. The argument then is that objects of study without this structure should be approached using qualitative methods. Others argue that almost all objects of study exhibit qualitative and quantitative characteristics, and as a result questions can be asked about them that generate both numerical and textual descriptions (Ercikan & Roth, 2006; Giorgi, 2009). As an example, a teacher can be asked about his perception of an unruly class session to generate rich descriptive information about the teacher's thoughts and feelings throughout the session. Additionally, counts of how many students acted out during the session and how often can be used to generate numeric information. Thus, the kind of questions the researcher asks about the object of study determines whether the approach is quantitative or qualitative, rather than a pre-selected philosophical stance or hypothetical assumption about the nature of the object under study.

In my staff work in a large university setting, the terms quantitative and qualitative have most often been used to describe data collection methods and characteristics of research designs, which probably is not unique to these situations as judged by the way these terms are often presented (Leydens et. al., 2004). As examples, the use of surveys in a study makes the research quantitative, regardless of the epistemological perspective of the survey designer or the "inherent structure" of the object under study. Classroom observations represent qualitative research, even if the purpose of the observations is to simply count instances of certain behaviors across different conditions. Experimental designs are quantitative, regardless of which variables are investigated and how they are operationalized. Similarly, interviews represent qualitative research, even if such interviews generate very basic reports. The terms qualitative and quantitative are considered in only the most basic sense. Clearly, the distinctions made between quantitative and qualitative work are not as clear as is sometimes assumed.

Beyond using the more general terms of qualitative and quantitative to describe the kind of work a researcher does, describing that person as a post-positivist, phenomenologist, or any other kind of "-ist", may lead others to be believe he or she possesses defined and accepted theoretical perspectives on reality, research purposes, methods, the role of the researcher in projects, and acceptable outcomes in projects as a homogenous set, as is often presented in the literature (Borrego et. al., 2009; Case & Light, 2011; Gall et. al., 2003). However, it may be that a researcher takes a post-positivist stance in reference to certain objects of study, but a phenomenological stance regarding others. In one case, the researcher may want to determine context free generalizations (post-positivist) without having to define all methods to be used in advance (phenomenological), essentially mixing perspectives. Maybe the researcher disagrees with those who claim that phenomenology cannot support a detached approach. At a certain point, labels become more limiting than useful.

Given these varying perspectives on what exactly constitutes quantitative and qualitative research and the fact that each perspective, however defined, represents a number of implications for practice, I believe it more useful to lay bare my philosophical assumptions regarding what can be known using psychological research so that each assumption can be critically reviewed. I find this preferable to allying myself with a certain kind of methodology and hoping that those reviewing my work share the same understand it the same way. This equips the reader then to evaluate the appropriateness of my philosophical, theoretical, and practical perspective in relation to my research questions to a degree that would not be possible if I simply described myself as, for example, a grounded theorist. The following represents the major points of philosophical consideration reviewed in preparation of this study as well as the stance taken on each of them, and represents an attempt to make my reasoning as clear as possible.

Creswell describes this activity as a necessary part of establishing the validity of qualitative work (1994, 1998), but it seems to me that it would also be useful for any work done in a field as relatively young and rife with disagreements about approaches and terms as is psychology.

What Is Real? It is necessary to determine the most basic characteristics of the objects under study to determine an appropriate method for coming to understand them. Philosophical empiricism defines real objects as those that exist in space and time and are regulated by causality. Any objects lacking one or more of these characteristics are considered irreal. Real objects are the interest of all physical scientists, who are often referred to as practitioners of the natural science method. Edmund Husserl, philosopher and mathematician and a proponent of the phenomenological approach to studying psychology, offered that the objects of interest to most psychologists should be considered irreal (1983). For example, it can be argued that since ideas and meanings lack spatial qualities (though still regulated by causality in that they are preceded and followed by related ideas and meanings), they should be considered irreal. However, a person experiences ideas, meanings, memories, dreams and more in her consciousness, so while they are irreal, they nevertheless manifest and have consequences for those who experience them. As a result, it can be said that real objects exist independently of consciousness, but irreal objects do not.

In a sense, valuing the real and irreal as a researcher requires a more comprehensive perspective than empiricism insofar as it allows for the study of irreal objects and well as real ones (Giorgi, 2009). This does not mean that the irreal cannot be studied using a scientific mindset. Theories can be proposed based on observations and tested against future observations as in all scientific practice. However, one important implication of this perspective is that methods used in the natural sciences may not translate directly and may need to be modified when used to study the irreal. Some have even argued vehemently that natural science methods should not be used to study the irreal at all (Mitchell, 2005). In either case, this point demands careful consideration of any methods used to study irreal objects. These assumptions, common to the thinking of those who describe themselves as phenomenologists (Creswell, 1998; Giorgi, 2009; Schram, 2003), are accepted as givens for the current study. Another way to think of the preceding ideas is to simply say that while the participants may describe experiences that may be based on distorted sensory information or flawed conceptions, they are related to the sensory world and have implications for those who have them, so are worthy of the same level of observational rigor when studied that is applied to the study of real objects. What is of foremost interest are the experiences though, not the sensory referents to which they may be related.

As such, the value in this study was placed on the reports and perceptions of the participants, and no efforts were made to assess the “validity” of these perceptions. For example, if a participant had claimed that current students were not as capable as students of previous generations, there would have been no attempt to assess student readiness over the years to determine if such a perception was warranted. That perception would have been assumed to be meaningful enough to motivate behavior. As a result, it would have been worthy of study regardless of accuracy.

What Can Be Known? People come to understand the world, the real and irreal parts of it, through the use of mental conceptions driven by the acquisition of sensory data. The completeness of this data in relation to the world is naturally limited by our biology as our sensory organs operate within certain limits, and while mechanical aids can expand these limits, such as a microscope examining bacteria or a video camera replaying an interview, they too have their own limits. Similarly, the structure of the mind interferes with the creation of completely accurate conceptions for objects and their interactions based on these data. A brief review of the research on cognitive biases such as confirmation bias, attentional bias, recency bias, hindsight bias and others reveals such interference. Simple memory and computational limits of the brain demonstrate another. Yet another is the social and personal pressures that sometimes indirectly influence scientific work.

Real objects and their interactions can only be known through incomplete sensory observations and described using models, frameworks, and theories which are subject to the cognitive biases and other limitations as described. As such, all proposed conclusions are open to revision and rightly so.

Evaluations of observations can be made by examining the extent to which they are able to sufficiently explain cause and effect in the world. Stronger theories will generate more accurate predictions than weaker ones as the physical world “pushes back” against these conceptions. (The man who believes that gravity is of no consequence will quickly realize his error.) This perspective is often referred to critical realism, in that people who hold it are critical of the ability to know reality with certainty (Phillips, 2000).

Irreal objects cannot be directly observed through sensory organs. They can only be experienced in a person’s consciousness and then shared with observers indirectly. Compared to observations about the natural world, observations of irreal objects must be shared. This requires the individual doing the sharing to reflect on her experience, filter her understanding of the experience for the audience, and then offer this to the observer who must then interpret what has been offered. What is more, the original experience involves conceptions of real objects and their interactions - conceptions which are necessarily flawed. As such, any study of an irreal object is obfuscated by several levels of interference.

With real objects, only observation and interpretation by the observer of the natural world is required when generating conceptions. With irreal objects though, there exists additional levels in the chain of understanding where the experience of the irreal object can be distorted before and during the act of sharing conceptions of it with others. This presents a special challenge for those interested in studying human experience as it requires the researcher to use methods that can foster a level of openness with participants that will help generate the most representative reports possible.

For this study then, there was a strong effort to foster relationships with the participants that would lead to frequent, high quality exchanges about ideas both in the interview sessions and outside of them. The goal was to develop as accurate conceptions of what the participants were sharing as possible, a challenging task for the reasons above. This required constant checking with the participants to make sure what they reported about their planning activities was appropriately represented.

How Do We Know? In general, the study of irreal objects should be conceptually similar to the study of real objects. Observations need to be made, links among them proposed, and those links tested to determine the extent to which they can demonstrate cause and effect. (Of course, it is not always possible to test possible causal links directly, so other types of evidence are gathered until the collection of such evidence is deemed sufficient to suggest reasonable connections.) The unique challenges involved in establishing an accurate representation of personal experiences have already been discussed, but beyond that, the study of irreal objects can differ from the study of real objects in that the purpose of the study can present a different meaning. While we study the physical world in order to be able to control it, we often study human experience to foster a better understanding of others and ourselves. (The study of the real can also satisfy in this way, but that would almost always be considered the secondary gain. Similarly, some studies of the irreal are done to determine which kind of situations best elicit desired responses from people.) This goal of understanding when studying irreal objects means that experiences are not studied in order to see which facts systematically stand out and can be truly counted on, as in the practice of natural science, but instead to discover the essence of an experience that can manifest in multiple contexts.

This may sound similar to the natural science approach - the quest to discover strong relationships between objects that can explain a large number of physical cases, but an understanding of just how experience has to be studied highlights the differences. As Giorgi describes the differences between how one studies the real versus the irreal:

> "It is a classic strategy to break down a complex entity into its component parts and then put it back together again. It is also a rather straightforward process when the component parts to be separated can exist independently of each other and can be discriminated on the basis of their physical contours. What complicates the analysis of experiential phenomena is the fact that the parts to be discriminated are dependent on each other, that is, they cannot stand alone independently of the entire conscious stream and they are fleeting, rather than static, and so cannot be held steadily before an act without the help of retention or memory. Furthermore, the contours that separate different moments of the experiential stream are not as evident as physical

ones and are often embedded in marginal states that contribute to the meaning of the significant moments (2009, p. 81)."

There exists real objects where it can be difficult to determine their "physical contours" exactly or the extent to which they exist independently of other real objects, such as in the study of very small objects like in microbiology or certain branches of physics. In any case the objects of study, however, do not exist solely as part of an observer's conscious stream. Again, it is not the physical object that is of interest, but the intentional interaction and the resulting experience of a person engaging with some part of the natural world. This requires the explication of each participant's perspective with the researcher fully engaged in the process, not treated as a variable to be controlled, as this approach requires that the researcher elicit responses as appropriate. The experiences of the participants must be taken on the whole as motivated by the questions of the researcher if fidelity toward the nature of this kind of variable (personal experience about something) is the goal.

Throughout this study, an effort was made to fully understand the stories told by the participants. Though some simple quantitative methods were used to help better organize the details, respect was maintained for how the contributions varied among participants. Similarly, to maintain full engagement in the process as the researcher, the methods used to conduct this research were made transparent to the participants on a regular basis with a final check for understanding conducted in the last set of interviews.

The Approach

As stated earlier, the purpose of this study was to begin development of a method to better describe the instructional planning processes of post-secondary teachers. This required a research approach that accepts that descriptions of experience or "the use of language to articulate the intentional objects of experience" as the valued and objective goal of data collection (Giorgi, 2009). To satisfy this criterion, I conducted a series of semi-structured interviews with each of the participants about their instructional planning. Seidman describes the purpose of interviews as follows: "At the root of in-depth interviewing is an interest in understanding the lived experience of other people and the meaning they make of that experience (2006, p. 9).” This necessarily required a respect for the contributions of the participants, which means that they were permitted to talk freely without too much leading or prodding. This did not excuse the need for careful preparation and planning, but served to foster a respect for the contributions of the participants against personal desires to see that certain questions were answered. The goal was to foster honesty from the participants while encouraging them to tell their stories fully.

Participants. Four engineering faculty members, two males and two females, with varying levels of teaching experience (one year to more than 20) were recruited to participate in this study. The participants were selected because they were each in the process of teaching an introductory level engineering course, and it was assumed they all possessed a relatively strong interest in teaching. (This assumption proved true in the interviews.) Another criterion for selection was that none of the participants had received significant formal pedagogical training. As discussed in Chapter 2, there is some research (for example Stark et. al., 1998; Stark et. al., 2000) that suggests how faculty members less focused on their teaching, in relation to their research or other obligations, consider their instructional planning, but the efforts of that kind of group were not the focus of this research.

Four participants were selected for this study as one to ten participants seem typical for similar studies (Asghar, 2010; Creswell, 1998; Schram, 2003). Ideally in a qualitative study using interviews, a researcher will keep interviewing new participants until the information reported reaches a point of redundancy per participant and across participants. However, the practical exigencies of time and access always play a role in deciding how many participants with whom to work. This study required each participant to give an average of five hours of time over the course of an academic semester, not a trivial commitment. Regarding analysis, transcripts of the interviews alone yielded about 320 pages. It was hoped that this effort would be sufficient to both provide interesting points of comparison across the participants as well as ensure that the participants were able to speak fully about their thoughts on general course planning and planning for the topics they selected to discuss.

Interviews and Classroom Observations. Four interviews were conducted with each participant. Additionally, one or two classroom observations were made of the participants teaching the topics they decided to discuss in the interviews. Details on the structure of the interviews and observations are found in the sections that follow.

The instructions and questions used in each interview are presented in Appendix A. The interviews and classroom observations were audio recorded using a flash drive recorder. The audio was then transcribed into a text file with the assistance of *Express Scribe* and subjected to content analysis using *Dedoose*, a qualitative data analysis program that permits the easy creation of excerpts, or selections of text for analysis, and attending codes. (All data are stored securely and will be destroyed three years after the publication of the final report as specified in the application to Penn State's Institutional Review Board, approved on December 1st, 2011.)

The structure of these interviews was adapted from the guidelines presented in *Interviewing as Qualitative Research* by Seidman (2006). The interviews were semi-structured, which means that while questions were created prior to each interview to be asked in the interview in order to generate some initial discussion, the participants were allowed to talk freely and move naturally from one point of discussion to the next. In other words, prompts related to the given questions were offered, but they were not pushed when it was clear a participant wanted to talk about something else. The questions were also not used to interrupt ongoing discussion. Again, the goal was to make the participants as comfortable as possible in order to elicit high quality responses.

The participants were asked to share course materials relevant to the discussion, which included any items related to the instruction of the chosen topic and related concepts and procedures. This was mostly limited to syllabi. Throughout the interviews, the participants were asked to talk about the roles these items played in their instruction as they referred to them.

A pilot study was conducted using the Second Session Guide (see Appendix A) to establish the validity of the questions and general approach. Overall, the pilot revealed that participants should be asked to identify any concepts or procedures they want to talk about, not just those they find challenging, which was the approach that was going to be used initially. The pilot also uncovered difficulties I had experienced previously when conducting interviews, such as fighting the urge to talk when I knew I should keep listening. This was especially difficult to manage when I had specific questions, or when there were moments of silence in the conversation. I kept this principle and several others in mind moving into the interviews.

During my work with the participants, I tried to follow up on what they said without interrupting them. I asked for clarifications when I wanted to hear more about specific topics they found exciting. I tried to limit sharing my experiences so as to not distract them from their own. I tried to avoid reinforcing what they said, either positively or negatively, as I did not want them to think I was evaluating their responses against any standards. (In the past, I found this especially difficult to do when a participant would laugh or express frustration.) The perceived efficacy of these efforts in this is discussed in Chapters 4, 5, and 6.The specific considerations made for each interview are as follows.

First Interview. The first purpose of this interview was to put the participants' experiences of course and topic planning in context by asking them about their educational histories and teaching experience. While they were asked about their research and service responsibilities generally, this was for the purpose of establishing how much time they usually spend on their teaching. The goal was to develop a reasonably complete educational history of each participant that included both experience as a student and experience as a teacher.

The second purpose of this interview was to have the participants talk about how they typically plan their courses and why they plan their courses the way they do. For this study, planning was considered to include, "the things that teachers do when they say they are planning" (Clark & Peterson, 1986, p. 260) as well as the reasons or factors that motivate those planning decisions. The goal was to develop a reasonably complete description of what each participant considers generally important when planning courses.

Second Interview. The purpose of the second interview was to listen to the participants talk about how they plan to teach specific topics. They were asked to identify an introductory engineering course they were teaching that semester (basically any course they did not consider an advanced course) and pick a topic they were going to cover in the course that they wanted to talk about. Similar to work by Hasweh (2005), they were asked to define the topic in layman's terms, describe the relevance of the topic for the course, and explain how they planned to teach it. While doing this, they were also asked to identify the reasons or factors that motivated their planning decisions. The goal was to generate a reasonably complete description of what each participant considers important when planning to teach their chosen topics.

Classroom Observation(s). The purpose of the classroom observations was to observe the participants implementing their plans for teaching their topics. This served as a check to see how closely the implementation of the participants' plans resembled their intentions as described in the second interview. It also served as another way to build better rapport with the participants by demonstrating support of their teaching activities.

Third Interview. In the third interview, the participants were tasked with reflecting on the class sessions. The participants were asked to assess how well they thought the classes went and describe any changes they made to their planned implementations during the class and why. They were also asked to talk about any changes they planned on making when teaching the given topic in future semesters. The goal was to get a sense for how stable their planned instruction was during the class.

Fourth Interview. In the fourth interview, the participants were asked to reflect on their experiences participating in the study. They were also asked to respond to summaries of information they shared in the first three interviews by working through some ranking tasks. This was meant to serve as a validity check on the interview process as well as generate feedback that could be used to improve the interview process in similar future studies.

The next few sections describe the data analysis methods and other study design considerations in general simply to orient the reader to the discussions in chapters 4 and 5. Chapter 4 provides more detail about the research process including logistical considerations, the development of the transcript coding scheme, and evolving reflections on the research design. Chapter 5 represents the analysis of the planning interviews and observations in detail.

Analysis. Several philosophical assumptions about the object of study (experience of planning for the instruction of a particular topic) for this research project have been described: (1) It is not real in the same way physical objects are real; (2) It should be explored in total before being subjected to any interpretation or analysis; (3) the researcher is there to lessen the distance between himself and those studied to best represent that experience; and (4) through studying the topic within its context and using inductive logic, emerging designs can be created. Similar assumptions are common to a number of qualitative methods (Creswell, 1998), but these were pulled from some modern writings on phenomenology (Giorgi, 2009) to flesh out the approach as it seemed appropriate given the goals of the study. These assumptions drive the methodology, including the techniques used to analyze the data.

Most of the techniques and best practices enacted for the data analysis were adapted from Siedman (2006) and informed by previous experience. While some researchers suggest analyzing interview data as it is collected to inform the questions asked from interview to interview (e.g., Lincoln & Guba, 1985; Maxwell, 1996), I avoided analyzing the interview data until all interviews were completed in attempt to establish consistency in the interview protocols. Once the interviews were completed, I transcribed them for textual review. I then analyzed the interviews a set at a time, starting with the first set of interviews and progressing to the fourth set.

The text from the first and second interviews was analyzed in a somewhat different fashion than the text in the third and fourth interviews. For the first interview, I reviewed the transcripts several times to form general impressions about educational histories, tagging the rich and interesting details using the excerpt creation feature in *Dedoose*. I then wrote summaries of the participants' histories, comparing and contrasting them. I then went back to the text and created excerpts where the participants' identified general course planning decisions and why they made them as they did. Regarding these reasons or influences, I coded them using a scheme described in detail in Chapter 5. For the second interview, I went through the same process of creating excerpts and coding the influences, but this time with regards to planning instruction for their topics.

After the planning excerpts were identified and related influences coded in interviews one and two, I created planning profiles for each participant that documented the most significant elements of our discussions across both interviews. The goal was to demonstrate the influences on the participants' planning decisions at the course level, as in the research on course planning in higher education (e.g., Lattuca & Stark, 2009; Stark, 1988; and Stark et. al., 2000) and the original research on course planning in the context of teacher decision making (e.g., Bishop & Whitfield, 1972; Shavelson, 1973; Shavelson, 1976; Shulman & Elstein, 1975), and compare and contrast that to the influences on planning at the topic level. The interest was in determining how planning decisions at the course level carry over or express themselves at the topic level. I wanted to know if asking faculty members to describe their instructional planning for topics would generate descriptive information of the kind that could potentially be more useful to those looking to help faculty members improve their instructional practices than the general descriptions of teaching interests and concerns often generated by participants in course planning research.

For example, asking a faculty member about planning might reveal a general interest by the faculty member in student characteristics when designing a course. Asking the same faculty member about planning a specific topic in the course might reveal that they take into account students' procedural knowledge and goal motivation as specific characteristics (though maybe not in those exact words) in creating the lesson for the topic. This then presents an opportunity for the person helping the faculty member to have a conversation about possible instructional changes that is relevant to the faculty member's specific interests, which should be more motivating than a higher level discussion on generally effective instructional principles. (This logic is described more fully in Chapter 6.)

In addition to creating profiles, I acknowledged the commonly identified course and topic planning influences across the participants' reported experiences. I did this by considering the top three types of influences most relevant to the participants for their course planning and topic planning as they indicated through the ranking tasks implemented in fourth interviews (described in Chapter 5). Previous research on course planning has identified some consistent influences on the course planning process including a concern for teaching the basics of the discipline, the characteristics of the students being taught, the demands of other obligations, and more (Anderson et. al., 1985; Lattuca & Stark, 2009; Powell & Shanker, 1982; Stark et. al., 1998; Stark, 2000; Young & Irving, 2005). I compared the themes identified in this study to these findings.

Ethical Considerations. In conducting this study, I honored the guidelines for research with human participants provided by the Institutional Review Board at the university where this study was conducted. I describe how I honored the values inherent in the chosen methodological approaches in Chapter 4. Additionally, I believe this works demonstrates respect for the field of engineering education by observing proposed standards of research. In, *The Emergence of Engineering Education Research as an Internationally Connected Field of Inquiry*, Borrego & Bernhard (2011) suggested that high quality engineering education research should satisfy certain criteria (p. 37).

Inspired by real educational problems. We should know more about how our engineering educators teach so we are better equipped to talk to them about it and ultimately provide them with what they need to thrive by engaging with their prior knowledge on planning for instruction. We should also be better equipped to demonstrate to developing engineering educators what is involved in the creation of effective instructional units. One of the first steps in doing this is developing a way to help engineering educators explicate their thinking on planning

Informed by theory and other literature describing prior work within and beyond the field/home country. I worked to identify all articles relevant to the specific topic of instructional planning in higher education in general and engineering education in particular. I did the same for the course planning studies in the context of teacher decision making. A few of the higher education planning studies are international in scope. Some of the related informative research, on PCK specifically, features work by international researchers.

Systematic and intentional, with documented decisions ideally based on well-planned collection and analysis of empirical data. Chapters 4 and 5 describe in detail how the data collection process was created and enacted. This includes justifications for each methodological decision.

Consistent with the perspectives and methodologies chosen (quantitative, qualitative, or mixed). This chapter makes an argument for the methods chosen that is rooted in a current and popular perspective in psychology for the study of experiential phenomenon.

Present (at least in part) in a form that engineering academic staff can understand and use; including by discussing implications of the research. As this is a dissertation in a field outside engineering, accessibility to academic engineering staff may be limited as methods are a large part of what drives the distinctions between disciplines. That said, Chapter 1 and the narrative portions of chapters 4 and 5 may be reasonably accessible. In any case, this work will be able to serve as the basis for more accessible reports on the subject.

Situated in international and interdisciplinary contexts, by demonstrating awareness of how common the problem is, what is being pursued elsewhere, and the likelihood that results are or are not generalizable/transferable to other contexts (disciplines and/or countries). We note that for an Engineering Education Research topic to be worthy of inquiry, it need not be broadly generalizable. Research on planning for instruction does not currently seem to be popular as demonstrated in the literature review. The specific results of this study are not intended to be largely generalizable, only the developed method. The results are meant to answer the question of whether or not applying said method can generate planning information that could be of interest.

Chapter 4

Process and Context

Although I spent most of my time in graduate school and in my employment working on projects using quantitative methods and perspectives, I was attracted to the idea of conducting research for my dissertation using a qualitative approach for a couple of reasons. First, the practical: As someone with fairly well-developed quantitative skills, I thought it would be valuable to spend time developing qualitative methodology skills in an effort to become more marketable in the workplace. In my professional field, institutional research, there is a growing interest in applying qualitative methods to study subjects that have most often been tackled using quantitative methods, such as student satisfaction and student engagement, and I wanted to be ready for future opportunities to conduct research in these areas.

Second, the personal: Over the years, I have grown less interested in the quantitative approaches often used in conducting much of the research in my field. Quantitative methods are most often used to control for the influence of a set of contextual variables on the specific variables of interest (Creswell, 1994). For example, when studying student success in a course, the goal might be to control for instructor effects, curriculum effects, and all other identified effects on student success by creating scaled numerical estimates for the strengths of those variables. The researcher seeks to understand how all these previously identified effects come together to explain variance on the dependent variable of interest.

The quantitative approaches, however, often employ strong assumptions about the variables of interest. They assume that the variables possess inherent quantitative structure, as discussed in Chapter 3, and that most or all of the relevant variables related to the topic being studied have been identified (Mitchell, 2005). For those reasons, quantitative approaches are most appropriate when studying topics that are well-established in the research and have demonstrated that numerical measurements of these topics are philosophically sound. (Perhaps unfortunately for me, the educational topics I am most interested, like the one explored in this study, do not have up to date, well-established research bases.)

Instead of trying to delineate and control for the effects of context on the variables of interest, qualitative approaches make understanding the context the point of the research endeavor (Cresswell, 1994; Creswell, 1998). There is much less focus on controlling for the effects of specific variables in the research design or data analysis, and a stronger emphasis on trying to understand how variables operate in relation to one another through examination of the larger contextual picture. Qualitative work generates descriptions that the researcher and others use to build abstractions, hypotheses, and theories. This often proves difficult since the open nature of analyses of qualitative data can typically spawn many interpretations. Quantitative work, by comparison, is more focused on gathering specific summary information to use in testing previously established hypotheses, and is more suggestive in terms of how one might interpret the findings as they typically focus on a few highly operationalized factors for analysis. (The challenge here then is more on determining how to assess and represent these quantitative relationships – no small feat either.)

As an example, this is the difference between writing a series of articles that describes how individuals without health insurance struggle with health care costs versus how this impacts their lives with suggestions that this may represent a larger societal problem, and gathering numeric information to generate graphs and charts on income levels and health care costs that carefully demonstrate who is being affected by rising healthcare costs and how. The former is more inclusive of all the details different readers will consider more or less relevant depending on their understanding of the subject. This approach may lead to more open interpretations. This tactic would likely describe daily struggles of the underinsured trying to figure out how to pay their health care bills and the emotional toll this takes on them. Rich descriptions of what this life is like for these individuals could be shared, and the analysis would likely yield more questions than answers. It will be more difficult for the researcher to establish generalized claims with such data given the focus on individuals, but the data will more easily lend itself to competing interpretations than a quantitative approach, due in part to the sheer breadth of the study.

The quantitative representation, however, would likely be much less open to interpretation with a strong focus on the analysis of specified variables. However, this tactic could be more effective than the qualitative approach in communicating concise information about the variables. The resultant report would likely provide summary descriptive information such as means and standard deviations of variables such as family income and average insurance rates and could describe relationships between these two variables. Generalizations about these variables to a larger population would be more defensible than with the qualitative approach, but it would be more difficult to surmise how other factors not included in the quantitative analysis could be relevant. This is not to say that there is no degree of interpretation with a quantitative approach or that those using qualitative approaches refrain from drawing conclusions; there is simply a significant difference in matter of degree between the two approaches.

In the case of developing a method for explicating the psychological process of planning for the instruction of a specific topic in a course at the college level, the existing research was sparse. Given my goals, this topic presented an opportunity to conduct the kind of research that provides readers with the larger context they need to better evaluate my thoughts on the topic and propose their own. This qualitative approach required both a willingness to discuss the process used to collect the data of interest as well as a willingness to be reflective about it. To that end, this chapter describes the logistical considerations in the beginning stages of the study as well as reflections on my initial interactions with the participants.

Recruitment

As described in Chapter 3, four engineering faculty members from a large research university, two males and two females, with varying levels of teaching experience (one year to more than 20 years) and research experience were recruited to participate in this study. All of the participants were identified by a dissertation committee member as possessing a stronger interest in their teaching practice than is typical of most faculty members in the same college. It was required that each participant was scheduled to teach an introductory level engineering course in the upcoming semester.

The participants were recruited through an email invitation to meet in person. The above mentioned committee member had spoken to each of them briefly about the study before the email was sent. I met with the participants in their offices on campus for about 30 minutes to explain the purpose of the study, which essentially involved a review of the material explained in the email. Each participant was told that the purpose of the study was to better understand how college faculty members plan for the teaching of a specific topic, as not much was known about how faculty members plan for their courses in general, let alone at the topic level. I explained that they would be asked to identify a topic and related concepts and procedures from one of their courses that they would be willing to talk about. I suggested that the chosen topic be somewhat less complex compared to other topics in the course to help keep the length of the interviews manageable. I elaborated that more complex topics would probably require more explication. All the participants agreed to this request, and two participants even asked me about my mathematics and science background to inform their topic choices. However, I did make it clear to the participants that they were free to choose any topic, and that we would work out the time commitment as needed.

The participants were told that they would be interviewed four times throughout the semester in which they were teaching their introductory course, with each interview running between 60 and 90 minutes, and that they would not receive any compensation for their time besides the opportunity to contribute to the knowledge base on planning for instruction. I explained that the interviews would be timed so that we would meet twice before the selected topic would be covered in class and then twice after it was covered to review the classroom instruction and conclude the study. I asked that I be allowed to observe the class or classes in which the selected topics would be covered. They were informed that all interviews and classroom observations would be audio recorded and that the recordings would be stored securely and then destroyed three years after date of study publication. They were asked to sign an informed consent form (a blank one can be found in Appendix B) after agreeing to participate.

Each participant expressed interest in the study. They seemed to readily understand the purpose and design and were eager to get started, though one of the participants, Pam, indicated that while she was willing to help, she did not believe she would present an interesting case as she, “pretty much did everything by the book.” In response to her concern, we talked about the structure of her course. During the conversation, she revealed that she used a textbook, but omitted coverage of a particular chapter. I explained to her that she omitted the chapter for specific reasons and hearing about decision making like that is what interested me. This seemed to ease her concern.

Overall, there were no administrative surprises or major difficulties in conducting the interviews or the classroom observations. There were also no technical issues aside from some spots in two of the interviews where the audio on the recordings was not as clear as it could have been, though this problem was rectified during transcription with the use of audio software to reduce background noise. In the beginning of each interview, I reviewed the discussion from the previous interview. Similarly, at the end of each interview, I gave the participant tasks, usually questions to think about, to be completed before the next interview. None of the participants expressed any confusion about this process, either indirectly or when asked directly. The guides I used to conduct these interviews can be found in Appendix A.

Identifying Influences

Going into the interviews, I considered how I might motivate the participants to talk about the influences on their course and topic planning decisions. I needed a list of possible influences to help generate questions to ask of my participants. The general course planning research in higher education (e.g., Lattuca & Stark, 2009; Stark, 1988; and Stark et. al., 2000), the work on course planning as a part of teacher decision making (e.g., Bishop & Whitfield, 1972; Borko, Roberts, & Shavelson, 2008; Shavelson, 1973; Shavelson, 1976; Shulman & Elstein, 1975), and the research on PCK (e.g., Grossman, 1990;

Koballa et. al., 1999; Lee et. al., 2007; Magnusson et. al., 1999; van Driel et. al., 1998) reviewed in Chapter 2 served as the starting point for generating this list. The research on PCK suggested that I needed to be as specific as possible with my questions if I wanted to generate responses that would lend themselves to analysis that was more detailed than what had been accomplished in the course planning research, so I was influenced by that perspective, especially Hasweh's presentation of it (2005).

Most of the planning influences referenced in the higher education research on course planning are collected in Lattuca & Stark, 2009). (I say most because it is complete in respect to the studies I reviewed, but there may be other planning studies in higher education that I missed in my search.) These influences are divided into two categories: content and context as indicated in table 1.

Table 1. Influences on Course Planning in Higher Education

Content	**Context**
faculty members' background and characteristics	student characteristics
faculty members' views of their academic fields	student goals
faculty members' purposes of education	pragmatic factors (e.g., classroom space)
	external influences (e.g., accreditation bodies)
	literature on teaching and learning
	advice available on campus (e.g. colleagues)
	facilities, opportunities, and assistance
	program and college goals
	other influences

Regarding the decision making research on planning, Shavelson and Stern created an overview of the domain of research on teachers' judgments, decisions and behavior (1981) regarding both course planning and implementation, and it included a list of "antecedent conditions" that relevant to planning. The three conditions were: information about students, nature of instructional task, and classroom/school environment. Information about students included examples like ability, participation, and behavior problems. Nature of instructional task included examples like goals, subject matter, students, and activities. Classroom/school environment included examples like school climate and external pressures on the classroom.

A review of the research on PCK reveals an inconsistent collection and use of terms for the planning influences across the different applications. As an example, different authors refer to subject matter knowledge as content knowledge, subject knowledge, domain knowledge, discipline knowledge, and more. They may be using these terms to note some significant difference from subject matter knowledge, but this is almost never made explicit. Similar examples of a general lack of precision are easy to find.

Larger issues of conceptualization can also be found. Some authors refer to PCK as that which is used in the transformation of subject matter knowledge for instruction. Others refer to PCK as a teacher's personal collection of knowledge transformations suitable for teaching a specific set of students. Others allude to it being both. In some cases, a reference to another author's work includes a misinterpretation of the PCK model presented in that work. Looking across the models, there are real differences in terms of what definitions get included as part of PCK and the included knowledge bases described as influencing variables. A sample of these different presentations, summarized in Table 2, makes it clear that not everyone conducting PCK research agree on the delineation of the construct.

That all said, it seems reasonable to claim that teachers do transform subject matter knowledge or at least make use of transformed subject matter knowledge using what they know about their students, and that it is useful to describe this as clearly as possible when studying teacher decision making for instruction. It also seems useful to be able to talk about how good teachers integrate their general pedagogical knowledge with their subject matter knowledge to better understand what goes into the creation of effective instruction.

Table 2. Differing Conceptions of PCK and Other Knowledge Bases or Influences By Author

Shulman (1986, 1987)	Smith & Neale (1989)	Grossman (1990)	Marks (1990)	Geddis et. al. (1993)
General Pedagogical Knowledge				
amalgam of content and pedagogy that is uniquely the province of teachers	student understanding	student understanding	student understanding	student understanding
	organized and sequence content	instructional strategies	subject matter	instructional strategies
most useful forms or representations of ideas	most useful forms or representations of ideas	curriculum (horizontal and vertical)	instructional processes	most useful forms or representations of ideas
what makes a topic difficult to learn	instructional strategies		media for instruction	
student understanding		instructional purposes		curricular saliency
instructional strategies				
how to reorganize and sequence content				
Other Knowledge Bases				
content knowledge	substantive content knowledge	subject matter knowledge	content specific pedagogical knowledge	subject matter knowledge
general pedagogical knowledge	teachers' orientations toward science teaching and learning, including beliefs	general pedagogical knowledge		
curriculum knowledge	knowledge of context			
knowledge of learners and their characteristics		knowledge of context		
knowledge of educational contexts				
knowledge of educational philosophy				

Table 2. Differing Conceptions of PCK and Other Knowledge Bases or Influences By Author (cont.)

Cochran et. al. (1993)	Magnusson et. al. (1999)	Park & Oliver (2008)	Loewenberg Ball et. al. (2008)
General Pedagogical Knowledge			
transformations of the subject matter given other knowledge (Pedagogical Content Knowing)	teachers' orientations toward science teaching and learning, including beliefs	teachers' orientations toward science teaching and learning, including beliefs	student understanding
	curriculum (horizontal and vertical)	curriculum (horizontal and vertical)	instructional strategies
	assessment	assessment	curriculum (horizontal and vertical)
	student understanding	student understanding	
	instructional strategies	instructional strategies	
	most useful forms or representations of ideas	most useful forms or representations of ideas	
Other Knowledge Bases			
general pedagogical knowledge	subject matter knowledge and beliefs	self-efficacy	common content knowledge
subject matter knowledge	pedagogical knowledge and beliefs	subject matter knowledge and beliefs	specialized content knowledge
knowledge of learners and their characteristics	knowledge and beliefs about context	pedagogical knowledge and beliefs	
		knowledge and beliefs about context	
knowledge of environmental contexts			

Moving into the interviews then, I had an idea of how to talk to my participants when they told me about a specific course or topic planning decision and I wanted to know more about what influenced that decision. Despite the different research on planning at the college level and nested in the work on teacher decision making and PCK, and the varying terms for influences or antecedents within and across those bodies of work, I knew enough to recognize a reference to an influence that could be thought of as part of a faculty member's purpose for education or a teacher's orientations toward science teaching and learning. I knew that if I did not hear a participant say anything about the availability of technology in presenting information, for example, I should ask about it to make sure it was not an influence on the planning decision.

Proceeding with the second set of interviews, I started to develop an idea of how I might later identify and code different influences on planning for the teaching of the participants' selected topics and related concepts and procedures for the analysis. Given that part of this project was to see if the application of PCK "thinking" could be useful for investigating teacher planning for instruction at the post-secondary level, I started to mentally operationalize a version of PCK that was informed by previous applications of the construct and other work on planning. What follows is the explication of this model used to help guide what questions I asked my participants and the organization of their responses. It should be noted though, that I never took this burgeoning perspective to be proscriptive, rather only a starting point for discussion in the interviews when there were lulls in the conversation or I suspected that a participant would have something to say about a particular planning influence even if it did not readily come to mind.

For this study, the PCK of a teacher was defined as his or her collection of subject-matter knowledge transformations of facts, concepts, and procedures coupled with discrete ways of teaching them using analogies, illustrations, examples, explanations, and demonstrations. These individual units of a person's PCK are referred to as pedagogical constructions throughout this text, a term and concept borrowed from Hasweh (2005), and organized into topics. These constructions may have been created by the teacher or learned from another source (other teachers, textbooks, etc.). In all cases, a construction represents a transformation of a teacher's understanding of a particular fact, concept, or procedure to facilitate instruction to a student or group of students exhibiting certain characteristics, including current understanding of the topic. In this sense, every construction is contextual and less effective outside its original context.

Much of the time, a pedagogical construction represents an "incomplete truth" about the fact, concept, or procedure being taught as the act of making it accessible to students requires pairing down the inherent complexity. As such, a construction can carry a cost against future understanding of a related topic as less “truthful” representations can foster misconceptions in students. More effective teachers seem to be more aware of this delicate balancing act than their less effective colleagues (Magnusson et. al., 1999).

Pedagogical constructions require the integration of a teacher’s subject-matter knowledge regarding the particular fact, concept, or procedure to be taught with the teacher’s general pedagogical knowledge and his or her knowledge about students, both at the individual and group level. These constructions get implemented in a larger lesson, a lesson which may be informed by factors such as available resources including time, knowledge of the curriculum (both horizontally or across current courses and vertically or in relation to future and past courses), and the teacher’s orientations toward teaching and learning in general. These lessons are organized into units, which are arranged to form the larger course.

What this meant practically for the second interview was that I used this conception as a way to hone in on possible points in the discussion for elaboration. When a participant would talk about using the analogy of a steep hill to help explain the concept of rate of change or a cup of coffee as an example of a heat system, I would ask for reasons how and why the use of the analogy or example was developed. If the participant had trouble explicating some of the reasons, I would ask about possible influences. Apart from talking about specific constructions, I would ask the participants to talk in depth about any procedures they used, which I defined as actions they took as part of instruction that were not strongly related to subject matter knowledge. Examples would be decisions about how to share notes with students or whether or not to share detailed feedback on assignments. In essence, I was trying to get participants to talk about the “what” and “how” of their instructional practices so I could learn more about the “why”. This developing conception then provided a kind of mechanism to help identify the “what” and “how” and help facilitate discussions of the “why” when participants seemed to need some assistance.

Coding Responses

Once all the interviews and resulting transcripts were completed, the transcripts were reviewed several times in the process of identifying excerpts of instructional decisions and developing and applying influence codes to them. Excerpts were identified using the logic described in the previous section, similar to the manner described by Seidman (2006). Basically, text selections that described teaching decisions regarding what to teach and/or how to teach it were marked for analysis. As an example from one of the topic interviews:

> I have thrown out the concept of unsteady, and the classic problem there would be I have a tank here and it's at sub atmospheric pressure, ok? And I open the valve and let air come into it and I shut the valve after a period of time, and you ask questions about the temperature and pressure in the tank, how much mass is in the tank.

As I created these excerpts, I was working through several drafts of coding schemes for the influences on planning decisions following guidance by Seidman to create categories that were representative and conceptually distinct. Initially, I created only three categories in an effort to be concise and address what I initially thought were redundancies in the various influences/antecedent conditions I reviewed in the previously described researched: Educational Philosophy, General Pedagogical Knowledge, and Curriculum and Resources. As I kept reviewing the transcripts and developing better understandings of the nuances of the discussions, I started to think these categories were not sufficient to accurately describe all the excerpts. As a result, I expanded the three categories to eight. For example, I conceived of Curriculum and Resources as any influence that was somewhat external to core teaching acts but presented constraints and affordances on planning decisions, but the participants generally talked about curriculum as a core consideration in planning, and they often talked about resources as an afterthought, so I split them. As another example, I originally conceived of Knowledge About Students as being a part of General Pedagogical Knowledge, but there were a few cases where participants talked about their knowledge of student characteristics separate from their knowledge about teaching.

The eight categories mostly resembled the final set. I then reduce those eight categories to six by combining some categories when I realized that the code counts in some of the categories were low or nonexistent. For example, Orientations Toward Teaching & Learning was separately Educational Philosophy and Educational Goals, but I combined them and expanded the scope of both kinds of influences with the final category.

I created two versions of each of the six final coding categories (so technically, I used 12 categories). Each code had an unprompted and prompted version. This was to indicate which points of influence discussion were raised by the participants without any prompting on my part and which were direct responses to my questions. I used the results as a rough measure of influence importance as I assumed that influences mentioned without prompting were relatively more important to the participants. In this way, an ordinal measure of influence salience was developed (unprompted or prompted), following a suggestion made by Magnusson et. al. (1999). The six coding categories used are as follows.

Subject Matter Knowledge (SMK). I applied this code to references of a participant's understanding of the given knowledge domain including facts, concepts, procedures, and subject specific strategies and the relationships among them (often referred to as substantive knowledge). Referencing Mayer (2011), facts were defined as something that is actually the case about a subject; concepts were defined as categories, schemas, models, or principles; procedures were defined as step-by-step processes; and subject specific strategies were defined as general methods to approaching problems relevant to the subject (as opposed to general problem solving strategies that apply across subject matter domains).

Subject Matter Knowledge also included references to syntactic knowledge, or an understanding how ideas are proposed, tested, and either rejected or accepted in the knowledge domain (Shulman, 1986), or in other words, possessing an awareness of what kind of evidence is needed to establish a new idea as common knowledge in a domain. This code was only assigned to an excerpt when a participant made specific mention of a particular fact, concept, procedure, or subject specific strategy while explaining a teaching decision. In this sense, it represented more of an antecedent condition (Shavelson & Stern, 1981) than a planning reason, but it seemed essential to be able to distinguish planning decisions that were specific to particular subject matter.

General Pedagogical Knowledge (GPK). I applied this code to references of a participant's consideration of broad principles and strategies of classroom management and organization (Shulman, 1987) and non-subject specific (general) psychological principles from the learning and instructional sciences in implementing planning decisions. Examples of the latter include understanding the value in creating instructional objectives that are specific, actionable, and amenable to assessment (Donovan et. al., 1999) and considerations of psychological principles relevant to education such as memory limitations, how new knowledge is integrated with old knowledge, the value of developing metacognitive processes, and more (Mayer, 2011).

Curricular Knowledge (CK). I applied this code to references of a participant's consideration of curriculum or the expectations of external bodies, such as accrediting agencies, in implementing planning decisions. This is similar to the definition proposed by Grossman (1990). For the code to apply to an excerpt, a participant had to make reference to how what is to be taught does or does not integrate with topics covered in other courses students are taking concurrently (horizontal integration) or might take in the future (vertical integration). Additionally, references to external bodies earned the same code. Examples include a participant deciding to cover a mathematical theorem in more depth than the participant might otherwise because many current students will take a course the following semester that makes heavy use of it, or the participant making references to coverage of a topic in another course students are currently taking to help explain a topic covered in the current course.

Resources (R). I applied this code to references of a participant's consideration of material resources in implementing planning decisions. This influencing factor includes any material resources that act as a constraint or affordance when implementing one or more planned actions by the teacher. In some cases, resources may impede the implementation of what the teacher wants to do altogether.

Common influences in this category include available media (Grossman, 1990; Marks, 1990) or technology (Mishra & Koehler, 2006). Class size and classroom space are obvious examples.

Orientations Toward Teaching and Learning (OTT&L). I applied this code to references of a participant's consideration of personal beliefs about the purposes of education both when considering engineering instruction generally and their courses and topics specifically. This included what the participant believed was valuable to learn about a particular subject (Smith and Neale, 1989). Examples include a participant expressing the belief that schooling should be about helping students learn how to make good decisions as democratic citizens or preparing them to function as professionals in the field or insisting that engineers need to understand a particular mathematical derivation fully because "that is just what engineers need to know."

Knowledge About Students (KAS). I applied this code to references of a participant's consideration of student characteristics relevant to how a student learns, including current level of subject matter knowledge, general scholastic ability, motivation, and larger contextual issues that may have an impact on how a student performs in school such as quality of home life or competing obligations such as work or sports. This same definition was used by Hasweh (2005).

As an example of the application of this coding scheme, consider the following selection from an excerpt created from a topic planning interview:

> Well, one of the biggest things I notice, and I think part of it is that they see it as trivial because their calculators – they like calculating things – and most of them can get fairly good at plugging things into the equation that we developed for this concept. And that's where most of the work is and so usually that's where most of the weight is, that's where most of the time is spent, but then at the end of that, when I say: Ok, sketch this, show me what this number actually means, what does it actually look like? And that's where I get people either dumbfounded like: really? I got the number, why does any of that matter?

Here the participant was talking about his students' tendencies to believe they possess well-developed conceptual knowledge just because they are proficient applying related procedures. In the discussion leading up to this point, found in the full excerpt, the participant expressed his desire to have his students develop strong conceptual understanding and described a specific decision he made in trying the help them do that (having them work with problems that cannot be easily solved through rote application of procedures). Here he expressed his understanding of how typical students respond to this effort. As such, the full excerpt was coded as Orientations Toward Teaching and Learning and Knowledge About Students (both unprompted).

A few other notes about the application of this coding scheme are needed. First, I made no attempt to assess the validity of my participants' different knowledge bases (general pedagogical knowledge, knowledge about students, etc.). Of course, I could not have evaluated their subject matter knowledge even if I wanted to, given my educational background, and I did not know about their students or anything regarding curriculums or resources. For general pedagogical knowledge, however, I did use personal knowledge of the learning and instructional sciences to determine when to apply the GPK code to excerpts, such as recognizing a participant making references to memory limits in information processing or that erroneous prior knowledge can interfere with new learning for example. I also used this knowledge in writing the interview summaries to provide additional commentary on participants' planning decisions. However, the aforementioned commentary was not evaluative in nature.

Second, there were instances where I applied a code that represented the same specific influence to different excerpts. In other words, there was no limit to how many times a specific influence was counted as belonging to a code category, as long as the influence was referred to as affecting different planning decisions. As an example, if a participant mentioned class size as an influence on how the participant conducted an in class assignment and later mentioned how class size affected the types of homework assignments assigned, I would count that as two applications of the Resources code. If the participant simply repeated the first or second point again later in the interview, I would not assign a new count of the Resources code.

Teaching Biographies and Course Planning

As mentioned in the recruitment section, all four participants in this study were identified as having a strong interest in teaching. This perception was reinforced by the fact that each faculty member indicated interest in participating in this study knowing that it would require at least five hours of uncompensated time throughout the semester. As described in the first session guide in Appendix A, the participants were asked about their educational experiences, teaching history, and work experience. This was done to better understand how they thought about their teaching, both in terms of implementation and professional importance.

The summaries of these responses follow. Note that each participant was given a pseudonym to protect their identities, though all participants were told that given the specific nature of the discussions, full anonymity could not be guaranteed as colleagues reading the study could probably identify them. None of the participants were concerned about this possibility. That said, the descriptions of the participants' characteristics, such as age, are often spoken of generally in an effort to make them less easily identified.

All interviews were conducted from January 2012 through June of 2012. Again, there were five meetings with each participant, the first to secure permission to participate in the study and the rest as the interviews. On average, about three weeks elapsed between each interview for each participant. There was a bit more variation with the timing of the third interview as that one required reflection by the participant on an observed classroom experience, and the timing of the observations depended on when the selected topics for discussion were covered in the course.

Gordon. I first met with Gordon to explain the purpose of the study and ask for his participation. After a short introduction, we spoke for about 20 minutes reviewing the logistics of the study. He did not express any concerns about how the study would be conducted or how the results would be presented. He seemed to readily understand what would be required of him.

Gordon explained that as a relatively new faculty member, he wanted to talk about a new introductory course on polymers that he was going to teach that semester to a course of 33 students, representing mostly undergraduate students with a few graduate students. Besides that, he did not speak too much about his course or perspective on teaching except to offer that he was glad to be a part of the project. He also expressed a bit of frustration about the teaching behavior of other teachers he often found odd, such as an insistence on covering a large amount of content in a shallow fashion at the expense of in-depth learning.

Personally, I did not feel an immediate connection to Gordon as he appeared standoffish. I found his speaking style a bit difficult to follow. He spoke at a rapid pace, and I was concerned that would make it difficult to keep up with him in the interviews. That said, he seemed eager to get started, so I was confident that the following interviews would generate useful discussion.

I met with Gordon a few weeks later to conduct the first interview using the guidelines described in Appendix A. We started talking about his educational background. He explained that he had studied chemical engineering as an undergraduate student and then as a graduate student at a prestigious research university. He specifically mentioned that at his graduate school, the chemical engineering program was situated in the college of chemistry, which he found “interesting” as he believes it helped him develop a stronger knowledge of pure chemistry than he might have otherwise.

After he received his Ph.D., Gordon spent a year as a post-doc at a highly prestigious university doing pure research. At that time, his main goal was to one day head his own research lab, though he always possessed an interest in teaching in one form or another (formal classroom instruction as well as mentoring). He came to his current position as an assistant professor on the tenure track not even sure he would have teaching responsibility. Up to that point, he had little teaching experience. As a graduate student, he spent one semester grading homework and exams and holding review sessions for an engineering course. He had spent another semester teaching a lab for a different course, which required giving a few lectures. Currently, he sees his work as the equivalent of three full-time jobs: teaching, conducting research, and fund-raising.

When asked about any experiences with teacher training, Gordon referred to four sources of teaching education and knowledge: a half day seminar at his Ph.D. granting institution on what he referred to as, “things not to do as a teacher”; a two or three day (he could not be sure) workshop given at a university on general teaching principles by Michael Prince, a well-known engineering education researcher; an engineering teaching orientation offered to all new engineering faculty members at his current university; and a broad review of the literature on teaching effectiveness Gordon conducted when putting together a proposal for a career development project. Gordon said he took two major points away from the workshop. First, that less is often more when teaching, or in other words, instead of covering so much content, focus on covering less content in more depth. Second, that some courses are more important than others in a given sequence, and they should be weighted accordingly in terms of the effort required from students. As he clarified, “Of course in every course there is some amount of expectations of how much time the course will be able to take and I know different faculty sees this differently, but I don’t see three credits as being three credits. There are critical courses in chemical engineering, introductory courses that are the foundation for everything else.”

This exposure to pedagogy motivated Gordon to reflect on why he felt some of his own teachers were effective while others were less effective. He realized that the effective teachers were the ones who could convey content in a way students could readily absorb, and often that meant not overwhelming them with sheer breadth. This perception is embedded is his core teaching philosophy:

> The goal for my students is really what concepts I am going to be able to help them understand. And that’s the course objective. Hopefully if I am thinking about everything correctly and doing

> things right, I write down three or four course objectives and that's really what I want them to know. That's the bottom line. Other than that, I think about what is the most effective way in which to sort of have them absorb those ideas or how can they get those ideas or help them get those ideas. So, they have homework assignments to do. What activities am I going to do? How am I going to assess them? Otherwise am I going to have them do a project or just exams? Am I going to have just one final and that's it? Or am I going to have quizzes every week? All of those things and what I think was the best way for me to be able to effectively help those students absorb the material. And I have to say I do balance that with the workload that that means.

Gordon continued to explain that his teaching is influenced by several other factors. He has worked within resource constraints, such as determining what activities are feasible given class size and time available for grading assignments. He has also worked to manage expectations from external bodies for his courses: the department and accreditation body for the program expect a certain quality of work from the students. He has designed courses that teach content effectively relative to the overall importance of the course in the students' lives. This has often involved helping them develop skills he considers important for practicing engineers and being a "versatile" person in general. For example, he has embedded work experiences into his courses, like memo writing, that are not usually encountered in an engineering course.

Gordon stressed that he still had a lot of work to do in becoming a great teacher. He related that he was very anxious when he first started teaching, and the general unease of "leading a course" took him months to overcome. At the end of his first semester teaching though, he looked backed and felt he had done a good job effectively communicating the essential ideas and principles to his students. Even at this early stage, he had adopted an approach of trying to get students to the point where they could "tackle, but not necessarily solve" problems given to them. When asked for clarification on this point, he said:

> So what I mean is that they can approach the problem. They don't look at the problem and say: I have no idea how to start. Instead OK, what I need to do here is that I need to understand this

> chemistry a little bit better and understand its reactions. Oh, you know, I learned in my class with Dr. so and so that these sort of reactions, you know, might do this or might do that or maybe these types of polymers are made with these certain types of reactions. OK, so let me look up in this book, this text what those reactions are like and maybe go back to my chemistry textbooks. In other words, give him enough information so that they don't completely just blank when they see a problem, he can somehow figure out that they can approach it. So they might not remember, they might not know exactly how to solve the problem but at least they have in principle the tools to be able to solve the problem. Now I know that is much harder done than said. Just because I give them the tools doesn't mean they are going to be able to do it, but at least I am hoping that the tools are there. Whether or not they will be able to always use them properly, of course I can't say.

Gordon summarized his thoughts by saying that he wants his students to learn the course content and develop proficiency trying to solve novel problems, with an emphasis of going through the experience of being somewhat overwhelmed by the various ways such problems can be approached. Solving them is important, but developing a level of comfort of working with the unknown even when an answer may be out of reach is just as important. Again, he wants his students to become versatile professionals, which means less of a focus on covering a large amount of content and more of a focus on learning what it means to operate as an engineer, from struggling to solve problems to writing effective office memos to colleagues and support staff. Along the way, he tries to make students aware of exactly why he requires them to do the activities he plans. He shared that his father never said to him, "Do this because I'm your father." He always gave Gordon a reason. In the same way, he does not want his students to feel like they are simply being ordered to task.

I wrapped up the interview by explaining to Gordon that he should identify a topic and related concepts and procedures he was going to teach that semester that he would like to discuss in detail in the next interview. He told me that he had already decided on the thermodynamics of polymers, specifically of polystyrene, and that this would include the procedure of drawing a phase diagram (type of chart used to show conditions at which thermodynamically distinct phases can occur at equilibrium). At this point, I was feeling a bit more comfortable with Gordon. I had found his perspective on being open with students and focusing a bit more on process over content refreshing and in line with my personal educational philosophy, and I was learning to better keep up with his speaking pace. I left the interview looking forward to our next meeting.

Mary. After initial email contact, I met with Mary in her office for about 30 minutes to discuss the project and ask for her participation. Following the description of the project, she expressed enthusiasm in being included. She did not have any questions about my proposal and did not talk much about herself except to say that she has been interested in teaching for a long time. She seemed energetic and affable, and I was interested to get started working with her.

About two weeks later I met with Mary again in her office to conduct the first interview about her educational background and teaching experience. There was a great flow to the conversation, and I felt like we had quickly developed a rapport. I went through the material in the First Session Guide with her just like I did with Gordon.

Mary told me that she had first taught as a Ph.D. student in the early 1990s. After graduating, she taught a couple more times during that decade. She taught again in 2001 in the same department from which she received her Ph.D. It was at this point when she started to think of herself as a teacher. She became a full-time instructor in the same department several years later and has maintained that job since. She has not had any other professional work experience. Currently, her responsibilities are split between teaching and service activities, such as coordinating an honors program. She teaches several large lecture courses in the fall and spring semesters.

Mary explained that she has tried to make time for professional teacher training. Early in her career, she applied for a week long engineering education scholars program where she was exposed to the general educational research on how people learn. The presenters in the workshop also reviewed teaching strategies, both general and specific to engineering, the latter of which she found very helpful as she had found bridging general educational theory to engineering education practice difficult. She attended a similar training a few years ago at a different university. She has taken advantage of teacher training opportunities on campus and has been active in the American Society for Engineering Education (ASEE), a nonprofit organization of individuals and institutions committed to furthering education in engineering and engineering technology.

Mary expressed that she regularly thinks about her teaching and how to improve it. She explained that when she first started teaching, she saw her role as being the "deliverer of content". That was the way she was taught, and she assumed that was what it meant to be a college instructor. Her exposure to engineering education best practices and realizing that her students were not getting what she wanted them to learn out of her lectures motivated a shift in thinking. She decided that she needed to become more of a mentor to her students:

> And I was focused almost entirely on making sure that every piece of information I expected them to learn went from me, onto the board and into their notes. And I have since really shifted it into me being more of a coach and a mentor and them being responsible for learning. And so, less deliverer of content and more of cheerleader and mentor, and I'm trying to inspire them to realize that this is important to do, but also to take ownership and they have to do it. No matter how well-crafted my presentation is, if they don't turn around and practice these concepts and really want to learn it on their own, they are not going to learn it.

Mary started to see herself as someone who provided exercises and learning resources to her students so they could come to the content on their own as opposed to having it thrust upon them. This meant cultivating a respect for individual differences when it came to preferred methods of learning. She started having her students talk with each other and share ideas in class. She started providing multiple resources to learn a given piece of content. Mary indicated that the provision of this kind of flexibility for the students was very important to her:

> And I also have recently even shifted beyond the ultimate control in the class where I have all these different elements and every student is required to do every element to more of a basket of tricks that each student then can pick and choose what serves them best. So I have reading assignments that students have to do or are supposed to do before class. And they get on and they type out answers to the questions. If they don't learn well from the book, if they're the type that absorbs better if they read it after they have heard about it rather than before, I don't penalize them for that as long as they are participating in other elements of the class, but I strongly encourage them to start out the semester doing it in that order because I think there is benefit, but partway through the semester if they've not seen that benefit and they know personally that they do better seeing it in class and then reading it, they can do that and their grade won't be hurt. And in the end, I think the grade has to reflect what they know of the course content, not what hoops they've jumped through and what rules they followed.

Mary also talked at length about her students. She mentioned that there has been talk by faculty and news media about how students are lazier about schoolwork than in the past. Mary said she believed this to be an unfair assessment as the K-12 education system, "has trained them into a certain mindset that isn't necessarily useful to them." Students resist more interactive and demanding exercises and teaching methods due to unfamiliarity, not laziness. That said, Mary admitted that she has largely come to accept that not all students can be reached. Some are going to resist whatever efforts she makes and "skirt the system" in an attempt to earn a grade without significant learning, a strategy that does not work well in her courses. She indicated that accepting this was a real struggle for her, and she sometimes fantasized about being able to engage every student fully.

Overall, Mary's goal is to motivate her students to approach the objective of the course and its related content in interactive and varied ways, such as with clicker questions in class and video explanations of concepts outside of class. She wants them to feel like she is assisting them in their learning instead of straight lecturing content to them, and believes they are capable of learning how to direct themselves when necessary. She does not believe that delivering only content to students, without asking them to learn how to manage their own learning, is a sufficient use of her time. That said, this can be a real challenge for her in classes that number several hundred students. In a perfect world, she would, "have 25 students and sit around and talk about the content and have deep discussions about what they understood and what they didn't understand." So, she is always thinking about how to make her classes as engaging, interactive, and flexible as possible within that constraint.

I wrapped up the interview with Mary by telling her that she should identify a topic and related concepts and procedures she was going to teach that semester that she would like to discuss in detail in the next interview. She told me that the topic would most likely be torsion, or as she explained it to me, "how force interacts on an object when twisting it." The class we would be talking about had an enrollment of 496 students.

Pam. I met with Pam to describe the project and ask for her participation in it. I gave her the overview. She understood what was required of her and agreed to participate, but expressed concern that she might not present an interesting case. I explained to her that I was interested in understanding her decision-making regarding her course, not evaluating it one way or another. She told me that she did things "by the book," so she was not sure I would find that useful for the study. I asked her what she covered in her class in terms of content from the textbook. She said every chapter but one. I told her reasons for including all the chapters but that one was of value to me, and that I would be looking for similar insights in our discussions. She seemed somewhat relieved at this and told me "ok."

Pam did not have any questions about the procedures of the study and seemed excited to participate. She told me that her focus in the course we would be discussing (heat transfer) was on delivering a lot of content in the most organized way she could manage. She said her goal was to make sure things were "not harder than they had to be" for her students. She said she knew they had to learn a lot of content in her course to succeed in future related courses and go on to be good engineers, so she wanted to make sure they could learn from her efficiently. She explained that the focus of this effort was on her notes, which she had revised many times over the years. She laughed when telling me that she had even read some literature on the value of taking good notes.

Pam was friendly and quite an energetic talker. Several times I had to interject to ensure I understood what she was saying. Before leaving the 30 minute meeting, she told me that she probably would choose something to do with conduction as part of her focus, and that the class we would be talking about had an enrollment of 117 students. I told her that she would have time to think it over following our first interview. I left the meeting positive that she would make a valuable contribution to the study.

I met with Pam two weeks after our initial meeting to conduct the first interview. I asked her the same guided questions I asked Gordon and Mary. She shared with me that she had been teaching full time as an engineering professor for more than two decades. She came into her current position directly from graduate school. For most of her career, she taught two classes a semester. When she first started teaching, she received some mentorship about teaching from a colleague, but aside from that, had no formal teacher training. Over the years, she attended campus workshops on teaching in engineering and ASEE conferences. She used to perform more professional service functions, such as Faculty Senate work and assisting with ABET (Accreditation Board for Engineering and Technology) accreditation, but is currently focused on teaching and transitioning back into research as administrative functions have prevented her from doing much of that.

Pam wanted to be a teacher since the first grade. Her father, an engineer, encouraged her to go into engineering because she enjoyed math and science. Her current position allows her to teach while furthering her knowledge about her field with research. She also sees her research as serving a teaching function. She enjoys mentoring her graduate students and watching them grow into competent researchers.

Pam explained her general teaching philosophy. She covers a lot of content in her courses, and wants to make learning that content as easy and efficient for her students as possible. She sees it as her job to take the content and organize it in a way that demonstrates how the topics continually build on one another. This involves figuring out when to introduce specific topics and when to delay others until the students are ready to move forward. As she explains:

> I think one of the most important things that I do is to organize that material in a way that they can learn in lecture one and the content makes sense and they can learn in lecture ten and the content makes sense in the course material. It's like the world web in that it's all intertwined and to unravel that and to tell a story that makes sense from day 1 to lecture 44 is a puzzle that I enjoy solving. So I need to figure out what material to tell them now and what material to hold back and how to describe maybe a particular problem very basically, in a basic way initially and then describe it in more detail later when they've learned more of the theory and more of the background.

Pam's classes resemble traditional lecture format. She displays notes on an LCD projector and completes them on a tablet PC over the course of a class session. The notes are complete except for sample problems she works out in class with her students. The students have access to these notes. Each lesson starts with a real world example of the concept under discussion. The notes are usually color coded to indicate concepts, problem-solving procedures, and examples and make it easier to visually distinguish the different pieces of information. The goal is to make sure that her students are not left wondering why a particular concept, procedure, or example is in the notes. She walks them through slides of notes: this is the idea and a relevant application; it is important because it can be applied as such; this is how you apply it and here is an example of it being applied. This structure is maintained throughout the course.

Pam has found that her students appreciate the level of organization she puts into the presentation of content. Over the years, as she has gotten more organized, she has observed her students putting in more effort. She assumes this is because they understand more clearly what they have to do to get the kind of grades they want. Her homework assignments serve as one example. She provides students with detailed instructions about expectations, especially for large projects. She also provides the answers for each problem as she has found that students work harder when they realize they cannot determine the given answers. In this way, she conveys to the students that understanding is the goal, not the simply providing the correct answers:

> ...and that is another thing I found is that if I don't give them the answers, they'll just attempt it the best they can and put it aside and turn in work that isn't correct, but if I give them the answer, they'll come to office hours and ask what they've done wrong if they don't get the right answer, and they work harder on the homework because they know whether they have done it correct or not, and they want to do it correctly, but if they don't have that indication that it's wrong, they will just do the best they can and throw it aside.

Pam said that the idea of providing detailed instructions to students not only came from her own observations, but complaints from her students. As they came to her and said that they did not know if they should label figures, for example, she started to think that she should provide them with the same guidelines she used to grade the projects. She has only seen a positive response from her students in both the effort they expend and how they evaluate her performance as a teacher.

Overall, the interview went well, and I was excited by her interest in continually improving the organization of the content in her courses. I did have to interject quite a bit to clarify some of what Pam was saying as she spoke at a quick pace like in our previous meeting, but there were no significant difficulties understanding what she said. I closed the meeting by giving her the task of selecting a topic to talk about in the next interview. She told me that it would most likely be lumped capacitance, a method for simplifying complex heat differential equations. She explained that students found being able to "visualize" it challenging. She talked about how she only has them work with simple geometries using this method, even though it can be applied to more complex geometries. She was currently working on a spreadsheet model to better demonstrate how it works.

Tom. After the email introduction, I met with Tom to talk about the research study and ask for his participation. He was fairly quiet as I went through the overview of the study, only stopping me once to ask clarifying questions about the timing of the study. After the overview, he agreed to participate and talked a bit about his interest in teaching.

Tom told me that he developed an interest in designing effective instruction over the years which led to doing research on pedagogy in engineering. This represented a shift in research focus away from a topic in pure engineering to one that "doesn't result in grants that fund lab space and research assistants." He shared that he had authored a few publications on teaching and had been a member of a research team on other educational research projects. He expressed that his specific interest is in active learning, or modes of instruction that require learners to be responsible for their learning.

Tom and I only spoke for about 20 minutes. His responses to my questions and statements about his teaching history and interests were brief. There were a few awkward moments of silence in our exchanges, and I had the feeling he was not really interested in participating in the study. I felt intimidated by him in a way I did not anticipate and worried a bit about our first interview. That said, I was highly interested in learning about his teaching perspective. He had given up a research focus that had been very rewarding professionally to focus on research in teaching and improving his teaching practice. That indicated to me a strong passion for education, and I wanted to know more about how this manifested in his practice.

I met Tom for our first interview at a local coffee shop per his request. (As a matter of practice, I encouraged the participants to hold the interviews in their offices, but gave them the option of choosing different meeting sites.) I asked about Tom's current employment. He is a full professor in the college working for more than 30 years at the university. He worked in industry as a researcher while earning his master's degree and before studying for his PhD. At his professional job, he realized he had the most fun giving presentations and otherwise functioning in an educational role, so when he was working on his PhD he thought teaching might be a significant part of his career moving forward. While earning his PhD though, he had few teaching opportunities except for filling in for his major advisor a few times, an experience he says taught him how much work goes into creating instruction for a 50 minute period.

Tom made efforts to better understand what constitutes effective instruction from the start. Early in his career, he would attend seminars on good teaching practices offered by one of the support units on campus as he was interested in the “nuts and bolts” of teaching. He would read relevant pedagogical research articles as they “came across his desk”. In the last several years, he became active in the ASEE. Overall, he has been very open to engaging with teaching resources relevant to his practice.

How Tom spends his work time has shifted over the years. While he maintained a fairly even split between teaching and research for much of his time as a faculty member, he now spends more time on teaching and less on research. Regarding his research, the focus has shifted from engineering topics to pedagogical topics in engineering. He started writing textbooks. He started reading more about pedagogy. He started writing about pedagogy and participating in larger research projects on pedagogy with education researchers. Working as an ABET evaluator, he started to think about how he could better represent the college’s objectives for students in his courses. He estimated that he has settled into a 75/12.5/12.5 split of teaching, service, and research efforts with his research now focused on pedagogy instead of technical topics in engineering.

I asked Tom to talk about his goals as an instructor. He shared that he makes heavy use of course objectives and that helping his students learn the principles that underlie and organize the content is essential. This was something he realized about his own learning as a graduate student:

> I think I was probably reasonably typical of most undergraduates. I could get the As, but I didn’t necessarily have a particularly deep understanding of things, probably pretty much a strategic learner and knowing what the professor wanted and you know, that sort of thing. And then when I went to grad school, I took a chemical engineering course, and it was a course that was a required undergraduate course, but it showed how the underlying conservation principles basically govern everything. And when I took separate courses, they were really just, you know, specific applications of this particular principle.

Tom believes exposing his students to these principles explicitly is more effective than only having them work through specific applications:

> The whole idea was that in terms of teaching, if you could just somehow do things that make the big principles obvious and see that everything was special cases from the big principle that you would have a much better conceptual understanding and you would also be a better engineer because you would know that you were dealing with all these special cases and it might be easier to select a special case.

This focus on principles over specific applications of content was featured in Tom's textbook on thermal fluids. He wrote it specifically as an example of how to present that subject to students in a larger conceptual framework. Some of his current research involves trying to understand how to help students learn principles.

Tom explained that he makes heavy use of examples in his classes. He also quizzes his students regularly to check their understanding and puts them into heterogeneous homework teams according to current course grade. He assigns in-class problems that are difficult so students have a chance to work with each other and manage their own learning. During these exercises, Tom monitors the room and provides assistance as needed. He said it was not uncommon for students to stay a bit after the end of class to work on these exercises together and that the feedback on them has been very positive.

Tom talked a little bit about how he thought the kind of students in his classes have changed over the years, and how this has influenced the resources he provides to them. For example, they regularly ask for practice exams, something his previous students did not do. He told me he believes that these students are simply brighter than past students, a shift he contributes to stronger enrollment controls on the different engineering programs (the standards for admission have been raised over the years).

Overall, the interview went very well. It was obvious that Tom is passionate about his teaching. He wants his students to develop strongly principled knowledge about the engineering topics he teaches. He wants them to collaborate when working on in class and out of class assignments that challenge them and introduce them to real world examples (though he sometimes treats parts of the problems in an unrealistic fashion to facilitate learning, like fixing a value that would normally be free to vary). He respects the larger objectives of the department and accreditation body for the college by integrating them into his course objectives.

When we first started the interview, I was concerned that the background noise would pose a problem and that Tom might have an issue speaking openly in a public space. Neither of these concerns proved true. I was nervous interviewing him at first due to the tone of our initial meeting and the fact that I found his demeanor somewhat intimidating. By the end of the interview though, I felt more comfortable with Tom. About halfway through our session, he admitted a negative bias toward education research in that he felt much of what he had seen was too careless with the scientific process. He hesitated saying this a bit as I think he did not want to offend me. I told him I share the same bias, and we had a laugh. From that point on, the atmosphere was significantly more relaxed. We parted after he decided that we would be talking about his thermodynamics course in the next interview, and I gave him the task to select a specific topic to speak about.

Summary. Overall, the initial interviews with the participants went well. I had already starting forming general impressions about how my participants majorly differed from each other in how they approached the practice of teaching. Gordon focuses on helping his students become engineering professionals. Mary works to expose her students to new resources so they can develop more responsibility for their own learning (and in some cases is enabling the independence her most capable students already possess). Pam is constantly working to improve the presentation of her course content. Tom is motivated to get his students to participate more actively in his courses and to understand the larger conceptual structures he sees as tying all the content together.

While these impressions felt natural and were useful in organizing my thoughts about the interviews as presented in this chapter, I knew I would have to be careful conducting the rest of the interviews. I made it a practice to remind myself that these first impressions did not represent the whole story in each case. All the participants were concerned about the organization of course content. All of them were concerned about making sure their students were prepared for the classes they took in the future and their eventual entry into the professional working world. It was a matter of emphasis and style with each participant. I wanted to represent the complexity of their thoughts on teaching, and specifically planning instruction, as accurately as possible.

The next chapter describes the results of the second, third, and fourth interviews with the participants. There is significantly less description of the general logistics of these meetings, as they were conducted in much the same way as the interviews described in this chapter. Except for Tom, who wanted to meet in the same coffee shop for the rest of his interviews, I met everyone in their offices for the remaining interviews. There were no issues with the recordings except for a couple minor audio playback issues or any interruptions, and all the participants seemed to fully understand both the purpose of this project and what I was specifically asking of them in each meeting.

Chapter 5

Topic Planning and Review Interviews

The first rounds of interviews with the participants were conducted to establish their teaching histories and identify their general course planning habits. This chapter describes, organizes, and compares their specific planning activities for selected topics in their chosen courses as detailed in Chapter 3. In the second set of interviews, the participants were asked to describe the topics they selected, how they planned to teach them, and why they made the decisions they did in planning. I then observed the selected topics being taught in the classroom as a show of support more than any sort of evaluation of the class. The third set of interviews was focused on asking the participants to reflect on the instruction of their topics. The fourth set served as a validity test by checking with the participants to make sure I had developed an accurate understanding of the influences important to the participants in planning to teach their selected topics. The scripts used for each of these interviews can be found in Appendix A.

This chapter is structured as follows. First, the results from interviews two, three, and four are described, organized, and analyzed by each participant. Second, a description of the commonalities and differences of planning influences across participants is given. As mentioned in Chapter 4, I used personal knowledge of the learning and instructional sciences in writing these summaries to provide additional commentary on participants' planning decisions. These comments are often presented parenthetically throughout the text.

Issues of reliability and validity are discussed throughout the analysis. Given that this study was mostly qualitative in nature (though with some reduction in the form of counts of behavior), it is necessary to be explicit about what is meant when talking about reliability and validity as the qualitative research community is divided on how to apply terms so strongly associated with quantitative measurement to this kind of work (Golafshani, 2003). Though some qualitative researchers reject those terms completely and substitute words like "verification" and "trustworthiness" in an effort to stress qualitative research as a distinct approach (Creswell, 1998), there is no meaning inherent in the terms reliability and validity from a measurement standpoint that precludes using them with data gathered through qualitative methods (Messick, 1995), so they are used in this paper with clarification.

Generally, the reliability of the results is established by indicating the degree to which the character of the participants' responses seemed consistent throughout the interviews. It is also established by making the case that the interviews and data analyses were conducted with a certain amount of organizational rigor. The validity of this study is established by asking the participants to assess the accuracy of my summaries regarding their instructional planning (the focus of interview four), as well as being open about my personal perspective on the participants. (A review of Chapter 3 will reveal that I began doing this in the very first interview.) The hope, in the end, is to equip the reader to better evaluate the trustworthiness of my observations and conclusions.

Gordon

Second Interview. In the second interview, I asked Gordon to talk about the topic he planned to teach in detail. He was teaching a new course on polymers primarily intended for undergraduate students, but it was also open to graduate students. He told me the course had 33 junior and senior students and a few (never got an exact number) graduate students. He indicated that the topic he wanted to discuss was the construction of phase diagrams as part of a larger unit on the thermodynamics of polymers. As he explained it:

> In other words, when you mix a polymer and a solvent sometimes the polymer will dissolve in the solvent and sometimes it won't. That will depend, of course, on how much polymer you try to dissolve and what temperature, etc. And you can describe all that with something called a phase diagram which essentially, you know, you can imagine one axis could be something like temperature, and the other axis could be composition. This tells you for what composition and temperature whether the materials are actually miscible or whether they actually separate like oil

> and water into two distinct phases. And we can, actually there has been a lot of work done sort of analytically in being able to describe the equations that would essentially allow you to predict that behavior.

Gordon was interested in teaching his students how to understand and create these diagrams which tended to consist of graphs along with equations describing the process, a development of conceptual and procedural knowledge. He wanted them to be able to finish incomplete diagrams by examining specific situations the diagrams were meant to describe. He wanted them to be able to evaluate, for themselves, just how much detail needed to go into a diagram to best represent whatever conditions they were looking at. For example, if Gordon asked his students to create a phase diagram of salt mixing with water, he would expect them to be able to represent that relationship, one in which eventually the solubility limit of the salt in the water is reached, graphically or using equations or both. This would include accounting for other added factors he considered pertinent, such as temperature or the purity of the water. In the end, a student would be using her diagram to make the argument that yes, what she has demonstrated is sufficient to explain the reality of the relationship.

Gordon expressed that he believed his students would be able to learn how to operate from problems that gave incomplete information and work from other graphs or equations to complete the phase diagram. He wanted them to understand that sometimes there are limitations in solving problems and that being aware of them and developing ways to work around them was part of being a good engineer. Some of the phase diagram problems might start with incomplete graphical information that would require moving back and forth between equations to derive the missing information. In the end, the students would need to know how to understand graphical and numeric representations of mixed polymers and solvents. Gordon knew they would be more comfortable working with the equations coming into class given their previous course experience, but wanted to give the students the opportunity to become more versatile in their problem-solving capabilities by first working with their strengths. He knew that he would be asking them to engage in cognitive processes of evaluation and creation (though he did not use those words specifically), and that his students, being more accustomed to application in the knowledge domain, would struggle

> I am trying to build up versatility more so than necessarily pushing the ability to extract information from graphs. But I will certainly concede to the fact that from my experience teaching chemical engineers is that they are much more comfortable with equations at least especially in the introductory courses – sophomore level and maybe first semester junior level because I think they are more used to that given the general education of you know, calculus and even physics. To hit them a little more with equations than graphs which is appropriate and so then when we start them in chemical engineering we do cover, you know, extract information from tables and graphical which are other ways in which you can sort of concisely represent information and extract it, you know, and use it for whatever purpose you need it. I think in polymer science and even in any of these topics it is important to have versatility to be able to go back and forth.

Gordon then went into a rather technical discussion of polymer science and the importance of introducing students to the thermodynamics of polymers as his students were likely to, "run across polymers in a variety of different disciplines whether they be industry, materials applications, and bio applications." Working with phase diagrams as a procedure was his way of making this introduction.

I asked Gordon what the structure of the class on the topic of phase diagrams would look like. He explained that he would introduce the topic with a problem statement involving a polymer to be mixed with a solvent. Students would be asked to explicate the problem space in writing at their seats in small groups. (He did not indicate that he had strong procedures for how to create or manage these groups when asked.) Then he would host a larger class discussion of the factors the student groups considered in noting whatever problem features they considered salient. Gordon would lecture to the class about ways of approaching the problem given the features identified by the student groups. They would then be asked to try to solve the problem given one or more of the methods discussed, again in small groups. Gordon explained that the following homework assignment would start with more direct polymer in solvent problems and then progress to open-ended problems as, "… some need to be much more open ended because nobody is going to, you know, when you are out in industry or anywhere, no one is going to be, 'Well, if I gave you this parameter and that parameter and this parameter would the answer be yes or no?' It doesn't typically go that way. You typically get something like, 'I want to polymerize this and that, is that going to work?'"

Gordon stressed that he expected his students to be resourceful in creating solutions, even if that meant referring to resources not discussed directly in class, and that this is the kind of thinking that is necessary to be a successful engineer or researcher. He felt that this versatility was well-developed in graduate school, but should be stressed more than it is in typical undergraduate engineering programs:

> The way in which the paradigm for engineering is, it is very well designed to teach some math skills, how to mechanically solve a problem. With the exception of design courses and some of these engineering design things and stuff like that, for the most part the majority of the curricula is not designed to be able to answer open-ended questions. But I think in the end that's really valuable. If I could teach them the mechanics while enforcing that in some way, why not do it?

I asked Gordon if this approach of having his students work on more open ended phase diagram problems would mean that they would not have time to work on as many problems as they would if they were more direct. He said this was not a concern of his, though he understood why it might be for others. To him, it was more important that they get the opportunity to experience what it is like to function as engineers, or those who analyze, evaluate, and create to solve problems, than simply develop as technicians, or those who simple remember, understand, and apply procedures.

Gordon offered that he was concerned about how much time to spend lecturing on this topic as he was aware of research than indicated that too much content delivered in a given time period could overwhelm students' abilities to retain it. He offered that he experienced this as an undergraduate and graduate student, which further solidified his decision to focus on giving his students an open ended phase diagram problem in class to discuss and work through in groups. Gordon would conduct a number of smaller lectures (no longer than 15 minutes each – another idea from the same research) to illustrate concepts then as the class worked through various parts of the given problem. He knew he would be very selective with the content as, “a big part of teaching is communicating the right details,” and it seemed that Gordon had an informal but strong sense of attentional and memory limits in learning. He made several references to his 15 minute “limit”. He also made several references to paring down the features of assigned problems so as to avoid straining students’ abilities to attend to and process given information.

Gordon then spoke more about his thoughts on trying to tie the instruction of polymers dissolving in solvents and representing that with a phase diagram into his students’ current knowledge as well as what they would be asked to learn in future lessons. As stated earlier, he knew they would be more comfortable with representations of problem states given in equations, so he would start with that. He also knew he would need to prepare them to understand how a polymer would interact with another polymer, an extension of the idea of a polymer interacting with a solvent. Understanding how to represent polymers interacting with solvents in a phase diagram would serve to be foundational for many of the other topics in the course as well as topics to come in later courses.

Gordon also expressed that some topics he considered foundational and important just were not feasible to cover in this class given his students’ lack of knowledge, such as the mechanical properties of polymers. Studying this requires a strong knowledge of fluid mechanics, and he felt he would not be able to address any deficiencies students might have on this topic in the time he had available for all the topics he wanted to cover in the course. Representing polymers in solvents using phase diagrams, he decided, represented a case where the students’ prior knowledge was sufficient to make instruction of it efficient in comparison.

Gordon explained that he planned to make use of one or more analogies to teach the concepts associated with this topic. When talking about similar topics in the past, he had used analogies of spaghetti on a plate, an inebriated friend walking home from a bar, and filling a toy chest with different colored balls. He stressed that using analogies like this was a typical in his teaching, and that he often came up with new analogies on the spot in response to students expressing confusion or asking questions.

As the interview drew to a close, I asked him about how he thought his students might approach the lectures and activities in the class. Given what he knew about his students in general, Gordon estimated that about 60 to 70 percent might enjoy it. Again, he expressed his assumption that many of them would express some frustration when trying to solve the more open-ended problems as he thought they probably would not be used to performing in that way. Gordon then started to talk about how if his class was a bit smaller, say 15 students, he would approach some of the planned activities differently. He told me that he thought it was more difficult to make sure he had his students' attention focused on visuals in larger classes and that the larger class size made doing some activities, such as structuring activities around games, more difficult. He also said he would prefer to have his students work in pairs rather than groups as he thought students were typically less able to manage group work than paired work.

We finished the interview by reviewing when the topic would be covered in his class so I could make arrangements to observe it. We also scheduled the interview to follow the class observation. Overall, this interview went well. Gordon seemed to have an easy time talking about how he planned to teach this topic, and I had no problems understanding what he said despite the fact that he speaks quickly. He seemed very well prepared for the interview, and I thought that this might partly be because this was a new course and as a result had been thinking about it more frequently than the other participants.

It was clear that Gordon was focused on giving his students experiences that prepared them for professional work or research as graduate students by promoting the development of what he referred to as "versatility". He stressed that he wanted his students to develop a level of comfort working on open ended problems and drawing upon different resources in solving them. Gordon also talked quite a bit about how he considers the previous educational experiences of his students in creating lectures, activities, and assignments. Gordon also admitted that he was very comfortable with the idea of spending more time in class working on a few difficult problems with an emphasis on multiple short lectures as opposed to covering more content. I found this surprising as the general course planning research indicated that the tension of teaching "depth vs. breadth" as a common concern.

Table 3 presents a summary of the various influence categories on Gordon's plans for teaching the topic of polymers in solvents using phase diagrams. The pedagogical constructions Gordon planned to use to teach this topic, such as particular analogies, examples, and exercises, are not represented in the table. As stated previously, the focus of this research was more on why the participants made the teaching decisions they did and less on nature of the decisions (though many of them are described throughout this text of course).

As a reminder, it needs to be noted again that each count in a particular category does not necessarily represent a unique influence. For example, Gordon brought up the fact that most of his students do not have strong knowledge of plastics mechanics regarding two different planning decisions. He mentioned this once regarding the lecture and once regarding the homework assignment. This reference to weak knowledge of plastics mechanics constituted two counts in his five counts of unprompted knowledge about students. Repeats of influences on the same decisions were not counted more than once. For example, Gordon twice mentioned his desire to break up his lectures with an activity every fifteen minutes because of exposure to research on lectures. This represented only one count of general pedagogical knowledge.

Table 3. Influences on Topic Planning: Gordon

	Subject Matter Knowledge	General Pedagogical Knowledge	Knowledge About Students	Curricular Knowledge	Orientations Toward Teaching & Learning	Resources	**Total**
Unprompted	7	5	5	2	10	0	29 (73%)
Prompted	0	3	2	2	2	2	11 (27%)
Total	7 (17.5%)	8 (20%)	7 (17.5%)	4 (10%)	12 (30%)	2 (5%)	40

Overall, Gordon referenced 40 influences across the six different categories on his instructional planning for his selected topic. Twenty-nine of these (73%) were unprompted, meaning that they were identified as part of his natural discussion. For example, Gordon talked at length about his factual, procedural, and conceptual knowledge on the subject of polymers in solvents without any prompting. Similarly, he talked a lot about his educational philosophy and goals for his students (versatility) and his desire to engage his students' prior knowledge while respecting their attentional limits without much prompting. Conversely, he did not offer any information about how resources either constrained or enhanced his instructional planning until I asked him, and then talked mostly about class size as mentioned.

For the influences that were more evenly divided between unprompted and unprompted, I asked Gordon about specific examples when I had the feeling that he might have more to say about a particular influence he already mentioned without prompting. For instance, with curricular knowledge Gordon spoke without prompting about how his students' previous course experience and future courses affected his planning, but not about how their currently enrolled courses affected his planning until I made a point of bringing that up. Similarly, he talked a lot about his students' knowledge and how that influenced his planning without prompting, but did not mention anything about motivation until asked, where he talked about trying to engage his students' interest by assigning problems that represented more authentic engineering work.

In the first interview, Gordon talked about influences on his general course planning activities. Counts for these are indicated in Table 4.

Table 4. Influences on Course Planning: Gordon

	Subject Matter Knowledge	General Pedagogical Knowledge	Knowledge About Students	Curricular Knowledge	Orientations Toward Teaching & Learning	Resources	**Total**
Unprompted	0	1	1	2	12	1	17 (100%)
Prompted	0	0	0	0	0	0	0 (0%)
Total	0	1 (6%)	1 (6%)	2 (12%)	12 (70%)	1 (6%)	17

As captured in the table, much of Gordon's talk on course planning was driven by his educational goal of helping students to become versatile thinkers and develop some practical skills as working professionals. (Seventy percent of the identified influences fell into that category.) His knowledge of how students learn and their prior knowledge did not come up to a great degree in that discussion. He did not talk about his knowledge of engineering in particular and how that drives his planning, even when asked, though this was perhaps logical given that he was asked to speak generally about his classes.

Some of these patterns were reflected at the topic level. As discussed, Gordon made quite a few references to his educational goals, though the discussion was not dominated by that kind of talk as it was in the first interview (30% and majority in the second interview; 70% and majority in the first interview). Instead, it was fairly well balanced by references to every other influence type except resources. Like in the first interview, Gordon did not need much prompting to talk about how this influence played a role in his planning, but it was integrated with his understanding of the subject matter to be taught, his awareness of the larger curriculum, his knowledge of teaching, and his knowledge about his students.

Class Observation. About a month after the second interview, I attended Gordon's class on using phase diagrams to describe how polymers behave in solvents. Gordon presented the material similarly to how he said he would. Using Power Point slides on a projector, he started the class with a presentation on an example polymer in solvent problem. He asked the students some questions about it which generated a discussion that lasted several minutes. He then had the students work in teams of two or three (he did not assign groups, but instead had the students work with those seated next to them) on an open ended problem as discussed. Gordon then reviewed the results of that exercise with the class and started another lecture. There was a second exercise administered like the first, a report out, and then a small lecture to finish the class.

Overall, the instruction seemed effective and efficient, if not very energetic. The students seemed engaged and committed to working on the given exercises. Gordon posed a few questions throughout the session and seemed to provide quick answers that the students found satisfactory. I met with Gordon after the class and scheduled to meet with him three weeks later to discuss the class.

Third Interview. Gordon started the interview by explaining that the class I observed picked up in the middle of his lesson on using phase diagrams to describe polymers in solvents. He shared that he went over how to describe the energy state of the polymers of interest in the previous class to prepare students to talk about how they might interact. He then talked about the structure of the class – lectures interspersed with the students working in groups of two and three:

> I try to do that as much as possible. At some point, I saw this plot, which is the attention span as a function of lecture time, which drops after 15 minutes to something like…students, on average, are only capturing...I don't remember exactly what the data showed, but if it was either 30% of the students, or whatever, are still paying attention, or students are only grasping approximately 30% of the concepts; either way. In any case, the attention drops dramatically is what that signified as a function of lecture time.
>
> That means that, in principle, I need to break up the class once, preferably twice. In other words, if I have a 50-minute class, if I break it into 15, 15, and 20, then that's the ideal case to try to maintain attention. Whether that’s actually having them stand up, twist in a circle, and then come sit back down to reset their curve, or whether that's actually to do an exercise. That's the main goal of stopping class, so that's the Number 1 priority. Number 2 is, of course, to get them to think about the material, because that's clearly really important, and then to get them to somehow think about how to do the problems.

I asked Gordon why he thought there were relatively few questions from his students. He said that he usually gets more questions as his students seem comfortable with him and are a “lively group.” He believed that the instructions for his exercises this time were a bit more clear and specific than previous exercises, so partly attributed the smaller number of questions to that. He also thought the students seemed more “in tune” with the lecture than average given the kinds of questions they did ask.

Gordon stated that he was pleased how well his students took to the exercises as the, “effectiveness of the exercises fluctuates significantly.” Given the open ended nature of his questions, they sometimes have difficulty developing plausible solutions and experience frustration. He thought that reviewing the basics in the previous lecture gave them time to think over the concepts before being asked to work with them, and that this could have also made a difference. Additionally, the math involved in understanding the concepts being mostly algebra made the exercises easier.

During the class, I had noticed that Gordon asked his students to ignore certain terms and make certain assumptions while working on the two exercises. When asked to talk about this point, he explained that he tried to get his students to understand that all models are wrong in one way or another, and in these cases he was telling them to ignore factors that were less significant in order to make using the given models easier. Yes, he gave his students open ended problems, but he wanted to cut down on the possibility of them “getting lost” by focusing on elements he considered less essential. He said that these less essential elements tended to be those that had been most likely covered in his students’ previous courses, so he designed the problems so they would not require too much review of previously taught topics. Essentially, Gordon made strategic decisions to cut down on his students having to engage in extraneous processing in order to focus on his lesson objectives.

Gordon talked about his preparation for the class. He explained that he planned out his exercises in detail, but reserved the option to come up with exercises on the spot given his understanding of what his students were thinking. As he said, “I get to a particular point and I realize, at the spur-of-the-moment, ‘You know what? This would be a great thing to stop and ask them.’ Sometimes I do, off-the-cuff, ask them particular questions and we'll do exercises like that." He maintained that this kind of flexibility was essential since it was easy to over or underestimate how much students had learned in previous courses.

I asked Gordon if he thought he would make a lot of revisions to this lesson the next time he taught it. He again said that he thought it went well and that he probably would not make any changes to the concepts or procedures taught. He said he would probably use a visual aid for the model under discussion (a lattice model). A few of the questions the students asked suggested that they were not thinking about it with total clarity. He said this would be an easy change that did not require modifying anything else about the presentation.

When asked about revisions to the course overall, Gordon said that there were to be some for sure, but the he felt a level of comfort with the course, even though it was new, that was uncommon with his other courses. He explained that his research interests build upon the material covered in the course, so he is extremely familiar with the subject. With some of his other courses, he has to spend more time reviewing material before developing lectures and exercises. He recognized that being too versed in the material can make it hard for someone to teach it at a less sophisticated level, but said that has not been a problem for him except when developing exams. Being more knowledgeable about the material, he sometimes makes them more difficult than intended. Conversely, when he is less knowledgeable about the material, he sometimes makes the exams too easy.

Fourth Interview. I had two goals for the fourth and last interview with Gordon. First, I wanted to review my perceptions of what he told me regarding factors he considered important in planning instruction. It was important that I represented his approach accurately as I wanted to make sure my impressions from the first and second interviews were valid. Second, I wanted to ask him his thoughts on participating in the study. I wanted to know why he chose to participate as well as how he found the experience overall.

A week before this interview, I had gave Gordon a list of factors, using his language as much as possible, that I heard him reference directly and indirectly as being important to planning his courses and the topic he choose. I told him he would be asked to rank them in order of importance in the last interview. When we met, I reviewed the directions and had him start right in on the exercise. He was told that he could use ties and add other influences as needed. The directions to the first part read, “Below you will find a list of factors you mentioned as being important when thinking about how to teach your course. As best you can, please rank them in order of how influential they were on your planning behavior from most to least influential.”

Table 5. Course Level Influence Ranking: Gordon

Factor	Ranking	Notes
a desire to focus on the process in problem solving	1	Gordon added “using critical concepts” to this.
student characteristics	2	
available time and other resources	3	
how the course relates to others	4	This is relation to other courses either taught by Gordon or others in his department.
teaching work/life skills (ex. memo writing)	5	
a desire to use certain kinds of assessments	6	
ABET (accreditation) standards	7	

After completing the first exercise, he was asked to do the same task for his selected topic of the thermodynamics of polymers in solvents. The directions read, “Below you will find a list of factors you mentioned as being important when thinking about how to teach the topic of thermodynamics of polymer solutions. As best you can, please rank them in order of how influential they were on your planning behavior from most to least influential.”

Table 6. Topic Level Influence Ranking: Gordon

Factor	Ranking	Notes
a desire to focus on the process in problem solving	1	Gordon added “using critical concepts” to this.
student characteristics	2	
students being able to work with different representation (equations, graphs, etc.)	3	
the use of outside examples/analogies (ex. spaghetti)	4	
alignment with the rest of the course	4 or 5	Gordon added this factor.
the use of group activities	5	

While working through these exercises, Gordon asked a few clarifying questions about the factors. For example, he wanted to know if “available time and other resources” referred to available class time or time outside of class. (I told it him was both.) He also asked a question about “how the course relates to others” and was informed that this meant how the course was integrated into the rest of the curriculum. He was required to speak out loud as he proceeded through these exercises and seemed to understand what the rest of the factors represented without further clarification.

Largely, his rankings reflected my expectations based on the discussions in the previous interviews. Gordon ranked “a desire to focus on the process in problem solving” and “student characteristics” at ranks one and two respectively at both the course and selected topic level. He summarized his approach by saying that he asks himself, “What are the critical concepts that are important for me to communicate in this course?” He then determines which open ended problems he can use to help students learn how to apply those concepts and related procedures to specific situations (in this case how polymers behave in solvents and how to represent that). These determinations are made taking his students’ prior knowledge into account, most importantly how difficult he believes they will find the problems based on their most likely previous course experience. Gordon tries to use real world examples to motivate his students’ interest and analogies to engage their prior knowledge when presenting new information, but admits that is not always possible. He also tries to use certain types of activities and assessments he considers to be more engaging such as working in groups or running *Jeopardy* type games to review content. He does all this while trying to keep in mind that talking too long about anything without some sort of shift every 10 to 15 minutes, as described in the research he read on this topic, can result in losing the attention of his students.

After completing these exercises, I asked Gordon two questions about the study itself to gather feedback relevant to future studies on planning for instruction. I asked what motivated him to participate in the study. He responded:

> Curiosity about teaching. Just to have more discussions about teaching and so on. One of the things I mentioned is that I never really sat down and tried to rank things like this. At the same time, I do recognize and think that they're critical to effectively teach, because how you prioritize what's really important in terms of planning the course or executing how you teach the course, I think, in the end is the key because that's what allows you to make the right versus wrong decisions. We have no training in articulating and we don't do a good job of articulating it ourselves.

I also asked Gordon what his advice would be for future participants in a similar study. He said that they should "react however they are going to react" and not worry about how they might sound as again, being articulate about teaching is not something most faculty have been trained to do.

Mary

Second Interview. In the first interview, Mary told me we would be talking about her materials class of roughly 500 undergraduate students. She had taught this course several times over the years. To start the interview, she identified torsion as the topic she wanted to discuss. She explained that much of the class consisted of identification of how outside forces (loads) acting on an object can affect the material inside and outside on the surface. The first type of force they covered was axial, where objects are being stretched or compressed. Torsion is a twisting force.

She said she picked this topic because students often had a hard time visualizing it. “It’s easy to picture things being twisted, but to picture what is happening internally with the loads at the molecular level and how they are holding onto each other and how you represent that with calculations is a bit harder.” She has noticed that students ask more questions about this section and struggle with torsion problems on the exam. She said she believed this was because while an axial force has a uniform effect on and throughout a material, one that is balanced on both ends of the force, the effect of torsion varies across the material. Students have to learn how to describe how the force affects the material internally and how this may be deforming it at different points. In short, students are asked to consider a new class of models that often require an increased demand on their cognitive capabilities, and they struggle.

Mary described herself as a very visual, physical learner. She enjoys this particular class because she can often use tangible objects to illustrate concepts “…as opposed to things that happen at the atomic level which I need a microscope to see.” She reflected on the first physical prop she used when she started teaching, received from a colleague, a clear piece of tubing with lines drawn on the inside. Now she uses potatoes and swim noodles, among other objects. Mary starts this class off using a potato to demonstrate the general concept of forces, but she uses swim noodles to help her explain torsion as she can twist them appropriately. When her classes were much smaller, she used to give every student a piece of pipe insulation so they could manipulate it along with her demonstration, but she said that was no longer feasible given the size of her class now. It seemed that over time, Mary had developed an understanding of the fact that students learn better when multiple senses are engaged simultaneously, notably through verbal and visual material (Mayer, 2011).

Mary said another difficulty students have with torsion is that they are asked to understand how torsion affects a material internally at a particular point using a cube as a mental model. The cube representation makes it possible to fully represent how stresses are operating at that point and enable mathematical operations on them, but:

> The problem is that it looks like a cube but doesn't look like a swim noodle or a potato or any real object. And so the notion that this cube is as if you had sliced the potato open and diced out a little piece of material and now you are dealing with just that. And so it's kind of abstract to then give them a problem that just has this cube picture with these stresses drawn on it without any context to where those stresses came from, what kind of loads produced them so that then they can manipulate that to make conclusions about whether the material will fail or not.

So, in the process of working up to the topic of torsion, students are dealing with stress that varies across the material, as opposed to when dealing with an axial force, and they are asked to work with a model, a cube that can represent forces acting on it, that has no concrete analog. This lack of a concrete example proves challenging for the students.

Mary said that most students do not come to her class well equipped to deal with challenges like this. They are used to working through given procedures like math problems, but she has found that when she probes their understanding during class with questions using a clicker (a device that allows students to answer multiple choice questions to be shared with the teacher in real time), the students present erroneous understandings of concepts. When talking to her students, they sometimes express that they do not understand why not having a full understanding of the concepts is a problem as long as they can generate the correct answers through the application of procedures. So, given the fact that they have to develop a strong understanding of the cube model to solve problems, it does not surprise Mary that they experience difficulty with this.

When I reviewed my understanding of what Mary was saying here, she was quick to point out that the fact that many of her students were "calculators" was not necessarily a detriment. They were trained to get the correct answers. Many of them were drawn to engineering because they did well in mathematics and could get the correct answers – and all that procedural knowledge is important. If they could understand the concepts but not the procedures, they would be in a difficult place. Mary then sees it as her job to help her students through the transition of working with more difficult concepts in preparation to solve problems, in this case understanding how to visualize the stress effects of torsion using a cube. They simply develop comfort with calculations first. Mary said that was her experience as a student too – her ability to solve given problems developed much earlier than her ability to frame them conceptually.

Mary expressed that it was essential for her to monitor how well students were learning torsion as she lectured on the topic. Using clickers as described above, she asks questions that she suspects will reveal emerging misconceptions about the subject matter being taught. (Before clickers were available, she gave each student a set of four colored cards to hold up to indicate answers.) Regarding torsion, experience has shown that her students have trouble understanding where the initial stress point on the cube should be and then how stress should radiate out from that point. After she asks these questions and reveals how the students answered, she has them talk to each other for a bit. She then asks the same questions so they can revote. She said that this often means the responses get better, but sometimes they get worse. In addition to using this exercise to develop a better understanding of where her students are at, she said it was important that students get comfortable talking to each other and asking questions. She thinks that students get a morale boost when they realize that they are not alone in having trouble understanding this topic. Mary also hopes that her students might learn something from her peers in these interactions, something she says studies have indicated as being a highly effective learning strategy.

Mary said that she also thinks this practice of having the students consult with each other before she addresses any misconceptions improves student engagement. They have to put some effort into trying to correct their perceptions before she will offer a full explanation. She believes this makes them more goal motivated. She said that without this step of having the students work a bit, they will just write down what she says and be somewhat apathetic about it. She clarified that she does not go through this process with every topic, only those that she knows students will find difficult. With easier topics, she simply asks them clicker questions to reinforce that they understand them.

Even though Mary does not have access to a good visual analogy to explain the stress torsion creates in an object internally, Mary said she still tries to approach the instruction with visual representations to accompany her explanations. She has a document camera that displays a picture of a stress cube, and she draws on it as she lectures. New for this year, she also had a video she made with a colleague demonstrating the topic to both play in class and serve as a reference for the homework assignment on torsion.

In asking questions about the logistics of her lesson on torsion, Mary shared that while she previously gave her students notes as a handout, she no longer does. She developed a perception that giving notes resulted in her students paying less attention, even when she gave them half-completed notes they would have to finish during class. She identified diagrams as an exception. Students are expected to draw them in class, but she posts completed diagrams online for them to access after class. She knows that drawing in class can take too much time for some students and result in erroneous drawings.

Mary talked about her flexible approach to teaching. As mentioned in her first interview, she originally thought her main role as a teacher was to deliver content solely through lecturing. In fact, she used to write out every step of her lecture beforehand and rarely deviate from script. Now she uses whatever techniques she can to help get her students understand challenging topics like torsion. To her, the only way to do that efficiently and effectively is to constantly assess their understanding. She expects her students to come to class having read the assignments and viewed the related videos so she can spend additional time talking about the more challenging aspects of the topic being taught. Again, she tries to maintain flexibility by being, “mindful of the fact that some students don’t get it right away when they read the book, and so I view my class as reinforcement of that, but that other students who can get it then can come in and ask specific questions about the pieces that they don’t understand.”

This segued in into a larger discussion of Mary’s desire that her students learn how to effectively consult different resources when learning. She wants her students to learn to be successful in their own ways, and she facilitates that by providing different avenues to learn any given topic. So with torsion, she provides visual examples, including a video, indicates appropriate sections of the text for them to read, stresses that they should visit her or the teaching assistants if they want to talk more about it, and uses the clickers and small class discussions. She said that it does not matter if a student decides to not take advantage of every opportunity and simply work from the text as long as the student is successful. She is there to provide options for them, not make sure they "do this or that."

Mary said she recognizes that while she is a visual learner, she believes that people have different learning styles and tries to respect that. Additionally, she believes that trying to micromanage the activities of students, typically by motivation through grading, does not work. She said she used to assign points for every activity she could, including reviews of readings, but it seemed to have little effect on learning and grades and generated a lot of work for her and her teaching assistants. She considers her current approach to be more respectful of students as adults in any case and seems to be aware that there exists a balance between using assessment for feedback and not overburdening the learner with too many assessments that may interfere with the processing of new information. In essence, Mary seems to possess a desire for her students develop their self-regulated learning capabilities, and tries to motivate them to do so by providing them with numerous resources and being open to multiple ways of achieving success.

I asked Mary more about the torsion problems she leads her students through in class. She said that in recent years she has focused on trying not to teach her students content that will not be useful to them as practicing engineers. For example, she used to teach her students to derive the formulas needed to solve torsion problems, but she received feedback that the students wanted more practice applying the formulas to solve problems, especially when she did not ask for derivations on her exams. She realized that most of her students would become practicing engineers and that the derivations would not be that useful. For those that went onto graduate school, they would be introduced to the derivations then. Now she teaches them about the derivations in a conceptual manner so they know where the formulas come from in general, but this is to improve their understanding of how to solve problems, not have them learn how to do the derivations.

Mary said she plans to use a somewhat different strategy to introduce torque as a topic this time around. In previous years she had her students work through readings before class so that they had some familiarity with the basics and the conceptual overview of the derivations used in solving torque problems. This year, part of that assignment includes watching the aforementioned video. This video is part of a series she and her colleagues created for several difficult topics that are related to each other across a couple different courses in the curricular sequence. She hopes they will find this complementary to the readings. The videos are a bit more comprehensive than the readings, so she also hopes that, "I'll spend even less time going through parts of the derivation in class and more time fielding specific questions of things that the students don't understand. And then, hopefully, more time talking about the application and limitations and the visualization." The idea is that the video will ground these students in the basics better than the readings have with past students. Mary thinks this will to free up additional time to address the more difficult parts of the topic during class. She added that the videos also feature visualizations of stress forces acting inside an object that are impossible to replicate with swim noodles or flat images.

I asked Mary to talk about the guided readings she uses for torque. She explained that they are chapter readings with a series of questions meant to be answered while reading, such as "What do you think this example means?" or "Why do you think the authors took this step in solving the problem?" She had participated in an educational research project a few years ago that convinced her there is merit in having students give interpretations of readings even if they are not graded (and these are not). This elaboration results in better learning, and as a result, students become more engaged. Additionally, she and her TAs randomly choose a few of the students' guided reading answers to review so she is better informed for the lecture.

Mary said that she gives her students a homework assignment on torque. There are a set of problems which feature simplistic situations but require a difficult "thought process that gets you from what you are given to what you have to find." She said the problems are designed so that students who take some time to plan how to solve the problems before starting on them will have an easier time than those who do not. Her goal with these problems is to teach her students the value of strategic thinking. Many of the problems can be approached in multiple ways, a truism for engineering as a practice. She hopes that giving her students problems that reward planning and creativity will improve their motivation.

I checked again with Mary that there were no graded assignments associated with her lesson on torque. She confirmed and shared her thoughts on grading. As mentioned, she and her TAs used to grade every assignment. Now they only grade exams and award general participation grades to students. Mary said that in addition to her previous grading scheme taking too much time, she found that students focused too much on how to gain every point while focusing less on understanding the topics in the course. The current structure encourages students to do the assignments in preparation for the challenging classes, quizzes, and exams. This also supports her goal of giving her students options. Some students do not need to spend as much time as others preparing and may decide to skip a guided reading here and there, and that is fine with her.

Mary talked a little bit about how she organizes the lessons on torque in relation to the rest of the course. She frames the discussion of torque by talking about it factually and stressing why it is important to understand it. She said that the text used for the class does not do a good job of this. She also uses a graphic to demonstrate where the topic of torque fits in the structure of the course. The graphic is a "Parthenon type image of three columns because there is really three core elements to the course that we bring into every derivation." The columns represent the larger topics of stress, strain, and materials with chains that run between them. Every part is labeled, and the hope is that this multimedia presentation helps students understand the larger organization of the course. A colleague shared this graphic with her, and she has found it useful to refer back to it with the introduction of each topic.

We finished the interview and scheduled the class observation. We also scheduled the interview to follow the class observation. Overall, this interview went very well. Mary was well-prepared and had a lot to say. It was even a bit difficult to keep up at times. This seemed to be largely because she had taught the course and topic quite a few times and was constantly making revisions to her approach, so she had a lot of material to draw from.

One of Gordon’s goals for his students was for them to develop into versatile problem solvers. Mary indicated that she wanted this for her students too, but she was also very interested in giving them multiple resources to learn in an effort to support their preferred learning styles. Mary expressed a high level of comfort with being somewhat “hands-off” with her students. This was reflected in the way she talked about her assignments and, most important to the students, her grading scheme. Several times she said she was comfortable with the idea of students who missed class but were still able to do well in the course by studying the other resources she made available (though she thought it was doubtful this was feasible for the most part). This was true for her lesson on torque. There were no graded assignments associated with it, and students had access to guided readings, a video lesson, the recitation sections, and the normal class presentations.

Mary stressed the importance of assessing student understanding without overwhelming them with too many assessments and having them become more motivated to ask questions. It was clear she spent a lot of time determining what questions she would ask during her presentation on torque that would reveal common misconceptions. Having the students respond using clickers would create the opportunity to have them talk to each other about their answers and potentially learn from their peers. She also thought framing the discussion in terms of practical use was very important, and using props like swim noodles and graphics like the columns to engage students with visual representations in addition to verbal was necessary to assist their developing perceptions.

Table 7 presents a summary of the various influence categories on Mary’s plans for teaching her students about torque.

Table 7. Influences on Topic Planning: Mary

	Subject Matter Knowledge	General Pedagogical Knowledge	Knowledge About Students	Curricular Knowledge	Orientations Toward Teaching & Learning	Resources	**Total**
Unprompted	7	8	6	1	3	4	29 (85%)
Prompted	4	1	0	0	0	0	5 (15%)
Total	11 (32%)	9 (26%)	6 (18%)	1 (3%)	3 (9%)	4 (12%)	34

Overall, Mary referenced 34 influences across the six different categories while talking about torque. The vast majority of these (85%) were unprompted, meaning that they were identified as part of her natural discussion. Mary laid out her philosophy about her goals for her students early in the interview and did not talk much about that afterwards except to reinforce the point about wanting her students to be free to use the available resources as she saw fit. It was clear that Mary had a strong understanding of the typical knowledge and behaviors of the students in her class, and was comfortable using the teaching principles she was familiar with to work with those students.

In the first interview, Mary talked about the influences on her general course planning activities. Counts for these are indicated in Table 8.

Table 8. Influences on Course Planning: Mary

	Subject Matter Knowledge	General Pedagogical Knowledge	Knowledge About Students	Curricular Knowledge	Orientations Toward Teaching & Learning	Resources	**Total**
Unprompted	0	2	3	0	5	3	13 (87%)
Prompted	0	1	0	1	0	0	2 (13%)
Total	0	3 (20%)	3 (20%)	1 (7%)	5 (33%)	3 (20%)	15

As represented in the table, much of Mary’s talk on course planning was driven by her philosophy of respecting students as having preferred learning styles (seventy percent of the identified influences fell into that category) and descriptions of their typical level of knowledge and typical kinds of behaviors. Given that Mary teaches such large classes, it was not surprising that resource limitations came up in the conversation. Like Gordon, she did not talk about her knowledge of engineering in particular as influencing general course planning decisions.

Some of these patterns were reflected at the topic level, the most obvious one being her interest in students having multiple resources to work from when learning about torque, but as with Gordon, the topic level influence analysis revealed more nuanced and specific thinking regarding her planning decisions. She offered detailed discussion about her perspective on her students' characteristics, much of this learned from experience, but also some of it from research on student engagement in the classroom. She talked about resource constraints in relation to visual analogs for the torque "cube". She also spent time talking about how her understanding of the topic of torque influenced her instructional design.

Class Observation. I observed Mary's lesson on torque less than a week after the second interview. It took place in a large lecture hall. She used slides projected from her computer and was able to draw on them using a digital pen to emphasis specific points. She used the swim noodle throughout the class to describe different stress points from torque.

Mary used the clicker with multiple choice questions to generate student responses. For each question, she had the students talk to each other in groups of two to three (the people seated to the left and right) about the answers. After that, she would ask the same question and observe the change in responses. She went through this process three times.

Overall, Mary conducted the class like she said she would. This was not surprising as she said she had been teaching torque this way for a few years. (The only notable change was in providing a video as part of the guided reading exercise.) Mary was a lively presenter and the class appeared to be engaged, though she did have to quiet some students down a few times after the small group discussions.

Third Interview. I met with Mary a week later to talk about the class. I started by asking her how she felt the class went. She said it went well and was "pretty typical" both in how she presented the topic and how students responded to it, but she spent more time on the derivations than intended. As discussed, she does not think learning the derivations in detail is very useful to her students, and in any case, the video the students were meant to view before class covered the essentials. She admitted that it is sometimes hard to exercise the proper degree of restraint when sharing knowledge with students.

Given that Mary talked a lot about how she uses clicker questions to probe student understanding and give them an opportunity to ask questions of each other, I asked about some of the questions specifically. She asked a question about stress, and during the class I had thought it seemed tricky in that it was more about reading the units used to measure stress than a challenging problem. Most of the students got it wrong. Mary said this was intentional. She was trying to get them to realize how easy it is to make unit mistakes, as many of the questions she asks are designed to reveal underdeveloped knowledge or misconceptions that motivate instructional follow-up.

We talked about her review of some of the other concepts and procedures related to understanding torque. She fielded a number of questions from students through the class, but one in particular was about a problem featuring gears fixed to a wall she asked students to work through. One of her students wondered why the problem featured an assumption he considered unrealistic. Mary explained that she put in that assumption to make the problem easier. She told me she often inserts such assumptions in her problems and then poses more realistic and difficult problems either later in the same class or in some follow up assignment. She said she wants her students to develop a level of comfort with the basics and then progress to more difficult problems.

Fourth Interview. Due to scheduling conflicts, I did not meet with Mary for her last interview until six weeks later. (I made an effort not to schedule more than four weeks between any meetings with my participants, and operated under the assumption that scheduling the meetings closely together was best.) As with Gordon, I told Mary about the exercise I would have her complete in our meeting about a week before we met and gave her the list of factors I had identified from our discussions beforehand. I used her language in labeling the factors as much as possible. Table 9 indicates the results from the first exercise.

Table 9. Course Level Influence Ranking: Mary

Factor	Ranking
student motivation	1
how the content in the course relates to other courses in the program	2
how students differ in the ways in which they learn	3
teaching students to pull from different available resources	4
using active learning techniques	5
being a cheerleader and mentor	6

After completing the first exercise, she was asked to do the same task by for the topic of torsion. Again, her language was used as much as possible.

Table 10. Topic Level Influence Ranking: Mary

Factor	Ranking
topics they (students) learned leading up to torsion	1
difficulties past students have had understanding torsion	1
student motivation	1
the use of visual aids	2
the use of peer to peer interaction	2
the use of clicker technology	2
teaching students to pull from different available resources	3
how the content in the course relates to other course in the program	4

Mary completed these two exercises at the start of the interview after I reviewed the instructions, which included briefly reviewing the meaning of each factor for clarity before she started. I did the same thing with Gordon, but spent a little more time on this with Mary in an effort to anticipate clarifying questions. As such, she did not ask any questions while completing the exercises. However, several times she expressed that it was difficult for her to prioritize some of the factors over others when completing the topic level ranking exercise. The three way ties for ranks one and two are the result of this challenge. She also stressed that ranking a factor last did not mean it was important. All of the factors were important.

Mary's evaluation of the important factors on her planning efforts at the topic (torsion) level differed from her evaluation at the course level in a few ways. First, the relation of course content to that in other courses in the program was more important to her at the course planning level (rank 2) than at the topic planning level (rank 4). When planning for torsion, she was more concerned about the topics preceding and following it in her planning than how torsion related to other courses. Asking her about this, she explained that the larger topic of stress is what she thinks about in relation to other courses, and torque is one kind of force that generates stress.

Second, I was surprised to see "teaching students to pull from different available resources" near the bottom of the list in the topic ranking given that Mary said several times in the interviews that she wanted her students to have options for learning resources. Mentioning this, she said that yes, she wants her students to have these different options available to them as she respects that they may have different learning styles, but she does not feel it is her obligation to teach them how to make best use of all the available resources. That is not to say she does not try to make them as approachable as possible, just that she refrains from providing specific examples or instruction on how to interact with the materials. As mentioned earlier, it seems that Mary wants to motivate her students to improve their self-regulated learning capabilities. However, this does not seem to involve explicit instruction on or modeling of say identifying a task, setting goals, and then planning to achieve those goals within the context of the topic or course, but instead more seems to involve providing relevant resources and respecting students' preferences.

I asked Mary if she would most likely change anything about her presentation on torque when she teaches the class again. She highlighted two probable changes. One, she plans to cut down on how much of the derivation for the torque problems she shows in class. She did cut it down a bit for this past class as intended, but thinks she can cut more based on feedback she received from her students. Still, this is something Mary struggles with as she is not clear how much coverage it takes to get students to realize where the derivation comes from conceptually. Two, she plans to evaluate the torque video. Several students told her that they did not find it all that clear or useful. Mary was not sure if this was due to it being too difficult to follow or redundant with information given in the readings and in class. She planned to investigate this.

As with Gordon, I asked Mary why she decided to participate in the study. While his answer was more about exploring his own teaching, Mary's answer was more directly about improving learning for students. (Although this study is not focused on teaching effectiveness, it is fair to say I am interested in understanding what high quality planning for instruction looks like.)

> Oh, I'm always interested in anything that furthers the understanding of how we can help students learn better, and that's what I got out of our first discussion: that you were trying to root out what are these common elements that folks who seem to be effective have in common, and how can we expand that to encouraging more people to be more effective?

Mary said the experience of participating was great, and that she appreciated how clear the questions were. I asked her what advice she would have for future participants in a similar study, and she gave an answer resembling Gordon's response:

> The only other piece of advice I would give people is to not over-think the problem. You were asking direct questions. There's no right or wrong answers, but I'm picturing a few of my colleagues who would become very – I don't know if "political" is the right word – but very contained, and being careful about the way they answer. I don't think, in the nature of what you're trying to study, that's helpful.

Pam

Second Interview. In the first interview, Pam indicated we would be talking about her heat transfer course of roughly 120 undergraduate students, a course she had taught several times over the years. For her topic, she wanted to talk about lumped capacitance. Lumped capacitance is a model used to simplify the solving of equations describing heat transfer, and can be used when it can reasonably be assumed that the temperature difference across different spaces in an object can be treated as negligible. This makes solving these equations more mathematically tractable. She said she considered this an important topic for her students as they often have difficulty with the mathematics involved in the study of heat transfer, and the study of lumped capacitance gives them the opportunity to ease into this:

> Well, the most difficult part of the heat transfer course for many students is the PDE solutions because it is going back to solving differential equations, and the unsteady conduction problems tend to be the most difficult for them to understand because they're not real comfortable with the math involved in solving it, so they get bogged down in the math, and they lose sight of the physics of the problem. So there's the lumped capacitance method that is used in some cases and in other cases we need to go to an unsteady one dimensional conduction analysis. This tends to be confusing for the students because it is very mathematical. They have difficulty then in seeing through the math and understanding what we're doing.

Pam explained that despite the less complicated math, students still have difficulty using lumped capacitance to solve heat transfer problems. She believes that they have trouble conceiving of heat changes over time. She tried displaying this concept in a static plot previously, but did not find this tactic very effective:

> They don't…some of them don't even know what to do with it, and they just take the equation which they can, they can solve the problems using the equations, but some students don't find the figures to be helpful when I find the figure to say everything about the problem. But the students don't always understand that, don't understand the figure and so they are just left blindly substituting it.

This time around she plans to use a more dynamic representation in hopes of making the relationship between what is happening conceptually and procedurally more clear:

> Visually seeing it because in a stagnant plot, a stagnant figure, a static figure you can't easily show time changes. We show time changes by these multiple curves, but it is difficult for students

> to understand that. I now have put together a spreadsheet that has a recursive relation equation in it, so that I can press the F9 key, just advances the calculation to make a movie of the process. So that is what I am going to show this time that I haven't done in the past….

She also started supplementing her presentation on lumped capacitance with an analogy of a person moving up a steep hill and determining which points are the steepest, an idea she got while driving up a snowy hill. She said she has noticed more students "have their light bulbs turned on" when using this strategy, but still thinks they need help seeing the link between the concept and the mathematical procedures.

Pam believes that the difficulty students experience conceptualizing the problem through the mathematics stems from the fact that most of them are not accustomed to solving applied math problems. They have taken several math courses before this point, but most of them were working with "X and Y" not "temperatures or velocities or forces." In evidence of this, she has observed that students who have had taken applied math courses previously in the engineering college tend to perform better than average in her class.

Pam stressed that learning how to apply the math was difficult even though her students do get some practice with it leading up to the introduction of the topic. She also said that the increased conceptual demands play a role. Before lumped capacitance, they are looking at heat transfer problems that are one dimensional (time). Then they are asked to look at problems that conceptually feature two dimensions, time and space, and even though space is abstracted to be treated as a negligible effect under certain circumstances to make the math easier, students are still challenged by the addition of this dimension. In addition, Pam, unlike Mary, expects them to learn the necessary derivations and present the assumptions based on those derivations when using the resultant equations in the homework assignments, which also adds to the challenge:

> I think it's important that they know where these solutions come from. And I go through in class, I go through derivations that they may not need to do for all of their homework problems or they

will not need to do for many of the homework problems because I think they need to know where the equations come from. And I've told them that engineers need to know where the equations come from so you know when they are appropriate to use. Engineering technology majors are just given the algebraic equations, and they just use them, but they don't really know where it comes from, but as engineers you need to know where the equations come from.

I asked Pam to explain her lesson format for lumped capacitance. She indicated that she considered her style to be fairly "standard." She shared that her lesson structure was the same throughout the course. She presents the topic in one or more lectures projected from notes using a tablet computer onto a screen. The notes are mostly incomplete and she completes them electronically using a digital pen as she lectures. She uses different colors to indicate different subunits of content on a slide, such as definitions, equations, and examples and to keep the material from visually "blending" too much. Students are given access to the mostly blank notes before class and are expected to follow along during class filling them in, though they are preloaded with relevant diagrams. After class she makes her completed notes available to the students. Graded homework assignments of four or so problems follow every major topic, and students are sometimes asked to do derivations in completing the problems. The problems are similar to those she demonstrates in class, but with different values and varying assumptions.

A reading assignment from a textbook precedes the lecture, but Pam is never sure how much her students attend to it. She thinks most of them do not spend much time reading from the text. She said it would be possible to get through the course and do well without reading the book as her homework assignments and exams are mostly based on her lectures. She said the content and presentation of the lectures differs from the book in some ways in order to tailor the material for what she knows about the typical student in her class.

I found it curious that Pam gave her students complete notes after asking them to fill incomplete notes in during class. She said it was her hope that they would fill them in and mark them with additional personal comments, but that she did not want students to miss any essential information even if they did not do that:

> I tell them…I think the best way to learn the material is to come with the blank slides and be writing as we go along and then making additional notes as needed. Not everybody does that. So I think different students learn in different ways. I know what would work best for me would be for me to be writing as they go along. I know when I was a student I was writing a lot more than what the instructor was writing on the board. I was writing the equations and the derivations, but I was also writing my own comments. Not many students do that. I know not many students do that because in order to write comments like that, you actually need to be learning, understanding along the way to write intelligent comments. For some students they need to go back home and digest it before it starts making sense.

Pam shared examples of her notes on lumped capacitance with me. They were very organized and detailed, and it was clear that she spent a lot of time working on them. She rewrites them each semester to "make her thought process" more clear as she believes there is a strong relationship between how well her students do in the course and how organized she is with the content. Indeed, the organization of her notes represents what she wants them to learn. They are Pam's understanding of the topic distilled to a level appropriate for her students.

Pam spoke at length about how she creates and uses her notes and how that has changed over the years. (She even reviewed old versions of her notes she pulled from filing cabinets and boxes during the interview.) The transition to PC tablets and projectors from blackboards made a large, positive difference for her. In addition to making it easier to maintain, expand, and share her notes over the years, it solved a significant logistical problem she had in the classroom.

> Since I'm not very tall, I can only use about half of the blackboard because the top third, I can't reach. The bottom third they can't see, so it's the middle third, middle half that works on the

> blackboard. The overhead projector let me project things up higher, and I could also face the class as I was talking which I felt was helpful for me in reaching the students.

Before the tablet and projector technology, Pam could not cover as much material as managing the blackboard and having to be cognizant of making the notes readable took more time and focus. The tablet and projector have also made it easier to share higher quality diagrams and images. As a result, she thinks her notes have become “more complete,” including those on lumped capacitance.

Besides the steep hill analogy, I asked Pam if she uses any other analogies in teaching lumped capacitance or any examples that she believes are generally accessible to students. She explained she uses “cookies” and “cakes” to demonstrate the differences between lumped capacitance and the 1-D unsteady conduction. She indicated that she gets a lot of use out of this:

> Your cookies bake evenly all the way through thickness. And they bake in 10 minutes. The temperature change across the thickness of that cookie is small compared to the overall heating and the changes in time. When in the cake, the cake is much thicker and the inside of the cake is at a different temperature than the outside. The baking takes 45 minutes to an hour to bake because it takes time for that heating to reach the center of the cake and to bake the center of the cake. So as I go to other problems as we go along, I’ll ask them, "Is this a cake or a cookie?"

In asking about her experience as an undergraduate student taking heat transfer, Pam said her presentation on lumped capacitance is very similar in terms of content. In fact, she uses the same book that was used in that class, though it is several editions older and larger due to improvements in presentation (though she lamented the fact that modern textbooks are much less portable). She remembers, as a student, finding the presentation in her class ineffective, so she relied heavily on the book. She also remembers having trouble understanding the derivations involved in heat transfer until graduate school, so she tries to make her students more aware of them. She believes that working through the derivation for lump capacitance makes its purpose and use much more clear even though doing so is challenging:

> They need to be lost in the math the first or second time that they see these equations, that's the learning process we all went through. If I hadn't seen the equations as an undergrad, then the first time I saw it in graduate school it would have been more difficult. And you need to get past that in order to be able to, to, uh, go beyond just the algebraic equations. I tell the students, I say, "When I was about five years old, I used a word that I shouldn't have, you know, and my mom instead of just kind of yelling at me, she asked me, 'Do you know what that word means?' I said, 'No.' She said, 'Then you shouldn't be using it.' And so I tell the class, I said, 'That's true with equations, too. You need to know what that equation means or you shouldn't be using it.'

We finished the interview and scheduled the class observations (the lesson would span two classes unlike the other class observations) and the follow-up interview. Overall, this interview went well. Pam was still apologetic at times due to the belief that her teaching approach was not that interesting, but this did not appear to impact the quality of information she shared. (I assured her again that her participation was valuable.) She was able to talk at length about her teaching perspective and methods, and there was a good bit of humor in the session.

The discussion indicated that Pam is highly focused on the organization of the content in her course in general, and this was the major theme when talking about the model of lumped capacitance. It was clear that her notes represent the organization of her topics, and the content within constitutes the fact, concepts, and procedures she wants her students to learn. She revises and often expands the notes each year as she develops more efficient ways to present the material, and puts a lot of effort into making the relationships between different concepts and procedures clear (hence the time spent on derivations). She is aware of some of the difficulties her students face learning lumped capacitance, and is continually trying to develop better ways to address them, which usually means more organizational work on her notes and the addition of more analogies and examples.

Table 11 presents a summary of the various influence categories on Pam's plans for teaching lumped capacitance to her students.

Table 11. Influences on Topic Planning: Pam

	Subject Matter Knowledge	General Pedagogical Knowledge	Knowledge About Students	Curricular Knowledge	Orientations Toward Teaching & Learning	Resources	**Total**
Unprompted	5	1	6	1	4	1	18 (90%)
Prompted	1	0	1	0	0	0	2 (10%)
Total	6 (30%)	1 (5%)	7 (35%)	1 (5%)	4 (20%)	1 (5%)	20

In total, Pam referenced 20 influences across the six different categories while talking about lumped capacitance. The vast majority of these (90%) were unprompted. Pam spent much of the interview talking about the presentation and organization of the notes for lumped capacitance (probably 50 to 60 minutes of the 90 minute interview). She also spent a good amount of time talking about the different concepts and procedures she covered, what she expects from her students, and the kind of difficulties they normally have when learning about lumped capacitance.

In the first interview, Pam talked about the influences on his general course planning activities. Counts for these are indicated in Table 12.

Table 12. Influences on Course Planning: Pam

	Subject Matter Knowledge	General Pedagogical Knowledge	Knowledge About Students	Curricular Knowledge	Orientations Toward Teaching & Learning	Resources	**Total**
Unprompted	0	4	2	1	5	1	13 (100%)
Prompted	0	0	0	0	0	0	0 (0%)
Total	0	4 (31%)	2 (15%)	1 (8%)	5 (38%)	1 (8%)	13

Much of the discussion in that interview was about Pam's goal of helping her students learn content by making it as easy to approach, and hopefully understand, as possible. This meant being highly organized and respecting some general learning principles such as providing students with clear learning objectives and expectations and conducting fairly frequent assessments. This concern for making content approachable through strong organization was obvious when she talked about lumped capacitance and reviewed the notes she created for the topic. Like Gordon and Mary, she did not talk about her knowledge of engineering in particular when talking about her course as a whole. Instead she spoke about her teaching philosophy, her general teaching strategies, and her students.

Class Observations. About five weeks later I sat in on the first of two classes where Pam talked about lumped capacitance. The administration of the class was exactly as she described. After handing out completed homework assignments and taking a question about one of the problems from it, she lectured from her notes while the students followed along. There were several questions from the students, which Pam answered with little trouble. It reminded me of the college mathematics and statistics course I had taken, but more organized than any of them. (As a testament to this fact, I felt I could follow the lecture fairly well even without an engineering background.)

The second class was held two days later. Only the first part of the class was about lumped capacitance. Then Pam showed the interactive graph she made in Excel that displays heat transfer across time and space of an object as she thought it would make it easier to understand the relationships between the different parameters. Again, she received several questions that she answered easily. The class was just like the first in presentation in all other ways.

Third Interview. I met with Pam a week later to talk about the classes I observed. I started the interview by asking her how she felt the class went. She explained that she went through the material a bit slower than she might have normally, and has been doing that throughout the semester. She had been getting more questions than average, and it was clear from the questions that students were struggling with some of the math related to the derivations. She said this lack of prior knowledge was uncharacteristic for the kinds of students she normally gets in the class.

Pam said every semester is a bit different and offered one possible influencing variable – the classroom. Referring to it as a “cave”, she talked about how it has no windows and with the class being at 8 in the morning, it makes it feel “a little groggy in there.” In contrast, last semester she taught the class at

8 in the morning as well, but in a room full of windows. She said that felt much better for her, which she assumes was true for her students too.

In the first class, Pam received a few questions regarding why she was simplifying certain equations. She was trying to get her students to understand that they needed to first define the problem space before they start simplifying with approximations. I asked her about this. She responded, “It is realistic for these problems. In all engineering problems we are making some approximations and we’re also focusing on a particular type of problem. And in a particular type of problem some terms are going to drop out.” She said that students learning how to move from the given situation to representing it with the math in a way that is no less and no more complicated than necessary is always a challenge for them.

Pam said she spends a lot of time thinking about this when preparing lectures. She knows that in each lecture she has to tell her students just enough to understand the concepts and procedures involved and no more than that to prevent confusing them. This is challenging because usually she cannot give them the complete picture on any given topic until a later related lesson, but needs to give them enough that they can make some sense of the current topic. She considers this to be one of the main challenges in creating the organizational structure for her notes.

Fourth Interview. I was not able to meet with Pam until six weeks later due to scheduling conflicts. As with Gordon and Mary, I told her about the exercise I would have her complete in our meeting. About a week before we met, I sent her an email and gave her the list of factors I had identified from our discussions beforehand. I used her language in labeling the factors as much as possible.

There was a miscommunication with these exercises. Pam ranked them before the meeting as opposed to just thinking them over and ranking them in the meeting (the document I sent her included the instructions). We walked through the exercises together anyway, and my impression was that her completing the rankings before-hand was not problematic. Table 13 displays the results from the first exercise.

Table 13. Course Level Influence Ranking: Pam

Factor	Ranking
organizing the content	1
making expectations for performance explicit	2
using real life applications as examples	3
being careful not to overwhelm students	4
how the content in the course relates to other courses in the program	5
how the content in the course prepares them to be practicing engineers	6

After talking through the first exercise, we did the same for the second exercise on the topic of lumped capacitance. Again, the language used for factors came from the previous interviews. Again, there was no indication that Pam completing the exercises prior to meeting was a problem. She seemed to have understood the meaning of the factors on their names alone, though I did elaborate on each of them in case she wanted to change any of her rankings. She did not.

Table 14. Topic Level Influence Ranking: Pam

Factor	Ranking
the desire for students to understand how the content is organized	1
the availability of a PC in the classroom	2
the class presentation differing in some ways from the book	3
student experience	4
how knowledge of lumped capacitance prepares students to be engineers	5
what is covered in more advanced classes on heat transfer	6

At the course level, Pam indicated “organizing the content” as the most important factor, which was no surprise. She immediately started talking about this:

> It's why I listed "organizing the content" as being the most important, because the students need to organize the content in their own mind to make sense of it and be able to solve the problems. I see part of my job is to help them in organizing that content. Also, the better organized my notes

> are and the course material is then the easier it is for them to figure out what they need to learn, where their weaknesses are, and where they need to focus more effort.

She elaborated on this point by saying that she often hears students talk about their other courses and how they often are unsure what to study in preparing for exams. She does not want her students spending 20 hours trying to figure out what to study only to “get 2 hours of worthwhile studying.” She wants her students to know that if they study the material as she prepares it, they will know exactly what is needed to do well on the exams. She believes this approach has been very successful. As she has made her notes more organized, students have gotten better at asking more specific questions about the content when preparing for exams. She has also noticed her student ratings improving along with this effort.

This desire for strong organization throughout the class was strongly evident at the topic level. Pam talked extensively about how she structures her notes. She elaborated on the kinds of examples and analogies she put in them, how she introduces problems, how she makes the notes available to students, and the specific concerns she has about how to best do this. She uses what she expects a practicing engineer to know about lumped capacitance to guide this process of creation, and tempers it with consideration of what the typical student in her class should have learned in other classes.

I asked Pam why she decided to participate in this project. She said she assumed it would be a good project since she had worked with a member of my dissertation committee previously and trusted him. She also said that she had been a participant in other educational research projects. They had been positive experiences in that they motivated her to look at some of her practices differently. She said she thought this project went as expected. She did not have much advice for future participants except to say that they should talk about a course they taught previously as opposed to a new course, as she thinks that makes it easier to talk more in depth about teaching practices.

Tom

Second Interview. In the first interview Tom indicated we would be talking about his thermodynamics course of about 100 students, a course he had taught roughly 10 times before. He identified energy conservation as the topic he wanted to discuss. We met, and he immediately started talking about how he introduces it to his students.

Tom explained that he nests the topic of energy conservation into a larger conceptual framework for the course – a framework he introduces to students on day one with a visual map of the relevant topics and examples. The visual displays devices and systems like jet engines and car engines at the top. Underneath these examples are the topics needed to understand these systems from an engineering perspective, like properties of matter and the laws of thermodynamics. Underneath the second law of thermodynamics is the conservation of energy. Tom refers back to this visual throughout the course as he moves from one topic to the next to highlight the relationships between them. He considers it necessary that his students understand this in order to develop flexible knowledge in solving thermodynamics problems.

In the classroom, Tom lists for his students the essential parts of his lesson on energy conservation. This includes the factual definition for it, the associated mathematical procedures, a warning not to rely on a specific equation when solving energy conservation problems, and a reminder that water is not to be treated as an ideal gas. I did not understand the last two parts. Tom explained that students tend to overuse a certain kind of equation (ideal gas) when learning about energy conservation because of how they learned to apply it in previous classes. They also tend to treat steam as an ideal gas. He has found it helpful to "make a big deal out of this" persistent misconception in an attempt to stop these problems before they start.

The use of authentic examples is very important to Tom. He uses color photographs on a projector to first demonstrate the practical application of whichever topic he introduces. He wants his students to know what they are going to apply the conservation of energy to in the real world. He believes this helps generate excitement: “And, you know, and I found that it really generates interest, you know, ‘Oh, I’m excited about this course.’ They see the practical applications right away. And then, uh, after I get them all excited, then we do all this boring crap. ” Tom explained that he sometimes varies the examples and proceeded to describe how he would analyze the energy system in a cup of coffee to his students. He related a story where he borrowed a student’s Thermos bottle and worked through an example with that.

In addition to continually reminding students about the larger course framework, Tom regularly reviews terms and definitions with his students:

> I give them… there are four handouts, and it’s called “Important Concepts and Definitions”. I tell them to print them out, bring them to class and then as we cover the new things I basically have the definition up on the slide, they already have that to follow and then I just highlight the key words in there. We discuss about why those key words are important and what that means. Why this, how this definition can be actualized or internalized or, you know, whatever.

So for conservation of energy, Tom introduces it as part of the larger framework for the course, refers to practical examples and stresses how knowledge of the topic is used to help solve problems, and refers to the definitions sheets as needed to explain the relevant facts and concepts.

Tom talked more about his perspective on the course. He said it took him a long time to understand the differences between the science of thermodynamics and what he considers to be engineering thermodynamics. He had to come to this understanding on his own. It was never covered specifically in any class or book. He gave an example of how the concept of equilibrium is a bit different when using it to refer to engineering problems as opposed to talking about it in a purely scientific framework. He does not specifically point out these differences to students, but they guide his thinking on how he presents topics like conservation of energy.

Tom said conservation of energy is usually a difficult topic for his students. It does not come up until two thirds of the way into the course, and much of the previous material is oriented toward getting them to understand the necessary facts, concepts, and procedures to begin thinking about conservation. So a large part of the course up to that point is focused on the properties of materials and how they are related to heat and work. In getting students prepared to talk about conservation, Tom often uses an ATM machine as a concrete analogy to help foster understanding (…at least for most students. Tom reported that rarely he will encounter a student that has no concept of this basic kind of accounting.)

> I just put it up on the screen and I say, “In the beginning of December your bank balance is $1200 and you know you write two checks for this and you have a direct deposit. You go to the ATM and take this much out and then I say it’s an interest bearing checking account and you know you get $30 interest added.” Then I ask two questions: “How much did your balance change and what is your balance?” Then after we complete that, everybody does pretty well at that then I say, “That’s what this course is all about. Only we aren’t talking money, we’re talking energy and you don’t have 4-5 different ways to take money in and out.”

Tom explained that because the content is so difficult, he has to present some of the topics leading up to conservation of energy in a somewhat incomplete fashion, similar to how Pam described her challenges in deciding what to include in her notes for any given topic. Students simply cannot understand everything they need to know about a topic when being introduced to it for the first time, so they end up asking a lot of questions as the complexity of the course increases. Tom uses these questions as opportunities to have the class reflect on what they learned previously and anchor the new knowledge to the old:

> I asked them to calculate an internal energy change which is just simply the temperature difference multiplied by CV and the student said, “This was a constant pressure process – how can we use CV, why didn’t we write this?” And I said, “Well, remember back when we talked about CP and CV, I said that they were thermodynamic properties independent of the process, so the temperature is the temperature, right, whether I do constant volume, constant…no matter how I change the state of the system, it’s still the temperature, same way? So I think the light went on.”

Tom said he expects students to make these “important and egregious errors” and works to anticipate and correct them in his presentations and interactions with students. It is part of the normal learning process.

Tom talked more about the first class on conservation of energy. He typically has his students analyze a model for a spark emission engine. They have a chart that describes the process with four different pieces. He describes this to the class and then asks them to calculate the heat and the work and the change in internal energy. They then have to decide where to apply the law of conservation of energy while doing this. Tom organizes the students into groups of two to three to do this, and the task gets progressively more difficult as they go along. He said they often get excited and enjoy this, as it makes use of everything they have learned up to that point and is challenging enough that working together is necessary to get the correct answers for most students. (Similar problems, different in the details, appear on the following exam.) Tom walks around the room and helps students when they struggle. He then reviews it at the end of the class or in the next session depending on time. He also assigns some additional ungraded problems for practice. Following this lesson, Tom teaches the class how to extend the application of these processes to more realistic systems.

It is important for Tom that his students are at least exposed to the necessary general equations for energy conservation and how they are derived to more specific applications. (He tells his class to “take out their machetes” to hack away at the general equation.) He realizes that many of his students will not learn how to do the derivations from the general case very well, but like Mary, he wants them to at least see where they come from. He said that every once in a while a student surprises him though and derives from the general forms on the exams.

Tom started talking about the exam for conservation of energy (it features other topics too, but largely focuses on that). A change this time around is that instead of using symbols in the problem statements for the questions, he is going to use words. He hopes this will encourage a stronger understanding of the concepts the symbols are meant to represent. He said some students have a habit of seeing the symbols and then scanning for relevant equations to “plug and chug.” He thinks this discourages them from expending the effort needed to fully understand what the equations are representing.

Another change for the class this year involves moving away from asking students to provide definitions of conservation concepts on exams to using multiple choice questions to indicate true statements that represent operational applications of definitions. So, they will not be required to write out definitions of terms. Asking what motivated this change, Tom said that practically, it was hard to assign partial credit “when someone is writing a bunch of gibberish.” Also, he thinks this is a better assessment of deeper knowledge as opposed to the ability to just repeat a definition, as the items require students to engage in exercises that require understanding, application, and analysis of the given concepts.

Tom talked about how his teaching has changed in general over the years. In the past, he lectured much more and the class was what he considered to be typical in structure for most engineering classes. He talked about the topic and asked questions of the students as he went along all the while hoping that they read the relevant sections in the course textbook. Now he tries to lecture much less and assign supervised activities, like with the conservation of energy problem. Tom had long thought that an approach like this would be more motivating for students, but seeing research on the possible value of active learning helped to encourage the change. In the last few years he even started participating in research projects on using active learning techniques in engineering education.

It was clear that Tom is very focused on making sure his students develop an understanding of the larger conceptual framework for thermodynamics in solving conservation of energy problems. He has them refer back to it continually as he moves from topic to topic and solves sample problems. He designs his exams so they ask more from his students than memorization and give students in class group work on problems that are realistically challenging. As he believes that doing is more motivating and effective than simply listening, he works to keep his lectures (or straight presentation of information) to a minimum and instead supervises students as they solve relevant problems.

Table 15 presents a summary of the various influence categories on Tom's plans for teaching his students about conservation of energy.

Table 15. Influences on Topic Planning: Tom

	Subject Matter Knowledge	General Pedagogical Knowledge	Knowledge About Students	Curricular Knowledge	Orientations Toward Teaching & Learning	Resources	**Total**
Unprompted	12	5	11	0	8	1	37 (86%)
Prompted	2	2	1	1	0	0	6 (14%)
Total	14 (33%)	7 (16%)	12 (28%)	1 (2%)	8 (19%)	1 (2%)	43

Overall, he referenced 43 influences across the six different categories while talking about conservation of energy. The vast majority of these (86%) were unprompted, meaning that he spoke about them without being asked to. It was clear that he knew a lot about the knowledge of the typical student in his class. This has influenced how he presents the topic of conservation. Tom believes that the presentation of practical applications and real world analogies and the assignment of group work and challenging problems are motivating, and sees this as being supported by the research with which he is familiar. This expresses itself in how he understands the topic of conservation of energy (he wrote the book he uses in the class), and how he tries to relate that larger conceptual framework understanding to his students. He presents to his students the overall structure of the course, refers back to it with each topic, works from real world examples, and demonstrates how these concepts are related.

In the first interview, Tom talked about the influences on his general course planning activities. Counts for these are indicated in Table 16.

Table 16. Influences on Course Planning: Tom

	Subject Matter Knowledge	General Pedagogical Knowledge	Knowledge About Students	Curricular Knowledge	Orientations Toward Teaching & Learning	Resources	**Total**
Unprompted	0	4	3	1	2	2	12 (67%)
Prompted	0	0	2	0	2	2	6 (33%)
Total	0	4 (22%)	5 (28%)	1 (6%)	4 (22%)	4 (22%)	18

The discussion in the first interview was mostly focused on Tom’s transition from doing engineering research to research on engineering education, how the students he gets in his thermodynamics class have changed over time (in short, they are more capable), and the efforts he makes to ensure his course reflects ABET expectations.. He talked a little bit about trying to get students to understand the “bigger picture” in his class and how a person uses that to solve practical problems, but this goal for his students was more apparent at the topic level. He also talked more about resources in the first interview, such as how course management systems have made it much easier to share information with students and the challenges in deciding upon a textbook for the course, than in the topic level interview where he only mentioned that students rarely come to his office because, he believes, of its more isolated location on campus.

Class Observation. I observed Tom’s lesson on conservation of energy less than a week after the second interview. It took place in a moderately sized classroom. Using projected slides, he started with an outline for the day’s activities and a brief review of the previous class. There were a few questions about that class which Tom quickly answered.

He spent the next 15 minutes introducing the conservation of energy and how it related to previous content. He did this by explaining the concepts involved as well as demonstrating them mathematically. Students seemed well-engaged and asked a good number of questions. The atmosphere was very relaxed.

Tom then introduced the exercise he had described to me in the second interview. Students worked with their neighbors on each side and groups offered answers to go up on the screen as they finished them, with some prompting by Tom. Again, the class seemed relaxed and the students were focused, and the class was conducted exactly as expected.

The students were not finished with the exercise by the end of the class, so I attended the following class, though that was not my original intention. The class started with a one-minute no-grade quiz on conservation of energy. After that, the groups worked again on the exercise. They finished that and the review of the answers with Tom in about 20 minutes. The rest of the time was spent on a graded quiz.

Third Interview. I met with Tom two weeks later to discuss the class observations. Asking him how he thought it went, he replied that it was very similar to past classes on the topic. He thought the students might have been a little less proactive this time around though as they asked fewer questions than normal while working on the exercise. He did not know if this was because they did not know what they were doing and were embarrassed to raise their hands, or if they really did not need his help. They asked more questions, mostly of a procedural nature, in the second class toward the end of the exercise.

During the first class I had noticed Tom "thinking out loud" while drawing diagrams and writing formula to solve example problems on the projected notes as he conducted his mini-lecture. I asked him why he does that instead of preparing them before class with the rest of the notes. He explained he was trying to model his problem solving behaviors for the students:

> I think I am trying to develop...in our research we have discovered that when I ask students why you draw a diagram, and as an expert I would say I draw a diagram so I can comprehend what the problem is and I know where to go. The students will answer, "I draw the diagram only when the professor asks me to draw the diagram, and it is worth points."

He said he regularly tells his students that defining the scope of the problem is just what experts do. For the homework, Tom has a guide students can use that explains the process an expert in the field typically goes about solving problems.

Despite his efforts, Tom indicated that his students usually have trouble generating diagrams useful for problem solving or describing a process. Like Mary and Pam said, he believes that most students are just more familiar with solving equations and less familiar with scoping out a problem in ways that would demonstrate conceptual understanding. Tom guessed that generating a diagram is simply “too open” for them.

Tom talked more about the exercise he conducted in the class where students have to describe energy conservation in closed system. He said he originally gave the problem on an exam several years ago, and the students “butchered it.” He decided to give it in class from then on to prepare students to work through a similar exercise on the exam. Given time constraints through, he had to fill in various pieces of the exercise (i.e. added additional known values) to make it manageable in the available time. He has noticed students doing better on the related exercise on the exam over time.

We finished the interview by talking about Tom’s plans for the rest of the course. The students worked with the general conservation of energy equation. Now they will be asked to work on analyzing the energy states of smaller parts of a system, such as a pump or nozzle in an engine. They will then learn how to take these smaller units of analysis and construct a larger system out of them. In this way, Tom will have taught the students how to solve conservation of energy problems deductively and inductively.

Fourth Interview. Due to scheduling conflicts, I did not meet with Tom again for six weeks. As with the other participants, I told Tom about the exercise I would have him complete in our meeting about a week before we met, and gave him the list of factors I had identified from our interviews beforehand. I used his language in labeling the factors as much as possible. Table 17 indicates the results from the first exercise.

Table 17. Course Level Influence Ranking: Tom

Factor	Ranking	Notes
ABET's recommendations for instructional objectives	1	What (C)
the use of active learning techniques	2	How (B)
what kind of support students expect	3	Metacognition/Monitoring (D)
difficulties previous students had in the course	4	Metacognition/Monitoring (A)
the desire to organize the course around larger principles	5	What (E)
how the course content relates to other courses in the program	6	How (F)

After completing the first exercise, he was asked to do the same task for the topic of energy conservation. Again, his language was used as much as possible.

Table 18. Topic Level Influence Ranking: Tom

Factor	Ranking
the desire to organize the content around the general application of conservation of energy	1
difficulties previous students had when learning about conservation of energy	2
the use of practical examples	3
focus on concepts as opposed to more specific procedures	4
the use of analogies (ex: ATM machine)	5

As with Mary and Pam, I reviewed the meaning of each factor as I went over the instructions for the exercises. Tom did not have any significant questions about the factors themselves, but for the first exercise he decided to put some of the factors into larger categories in addition to ranking them in order of influence.

> I guess what I did is, after looking at these, they didn't all seem to be in the same category so to speak, so what I did was I said, "Well, what are these getting at?" Then I just went from A through F to locate them. So I said what the course is about, so that's C, and that would be the higher priority in that category, and then E, the desire to organize around large principles. Then the second category was how do you do that? I put, then, as the most important under that is to

> use active learning. Underneath that one is how courses relate to other courses in your program. Overall, that was my lowest grade. I'm not quite sure what to say, how to define these other than that they're monitoring functions or meta-cognitive things, that they're neither what nor how, and that's where I put the difficulties that students had seen previously, and then what kind of support students expect.

He added that all the given factors are important influences to his course planning, but he does not necessarily think of them that way.

Tom talked about how his desire to respect the expectations of ABET, the accreditation body for the engineering program, and accurately reflect one of the major components of the engineering curriculum, thermodynamics, in his college. He tries to prepare students to integrate what they learn about conservation of energy with conservation of mass and momentum. He does this through the use of practical examples and analogies and active learning experiences whenever it is feasible to do so, and puts significant effort into balancing the difficulty of assigned exercises so they are challenging enough to be motivating and meaningful. Additionally, he considers the knowledge level of his typical students and tries to model the kind of problem solving behavior he thinks will help them develop their abilities to monitor their own problem solving practices. Overall, there was a large degree of congruence between how Tom ranked the influencing factors at the course level and topic level.

I asked Tom why he decided to participate in this study, what the experience has been like for him, and what recommendations he would have for future participants. He said he decided to participate because he trusted the recommendation of the committee member who arranged our meeting. He did not have any strong ideas about what the study would be like, but it was in line with his expectations. Tom did not have any specific advice for future participants, but said he appreciated that he did not feel "pushed" in any particular direction in the discussion or judged for his answers.

Reliability and Validity

Gordon, Mary, Pam, and Tom all did excellent work in the interviews. They were friendly, open, and accommodating. This being my first major qualitative study, I expected to experience some difficulties conducting the interviews beyond minor technical issues with the audio recordings. Given that I asked the participants to reflect on their teaching practices, I thought there might be some resistance to my questions or guarded responses. This was not the case. I received direct answers to every question and the participants gave very detailed accounts of their teaching activities. For Mary, Pam, and Tom, only around 15% of the conversation was prompted; for Gordon, about 25%. They talked, a lot, and they were eager to show me class notes, slides, programs, and more as we went through the interviews. With the class observations, I was not surprised then to see the courses conducted much as the participants said they would be given the openness of their descriptions.

Although I conducted four interviews with each participant, I started to develop strong impressions of each faculty member's teaching "style", for the lack of a better word, by the end of the second round of interviews. I started thinking of Gordon as a mentor type preparing his students for the world outside the classroom. He tries to give his students authentic experiences that reflect how engineers typically do their work. He gives his students challenging, somewhat ill-defined problems and asks them to pull from multiple resources to solve them. Gordon regularly makes references to what it is like to practice as an engineer during his classes hoping this will help students transfer what they learn in class to their future work. He even tries to fit in practical work exercises, like memo writing, when he can. He also seems to have a particular interest in respecting the attention spans and memory limits of his student with the way he structures his classes and limits problem sets.

Like Gordon, Mary places a strong emphasis on having her students work with different resources to solve relevant engineering problems, but the motivation is somewhat different. She seems to be more concerned about respecting her students' different learning styles by giving them increased access to resources than necessarily giving them experiences that reflect practice as an engineer (though that is important to her as well given the way she referred to the sequencing of her course in the program and the importance of understanding the subtleties of torsion for an engineer). With torsion, the students have access to guided readings, study questions, sample problems, a video, and the class lecture. Mary said several times that it did not matter to her how students decided to learn the material, as long as they learned it, so she gives them multiple ways to succeed while stressing the importance of coming to class.

Pam's style is centered on organization. She organizes the content of the course according to how she believes engineers need to understand it, and presents it to her students through lectures and problem solving exercises. She constantly thinks about how to improve her notes so that they are easier to understand. She improves existing examples and analogies and adds new ones. She modifies the visual display of the notes in search of clarity. She experiments with how she makes the notes available to her students. She wants them to be aware of what she expects them to know at any given point, and those expectations are made clear in the notes. (This also extends to the exams where she shares with students the past four versions to help them prepare.)

Tom's style is a bit more difficult to summarize. Like Gordon, he is very interested in giving his students challenging, realistic problems to work through. Like Pam, he is strongly focused on the organization of his course content, but the focus is at a larger level of teaching students how to navigate thermodynamics though application of a conceptual framework than at the level of facts and procedures. (Pam cares about giving her students that view as well, and Tom cares about making facts and procedures accessible to his students. The difference between them represents a matter of degree than kind). More than the other participants though, Tom is interested in the study and application of effective pedagogical strategies and techniques like the use of conceptual maps and modeling expert behavior. While Gordon, Mary, and Pam all made a couple general references to how educational research has impacted their teaching activities in the interviews, Tom talked in detail about his shift in research agenda to engineering education and how he implements various techniques, such as active learning and novice/expert comparison, in his classroom. As a student in an educational research field, it was clear to me that he had a very strong grasp of what I would consider fundamental learning and instruction science principles.

As stated early, I experienced no major problems, technical or otherwise, conducting the interviews. Overall, it was enjoyable experience working with the participants. Though the first interview with Gordon was somewhat awkward as some of my questions did not make sense to him, and it was a bit difficult for me to keep up with his rapid speaking pace, we settled into a good style of exchange by the middle of the second interview. By the end of the process, I developed a lot of respect for how he sees his students as adults and the concern he has for fostering their professional development.

I experienced an instant connection with Mary. Beginning with the first interview, she was lively, energetic, and funny. I sympathized with her desire to give her students multiple ways to learn course material as I was more of a “read on my own” student, and some of my teachers did not appreciate that. It was interesting and amusing to listen to her talk about her initial efforts as an instructor when she prepared whole scripts for each class session and her change in perspective where she is more reactive to her students.

As previously mentioned, Pam did not think I would find her teaching practices interesting as she considers her approach to be typical. She lectures while presenting notes on a screen and assigns students homework problems and readings from the book. A casual observance of one of her class sessions might suggest, given the absence of any novel teaching techniques and the fact that lecturing as an instructional technique is often considered uninspired and ineffective, that she does not make her teaching a top priority. It became clear during the interview on her topic though that she took her teaching very seriously and applied her highly analytical mind to the task of making sure her students have what they need to understand the course content. I found her enthusiasm for this task of continually revising the class notes for clarity, and the results, intriguing.

I initially found Tom intimidating. He appeared to have a somewhat gruff demeanor and had very little to say in the recruitment meeting. Early in the first interview it became clear that he had a strong understanding of pedagogy, and I felt more self-conscious with him than with the other participants about making sure that it was apparent the study was being conducted with care and transparency. By the end of the first interview, Tom was laughing and making jokes, and our interactions started to feel more natural. The level of comfort only increased in future interviews as he talked about his specific educational interests, some of which align with my own.

I knew from planning this study and previous experience that interviewing as a data gathering technique poses several challenges (Ashgar, 2010; Creswell, 1998; Seidman, 2006). Participants may hesitate to speak due to being shy or being concerned about how the results of the interviews might be perceived by others. They may simply find talking to the interviewer uncomfortable due to the structure of the interview or personal characteristics of the interviewer, such as a tendency to interrupt participants or respond to participants too excitedly or with not enough interest. I caught myself making some of these errors in the pilot interview, as previously discussed, and worked to avoid them throughout this study.

I believe the participants felt comfortable and respected in the interviews. They all expressed satisfaction with the conduct of the study and gratitude for being included in it. Perhaps they did not want to offend me with strong criticisms of my conduct as an interviewer, but none of them offered ideas for significant revisions to the interview process. It seemed they were all being open and honest about their teaching practices and goals, and I had no reason to suspect that they held anything important back. In fact, at times I was surprised by their frankness about their perceptions on typical teaching practices and the organizational reward structure, or lack thereof, for teaching.

I believe the reports generated in this chapter regarding the participants' general and topic specific concerns are valid. At the beginning of each interview, I summarized my impressions from the preceding interview and asked the participant to react with any corrections. I followed up with a classroom observation to develop a better understanding of what their teaching practice looked like as planned. Perhaps the most valuable step, however, was conducting a final review interview using the ranking tasks. Again, the items selected for ranking were based on what seemed to be the most important planning influences to the participants as revealed in interviews one through three. The participants were instructed to modify any of the given influences and add new ones as they saw fit. Gordon made one minor modification to an existing factor and added a new factor to the topic level influence ranking task. Tom made the biggest change by grouping the given course level influences into three larger process categories, but he considered the given influences valid in any case.

There was a concern that the act of interviewing the participants about their topic plans might alter their plans or how they implemented them in the classroom. There are two reasons I believe that this did not occur to a significant degree. First, I instructed the participants to tell me about their plans as they were, and upon observing their classrooms, there was a strong degree of congruence between what they told me they were going to do and what they did. Mary, Pam, and Tom had all implemented their plans several times before in previous semesters. Gordon was talking about a new course, but even then, he had already developed a large portion of his topic plan before I spoke with him. Now, it seems reasonable to assume that participation in the interviews helped to clarify the participants' thinking about their plans, and that they might have made small adjustments in implementation as a result, but there was no evidence to suggest larger changes had been made.

A reliability check was conducted on the coding process to generate the given planning factor counts for each participant. As a reminder, the factors were Subject Matter Knowledge, General Pedagogical Knowledge, Knowledge About Students, Curricular Knowledge, Orientations Toward Teaching and Learning, and Resources, each of them having prompted and unprompted versions. Excerpts where the participants talked about an influence on their general planning and topic specific planning activities were created. These excerpts were then coded as belonging to one or more influence categories as appropriate. All the interviews were coded personally over the course of roughly 10 days. Six weeks later I recoded them and made comparisons for accuracy.

Some reminders and clarifications about the coding process are needed. An influence was coded as unprompted if the participant talked about it without being specifically asked. So, starting the interview by asking them what influences they consider important when planning instruction generated responses that were classified as unprompted. The same was true for any other spontaneous mention of a given influence. When I asked about specific examples from one or more of the possible factor categories, such as class size possibly influencing planning, those responses were classified as prompted. Regarding the category of Subject Matter Knowledge, an influence was only coded as belonging to it when the participant explicitly talked about his or her knowledge of the topic influencing a specific decision. Technically, a teacher's subject matter knowledge is always at play in planning as a selected part of that knowledge constitutes the core of any course.

I only did a reliability check on the first two interviews for each participant as there was no coding of factors for the third interview (the class observation discussion) or the fourth interview (the study review). Note that I counted codes as congruent as long as I captured part of the relevant excerpt in each coding session. For example, here is an excerpt from the second interview with Mary:

> What I used in between when I had my small class, and I still have a box of them under there, is that I went and bought pipe insulation from the store. I cut chunks this big and passed them out to the whole class so that everybody would have one. When I evolved to the large setting I teach now, that wasn't feasible, and it was hard to see that little object from the back, so I came to the bright, colorful swim noodle so you can see it better.

In the first coding instance, I captured it as such and coded it as R – U (resources unprompted). It was part of a larger discussion she initiated regarding the props she uses in class. The second time I coded it, I only captured the first sentence of the original excerpt, but I coded it R – U again. Despite the fact that I extracted a shorter version of the excerpt during the check, I considered it congruent. In my final set of coded excerpts, I kept the longer version of each excerpt if there was more than one to preserve context. (I did not keep track of these changes, but I believe that my excerpts were very similar in length from coding session one to two.) For missing excerpts from session to session, I considered the total number of excerpts to equal the total number of unique excerpts across both sessions in calculating the congruence percentages.

Regarding interview one with Gordon, I determined 100% coding congruence across 17 total codes. In interview two, I determined 88% congruence across 40 total codes. In five cases, I did not assign the Subject Matter Knowledge influence properly. In one case I marked it as prompted when it should have been marked unprompted. In two cases, I should have identified and marked an excerpt as including Subject Matter Knowledge influences. In two other cases, I should have applied the Subject Matter Knowledge code to existing excerpts.

Regarding interview one with Mary, I found 87% coding congruence across 15 total codes. In two cases, I applied Orientations Toward Teaching and Learning in the place of Knowledge About Students in the second coding session. Upon review, Orientations made more sense as the excerpts were more about what Mary believed should be required of students and not about what she thought their capabilities were. With interview two, I determined 92% congruence. In two cases, I should have applied Subject Matter Knowledge (unprompted) in the second coding session to match the first.

The review of Pam's first interview generated 13 codes with 92% congruence across the two coding sessions. There was one instance where I added the code Orientations Toward Teaching and Learning to an excerpt already marked with Knowledge About Students as the excerpt referenced not only expectations Pam has for her students by an assessment of their capabilities. The review of the second interview exhibited 100% congruence across the codes in both sessions.

I applied eighteen codes to excerpts from the first interview transcript for Tom. There was 88% coding congruence across the two coding instances. In one case I marked an excerpt with Knowledge About Students in the first session and changed it to Orientations Toward Teaching and Learning in the second. This made sense upon reflection and was left as such. I added a Resources code to an excerpt with a Knowledge About Students code and rightly so, as the excerpt involved Tom talking about the distance of his office from the center of campus being a deterrent to students visiting him.

Forty-three codes were applied to the second interview transcript for Tom. There was a coding congruence of 79%. I missed five excerpts to which I should have applied the Knowledge About Students code. In each case he was making statements that drew upon his General Pedagogical Knowledge, which was coded as such, but it was not clear the first time whether he was talking about his students specifically. For example, he talked about structuring notes in a way that clearly summarizes general concepts. However, he also mentioned earlier that he did not think his students read the text all that much, and upon further review it became clear that this knowledge of his students activities (or lack thereof) influenced the way he structured the notes. In three other cases I failed to apply a Subject Matter Knowledge (unprompted) code. Not being familiar with the subject-matter, I simply missed them the first time. In one case I coded an excerpt as unprompted Curricular Knowledge when it should have been prompted, a simple typographical error.

Chapter 6

Final Discussion

This study attempted to address four research questions within the context of the initial development of a method to better describe the instructional planning process of post-secondary teachers that was approachable and contextualized using established instruction and learning principles. Long term, it is hoped this work and the answers to those questions might have constructive implications for faculty development by providing a few case studies demonstrating how instructors with a strong interest in teaching think about what is important to them in planning their courses and how this relates to planning for the instruction of specific topics. Again, if faculty members are to be instructed on how to improve their teaching, it is necessary to be able to accurately describe their knowledge and application of instructional practices in ways specific to their disciplines so they can be engaged in high quality discussion about effective instruction and learning. The four research questions were:

1. What do the participants identify as specific influences on their planning for the instruction of their courses in general (including goals, knowledge-bases, resources, constraints, and more)?
2. What do the participants identify as specific influences on their planning for the instruction of self-selected topics and related concepts and procedures (including goals, knowledge-bases, resources, constraints, and more)?
3. How do the reports of the participants generally compare to those in previous research on planning for instruction in higher education?
4. Are conceptions of PCK useful in prompting discussion or organizing and understanding descriptions of instructional planning?

Regarding the second question, Chapter 5 describes and summarizes the responses from the participants about their planning at the topic level in detail and makes comparisons to influences on their general course planning activities. While the analysis of the interviews in Chapters 4 and 5 provide the basis for answering questions one and three above, more explicit comparisons and deductions are made in this chapter. The remainder of the chapter describes potential improvements that could be made to the conduct of a study like this, which necessarily includes addressing the question about the usefulness of PCK (question four) and the overall value in using an approach like this to learning more about how post-secondary faculty members plan for instruction.

Higher Education Planning Comparison

As fully described in Chapter 2, research on course planning in higher education has identified some consistent influences on the planning processes of faculty. (Anderson et. al., 1985; Lattuca & Stark, 2009; Powell & Shanker, 1982; Stark et. al., 1998; Stark, 2000; Young & Irving, 2005). The participants in those studies expressed a strong concern for teaching the basics of their disciplines. This entailed covering a certain amount of content. They typically taught the way they were taught as students, which most often meant placing an emphasis on lectures to deliver that content. To a lesser extent they took the characteristics of their students into account when planning. When they did, it was mostly a consideration of what the students should come into class already knowing given the typical course sequence. These participants were usually not interested in research on pedagogy and did not often take advantage of teacher training opportunities. The demands of their other obligations, most notably research, restricted the level of effort they would expend on their teaching.

Gordon, Mary, Pam, and Tom all indicated similar influences on their general course planning activities. They all said they wanted to engage their students with a certain amount of content representative of their disciplines. Gordon and Tom indicated that they want their students to experience what it is like to be a practicing engineer by having them work through difficult, ill-structured problems. Mary and Pam described how they emphasize how formulas are derived with the goal of preparing their students to solve real engineering problems in the future. Essentially, they were all interested in fostering the abilities of their students to transfer knowledge learned in class to novel situations.

Unlike the groups discussed in the previous research who tended to be only interested in general student characteristics such as majors and grade levels (Andersen et. al.; Cross, 1993; Stark et. al., 2000), Gordon, Mary, Pam, and Tom indicated a strong interest in the characteristics of their students. Gordon referenced his knowledge about his students influencing his planning activities seven times in the interview about his selected topic. Mary did this same six times, Pam seven times, and Tom 12 times. “Student characteristics”, “student motivation”, and “difficulties previous students experienced” are examples of influences all the participants ranked relatively high in the ranking tasks from the fourth set of interviews. A common point of discussion involved working to better understand the knowledge typical students have regarding the topic to be taught and how to make sure they are not overwhelmed by the presentation of the content. A related point, they all also talked about how they considered various instructional methods to convey the content, whether this was Pam’s intense interest in providing a strong organizational structure for students to work through or Gordon or Tom assigning teams to solve difficult problems.

Also unlike the group discussed in the post -secondary education course planning research (Stark et. al., 1988), Gordon, Mary, Pam, and Tom referenced the influence of education research on their teaching practices. Gordon talked about the research on content breadth versus content depth, the attention span of students regarding lectures, and the use of authentic exercises in the classroom. Mary talked about some of the research on active learning and learning styles. Pam referenced education research as a planning influence less than the other participants, but did speak a bit about research on the value of sharing notes with students. Tom talked about education research the most out of the group, which was not surprising given that engineering education is his primary research interest. He spoke about active learning techniques, group work, conceptual maps of course content, and the modeling of expert behavior.

All considered, there was a fairly strong degree of overlap between the planning influences indicated by the study participants and those indicated by the participants in the post-secondary course planning research, but significant differences as well in the consideration of student characteristics and interest in education research. Regarding their students, there was also a sense throughout the interviews that the participants were very proactive in anticipating student needs and potential disappointments. For example, Pam talked at length about how she uses her course reviews and office visits with students to gauge the success of her planning and implementation efforts. Tom talked about how he thinks his students will react to in class activities. This is quite different from the research on post-secondary course planning that suggests most faculty members tend to react to student needs as they present them instead of proactively anticipating such needs (Andersen et. al.; Cross, 1993; Stark et. al., 2000).

PCK in Studying Post-Secondary Instructional Planning

As explained in Chapter 2, while the desire to use PCK as a way to represent the unique knowledge of teachers is consistent among those who conduct research using the construct, the specific understanding and application of it varies significantly in the reviewed studies. The knowledge bases included in any particular writing on PCK may vary dramatically from those included in another, and often there is a failure to discuss the motivations for these changes. Additionally, general pedagogical knowledge as a knowledge base is regularly redefined, and again, the reasons for this are largely unaddressed.

It is sensible to wonder then what value PCK has in conducting a study on post-secondary instructional planning given this level of inconsistency. That somewhat differing conceptions of PCK have been used in studies on primary and secondary instructional planning does seem to offer sufficient reason for its inclusion, even if the work that has been done on it represents the most recent and active line of research on how teachers transform their knowledge when making planning decisions. However, it is possible to disagree with the answer to a question without diminishing the value in asking the question. In this case, the question is whether describing the decision-making of teachers planning instruction at a highly analytical level serves to clarify what it is teachers do in preparing to teach a lesson (in this case limited to a single topic).

For this study, the work on PCK specifically (e.g., Hasweh, 2005; Lee et. al., 2007; Park & Oliver, 2008) and earlier work on instructional planning in the context of decision making generally (e.g., Bishop & Whitfield, 1972; Shavelson, 1973; Shavelson, 1976; Shulman & Elstein, 1975) served as a reminder to clarify what it was I was interested in hearing my participants talk about. It also served as a reminder to work toward the creation of a reasonably complete representation of what knowledge-bases, beliefs, and resources that influenced the participants as they created their instructional plans. When there was a lull in an interview and the participant had not said anything about class size having an effect on the kind of activities they did in class, I would ask about resource constraints on planning. The same kind of approach was employed in reference to curricular matters or any other potential planning influence that seemed to be unaddressed.

In the very least, the work on PCK helped inspire the idea to ask a selection of higher education faculty to talk about how they planned to teach a topic in one of their courses in addition to general course planning behaviors. Several studies on PCK provided evidence that asking teachers to talk about topic preparation in detail yielded detailed descriptions of what they considered important when planning (Geddis et. al., 1993; Geddis et. al., 1997; Grossman, 1990; and Marks, 1990). The descriptions were more detailed than those generated in the studies on course planning in higher education and more focused at the level of topic planning than the older studies on teacher decision making, so it seemed reasonable to assume that asking higher education faculty about planning to teach a self-selected topic in addition to planning to teach a course would generate rich descriptions of not only why they planned to teach what they wanted to teach, but also why.

I found the application of “PCK thinking” relatively useful for this study. It was helpful to have some general planning influences in mind when asking the participants about possible influences on instructional planning. There was never a moment where I lacked questions for the participants, though admittedly they were all fairly talkative. I do not think all the various influences I had in mind before conducting the interviews were important specifically, just that I had some idea of the kinds of planning influences the participants might find relevant. (This might partly explain why there are so many variations in presentations of PCK in the literature; the process of considering possible influences is just as important as the resulting list of influences.)

The general practice of asking teachers to talk about planning for the instruction of specific topics proved valuable in this study. The research on post-secondary course planning suggests that faculty members tend to teach what they what they were taught in the manner they were taught, do not put in a lot of effort into understanding student characteristics, and have little interest in education research and resulting innovations. Detail is lost, however, whenever one looks at the aggregate, and it is reasonable to think there might be significant differences in planning behavior at the topic level versus the course level. This was apparent in the interviews with all the participants as the focus on teaching goals and philosophies in the general course planning interviews gave way to more specific considerations of context in the topic planning interview, but most notable in the interviews conducted with Pam. She expressed concern that her teaching approach was “standard” in the first interview, in that she lectured to deliver a certain amount of content, and as such she would not represent an interesting case for the study. However, later interviews about her selected topic revealed sophisticated thinking about her teaching goals, methods of content organization, and students’ typical expectations and behaviors driving this “standard” approach. This suggests there might be other faculty members who would describe their teaching practices as typical or uninteresting until discussions on instruction for specific topics revealed that the reality was more complicated than that.

I found using the influence categories I created based on the interviews and planning research less useful in analyzing the interview transcripts. I had expected that highlighting excerpts where the participants identified pedagogical constructions and being able to code them as being influenced by one or more influence categories would be more revealing. Aside from a couple instances where I checked the list of influence counts for added support when making a strong statement like, “Tom has a great interest in education research and innovations,” they did not exert a significant influence on the impressions I formed about the participants from conducting the interviews, taking thorough notes, and reviewing the transcripts several times. They did serve as a kind of validity check, but I am not sure using them yielded much benefit beyond that accrued when referencing the ranking tasks conducted in the fourth set of interviews. First, the ranking tasks had the advantage of using the participants’ own words which reduced the amount of interpretation involved in trying to accurately identify influential planning factors. Second, it made a validity check an interactive experience with the participants providing immediate corrections. (Gordon, for example, changed two factors during the exercise to be more accurate with what he felt he had said previously.) That all said, comparisons of the counts in the influence tables from the course to planning level for any participant does help to highlight the fact mentioned in the last section – discussion at the course planning level tends to be more focused on educational philosophies and goals with discussion at the topic level more considerate of context.

The Value in Investigating Topic Level Planning

This study was motivated by the desire to generate a level of detail in planning descriptions not seen in the research on course planning in higher education generally or engineering education specifically, but often seen in research on PCK. There was an assumption that asking participants to talk about selected topics in addition to their courses generally would generate a level of insight into how they thought about their teaching greater than would be gained from asking them about their courses alone. I believe the reports on their interviews given in Chapters 4 and 5 provide evidence of this. While initial interviews with the participants about their courses revealed general teaching concerns and interests, the topic level interviews required the participants to be more specific about how they try to achieve their teaching goals (at least for the selected topics).

I believe asking faculty members to talk about planning for the instruction of specific topics may be beneficial to those working in faculty development. In her work with instructional planning using a PCK framework, Grossman found that having student teachers reflect on their topic planning activities while assessing their knowledge of pedagogy and the subject matter (English topics in this case), often proved motivating to the students and informative to instructors. The instructors could target pedagogical or subject matter misconceptions relevant to what the students were already doing in order to mentor them in developing more effective teaching practices.

In the realm of faculty development in engineering education, Felder et. al. suggest that an inductive approach to working with faculty to help improve their teaching may be more effective than a deductive approach (2011). A deductive approach starts with general theories of cognition and learning and proceeds to apply the theories to course and lesson planning. An inductive approach, however, starts with specific observations and challenges and guides the participants to explanations and strategies. If the faculty member becomes interested enough, they eventually work to better understanding larger educational principles.

In the same article, Felder et. al. reference the difficulty non-STEM consultants face when dealing with STEM faculty members, much of that attributed to lack of consultants' subject matter knowledge (also noted by Fink et. al. (2005)). The approach described in this study does not require any specific STEM knowledge (though of course it would probably be beneficial). By asking faculty members to describe their instructional decisions and why, their reasons can be considered in light of different knowledge bases and other influences. Knowledge of pedagogy can allow the consultant to consider these reports and identify possible points of improvement.

With this study, for example, Gordon repeatedly mentioned students' attention spans and trying to structure his classes around his knowledge on that. That suggests that he might be open to learning more about research on attentional processes and even memory limitations and the instructional implications (Mayer, 2011) Mary mentioned using assessments in the form of clickers several times to reveal student misconceptions. Perhaps she would be interested in learning more about confronting naïve beliefs and a model for changing them such as the threefold strategy (Nussbuam & Novick, 1982). Given Mary's interest in creating the most effective notes possible, she might appreciate learning more about the spatial and temporal contiguity principles (Mayer, 2009) in designing multimedia presentations. Gordon, Mary, and Tom may all be receptive to additional information on how to structure cooperative learning groups for maximum effect (Slavin, 1983). If we are going to instruct teachers on instruction, it seems sensible to engage their prior knowledge as we expect them to with their students.

Limitations and Lessons Learned

There are several limitations to this study regarding generalizability and design. The most obvious limitation to generalizability is that only four participants were interviewed. Although a tentative conclusion that asking post-secondary faculty member to talk about how they plan to teach specific topics in their courses is offered, this study represents a test case. Faculty members who express less interest in teaching than the participants may not describe the same level of detail when asked about their planning. There could be other differences accounting for teaching experience. (Though Gordon had significantly less teaching experience than the other participants, and there was not an obvious difference in interview quality.) There might be a discipline effect as well. On average, engineers might be better able to reflect on instructional design than those in certain other disciplines because engineers are trained to solve design problems. (It also stands to reason that those who train educators should be the best at this.) It is also not clear how well the method used in this study would work in talking to faculty in disciplines that are less well-structured engineering, for example philosophy or certain kinds of artistic study. The participants in my study were able to readily identify discrete facts, concepts, and procedures to discuss. It seems it would be more difficult to ask a faculty member to analyze their understanding of how to go about helping students develop effective arguments, for example.

There are a couple other ways participant characteristics might affect the results of this kind of work. With the exception of Mary, the participants had research responsibilities. All of the participants had service and outreach responsibilities. At institutions where faculty have fewer responsibilities in these areas and even greater demands for teaching, faculty members may have a stronger interest in pedagogy on average, or at least more time to spend on teaching. This would most likely affect the character of their responses, especially regarding resources. Additionally, this study was conducted with motivated participants who all expressed a relatively strong interest in teaching. They were all reflective regarding their practices and open to discussing them fully. It is reasonable to assume that conducting a similar study with faculty members who were less interested in teaching or less articulate about their teaching would present a challenge. In that case, the interview process might have to be extended or perhaps other information collecting procedures, like deep analysis of assignments and lecture notes, might have to be implemented to gather sufficient information.

The design used for the study could be improved in a few ways. As mentioned when discussing the value of PCK, while extracting excerpts from the transcripts is essential to identify what participants are trying to do when teaching a specific topic and how, tying the excerpts to codes may not be worth the effort for the reasons given. That time might be better spent developing more robust ranking tasks, like asking the participants to organize their ranked influences into larger influence groups for further discussion. (This would obviate the need to create factors before the interviews or provide a point of comparison to previously created factors.) They could also be asked to go through the ranking tasks on two separate occasions, which would provide an additional validity check.

I am also not sure the class observation and the follow-up interview were all that valuable beyond further demonstrating an interest in the participants' teaching activities. There was a very large degree of congruence between what the participants said they would do in class and what they did. The interviews following the class observations were not particularly insightful. Much of the discussion was about whether the participants would make changes to a future instance of that instructional unit and the nature of any possible changes. While this was somewhat interesting and may have fostered some good will, it merely confirmed what was learned in the earlier interviews: the participants’ planning decisions are informed by how they see their students. The time spent on the observation and follow-up interview might have been better spent on a fifth participant.

Suggestions for Future Research

The current study represents an important first effort at developing a method to better understand how post-secondary faculty members think about their planning at the topic level in order to generate information that may be useful to those interested in working with faculty to improve instruction. Additionally, work like this has the potential to contribute to a more complete view of how faculty members think about the specific content and activities in their courses. This dissertation also represents an attempt to develop better models to represent and summarize discussions about teaching.

I have already mentioned some recommended changes that would benefit a replication of this work. For example, I would interview more than four participants. I would probably not conduct class observations. I would reassess the value in coding interview excerpts according to influence categories. There are also many opportunities to conduct a similar study with faculty members in different disciplines to determine unique effects of disciplinary thinking on instructional planning at the topic level.

Though I do not think it would be an essential change as discussed earlier, it might be useful to conduct a similar study in a discipline in which the researcher or a co-researcher is schooled. While I felt I could generally understand the particulars of what my participants were talking about when referencing subject-matter knowledge, it would have been valuable to be able to check that understanding more thoroughly. If, for example, one was interested in identifying unique influences on planning decisions, it would be valuable to have someone with a level of expertise to confirm that what the participant was saying as a unique statement and not a restatement or expansion on an earlier statement. Of course, this would not replace checking with the participants to confirm the validity of such perceptions, as done in this study, but serve as an additional measure of quality control.

It might be valuable to put a stronger focus on identifying the specific pedagogical constructions faculty members identify in relation to their selected topics. For this study, the focus was not on the specific pedagogical constructions discussed by my participants, but rather the parsed factors that influenced the creation and implementation of said constructions. Once a participant told me about a particular construction, like Mary's example of a man climbing a hill to demonstrate rate change, I quickly moved onto trying to determine the "why" without making a strong note of the "what". If a researcher was interested in creating a more detailed picture of these planning processes, it could be informative, and perhaps instructive, to be able to see a visual display connecting the constructions and all the influences related to them.

A research process like this that asks participating faculty to share their detailed thoughts about planning might benefit from greater participant involvement in the execution of the study. As stated earlier, the ranking task proved to be effective, and the participants reported that they enjoyed having the opportunity to reflect on what had been learned from the interviews in a way that asked them to, in a sense, evaluate some of the findings of the study. The task of identifying the use of pedagogical constructions and other decisions and the influences on them might be made more valid by telling the participants not only what the researcher hopes to achieve with the study, but also how it will be achieved, and recruiting them to engage in a way that goes beyond answering interview questions. Participants could be the ones to confirm the use of specific pedagogical constructions and to share other decisions. They could evaluate the influence maps to them for accuracy. Furthermore, participants could be asked to describe where their chosen topics are nested in their courses in detail. In other words, faculty could be recruited to take the lead on developing the language and structures used to organize the content they share. In any case, future studies on post-secondary faculty planning activities should strive to develop better ways to take full advantage of the types of expertise possessed by the participants.

Appendix A: Session Guides

First Session Guide (60 minutes)

Briefly explain to the participant what the study is about again as a review. Go over the possible benefits of the study again as well. Tell the participant that the purpose of this interview is to establish a life history relevant to the participant's practice of teaching

Purpose of Study - Explain the purpose of the study, which is to describe how four engineering faculty work through the process of creating and modifying instruction for a selected topic and related concepts or procedures. This includes identifying the knowledge-bases they draw upon in doing so. This would also be the point where I explain the structure of the study.

Possible Benefits of Study - To extend similar work done at the secondary levels in science, mathematics, and other subjects and to provide a more finely grained picture of how some faculty members plan for instruction. This may be informative to those training students to be teachers in higher education as well as those in professional development working with faculty members. It may help the participants become more reflective of their teaching practice.

Questions - The order of these questions will vary depending on how the participant responds. The idea is to allow the participant to talk freely and fully and lead naturally from one question to the next. The goal is to establish the context for why and how the participant became a researcher/teacher and establish a baseline for how they think about their teaching and other responsibilities.

- What is your current position at the University? How many years have you been in it?
- How many years have you been teaching? In what capacity?
- Have you held any other positions at Penn State or other educational institutions? What about other work experience?
- Have you had any formal teacher training through courses, workshops, and the like? What exposure to teaching and learning did you have in your graduate studies?
- How do you envision the learning process of your students? What do you think your role as a teacher is in this?
- When creating or updating a course, what factors influence how you plan?
- In addition to teaching, what do you consider to be your other responsibilities? In rough percentages, how would you say you spend you typically spend your time across your responsibilities? Has this changed over time?
- Do you participate in other educative activities outside the classroom (workshops, mentoring students, advising, coaching, etc.)?
- Would you mind sharing your vita and the syllabus for the course with me? Do you have a biographical sketch you can also share?
    - It will be interesting to see to what extent the biographical sketch talks about teaching.

Task

- In preparation for the next interview, please identify a topic and the related concepts and procedures you teach in your course. It should be one that you have put extra care and consideration into when preparing to teach it, relative to the rest of the course. It may be something that you have a special interest in or something that your students find particularly challenging.
    - I need to be sure that the next interview happens before they are teaching the topic so the observation(s) can be done.

- Please be prepared to talk about this topic including how you have taught it in the past, changes you have made to the way you teach it, and how you plan to teach it this semester.

Second Session Guide (60 to 90 minutes)

Have the participant talk about the topic he or she identified and how the participant has taught it and plans to teach it.

Review - The purpose of the study will be reviewed and this discussion's place in that study established. The participant will be reminded that one or more classroom observations of the topic to be taught will follow this interview.

Questions - The order of these questions will vary depending on how the participant responds. The idea is to allow the participant to talk freely and fully and lead naturally from one question to the next. The goal is to establish how the participant works or plans to work with the topic in the present and describe how past experiences have informed these decisions.

- Can you describe the topic you selected to me in layman's terms as fully as possible? Additionally, can you give me a more technical description that would likely be recognized by most practitioners in your field?
    - *This is both so I can develop a general sense of what is being discussed while eliciting the participant's take on the concept or procedure.*
- When does this topic first appear in the course? How does this topic relate to other topics that are covered in the course? How important do you think this topic is relative to the rest of the course material?
- Do you find this topic particularly challenging to learn or teach? What makes you think so? Have your thoughts on what makes it challenging to learn or teach changed over time?
- How do you plan to teach the topic this time around? Does this differ from how you taught it previously? If so, what motivated the changes you will make (possibly an external source)?
- How do you think your students might react to this instruction?
- *Once what they plan to do has been establish, ask follow-up questions on the origin of their plan. The goal is to identify the knowledge-bases and other influences they are drawing upon in putting together these pedagogical constructions (with the understanding that they may be using previously created constructions).*
    - *If they need prompting, try asking them if how they plan to teach it differs from the way they were taught or the way they know others teach it.*
    - *May need to have them imagine the classroom scenario and walk them through it.*

Third Session Guide (60 to 90 minutes)

This will occur after the classroom observation. Have the participant reflect on their teaching of the identified topic and respond to questions the researcher has about responses observed in the classroom.

Review - The purpose of the study will be reviewed and this discussion's place in that study established.

Questions - The order of these questions will vary depending on how the participant responds. The idea is to allow the participant to talk freely and fully and lead naturally from one question to the next. The goal here is to be able to describe the participant's honest self-assessment of the classroom proceedings and how his or her reflections on that may or may not influence her thinking about the identified topic and related concepts or procedures.

- How do you think the class went overall?
- How do you think students responded to the way you taught them about the topic? Did that work out as you expected? If not, why do you think that is?
    - *There might be questions about specific observations. I will be looking for points at which it seems to me students are confused. We will review the audio recording for those moments so the participant can respond to the context fully.*
- How does this instance of instruction compare to previous classes?
- Do you think you might make any changes to the way you taught the topic given how the class went?
    - *I would not be expecting specific changes at this point, but would welcome discussion about them.*

Task - At this point I would explain that they will be receiving a summary of my interview notes in the near future. They can review them for accuracy and representativeness to be discussed in our last meeting.

Fourth Session Guide (60 minutes)

Have the participant reflect on the experience of being a part of this study. In addition to being informative to the larger study, it serves as the main validity check.

Review - Talk about everything that has been done so far and what will be done with the results. Explain the purpose of this interview.

Questions - The order of these questions will vary depending on how the participant responds. The idea is to allow the participant to talk freely and fully and lead naturally from one question to the next.

- Did you have a chance to review the notes? Did you have any comments or suggestions?
- Do you have any additional thoughts about how you might change the way you teach the topic in the future?
    - *Once again, references to motivating influences will be explored if appropriate as in session two.*
- Previous studies have found that post-secondary teachers mostly rely on their own experience when planning their courses and that time constraints often prevent them from doing everything they want to do in their instruction. These studies have also found that post-secondary teachers do not often refer to educational research in their planning. Do you think that is accurate for yourself or others with whom you work?
- What initially motivated you to participate in this study?
- How has this experience been for you?
- If I were to conduct a similar study in the future, would you have any advice for those who chose to participate?

Wrap-up - Thank them for their time and efforts. Tell them they will receive a copy of the study report once it is completed.

Appendix B: Informed Consent Form

Informed Consent Form for Social Science Research
The Pennsylvania State University

Title of Project: The Creation of Pedagogical Constructions By Engineering Faculty Members

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1. **Purpose of the Study:** The purpose of this research is to describe and summarize how four engineering faculty members create and modify instruction for the teaching of challenging concepts or procedures. This includes identifying the types of knowledge and resources they draw upon to do so.

2. **Procedures to be Followed:** You will be asked to participate in four interviews in which you will be asked about your teaching practices. You will also be asked to allow the principal investigator to observe one or more of your classes. The interviews and classroom will be recorded for audio. These recordings and all other data will be securely stored in the principal investigator's office and destroyed three years after the date of study completion.

3. **Discomforts and Risks:** There are no risks in participating in this research beyond those experienced in everyday life.

4. **Benefits:** You might learn some ways to think differently about how you create and modify your instruction. It may also help other engineering faculty members who teach better understand their own practices. This research may help those preparing students for instruction at the post-secondary level by better informing them about what college teaching looks like. It may also help those in professional development who work with faculty members on teaching for the same reason.

5. **Duration/Time:** There will be four interviews. The first interview will run 60 minutes. The second and third interviews will run 90 minutes each. The last interview will run 60 minutes. I will ask to observe one or more of your classes, but that requires no extra effort on your part.

6. **Statement of Confidentiality:** Your participation in this research is confidential. The data will be stored and secured on a computer in 502 Rider in a secured and password protected system. Only the research team and the given advisor will have access to this data. Only the PI will have access to the audio recordings. The Pennsylvania State University's Office for Research Protections, the Institutional Review Board and the Office for Human Research Protections in the Department of Health and Human Services may review records related to this research study. In the event of a publication or presentation resulting from the research, no personally identifiable information will be shared.

   A pseudonym will be used for your name to protect your identity. Given the relatively small number of faculty members in the college, it may be possible for someone you know to recognize the character of your responses in a resulting report despite the pseudonym. This is unlikely, however.

7. **Right to Ask Questions:** Please contact Nicholas Warcholak at 814-933-6752 with questions, complaints or concerns about this research. You can also call this number if you feel this study has harmed you. If you have any questions, concerns, problems about your rights as a research participant or would like to offer input, please contact The Pennsylvania State University's Office for Research Protections (ORP) at (814) 865-1775. The ORP cannot answer questions about research procedures. Questions about research procedures can be answered by the research team.

8. **Voluntary Participation:** Your decision to be in this research is voluntary. You can stop at any time. You do not have to answer any questions you do not want to answer. Refusal to take part in or withdrawing from this study will involve no penalty or loss of benefits you would receive otherwise.

You must be 18 years of age or older to consent to take part in this research study. If you agree to take part in this research study and the information outlined above, please sign your name and indicate the date below.

You will be given a copy of this consent form for your records.

____ ____________________

Participant Signature Date

____ ____________________

Person Obtaining Consent Date

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SELECTED PUBLICATIONS AND PRESENTATIONS

Stevens, R.J., Van Meter, P.N., & Warcholak, N.D. (2010). The effects of explicitly teaching story structure to primary grade children. *Journal of Literacy Research*, *42*(2), 159-198.

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Sperling, R.A., Warcholak, N.D., Van Middlesworth, H.Z., Kidwai, K.H., Kim, K, & Ramsay, C.M. (2006, February). *Multiple Representation Comprehension: The State of Affairs and Suggestions for Change.* Paper presented at the annual meeting of the Eastern Educational Research Association, Hilton Head, SC.

Warcholak, N.D., & Kulikowich, J.M. (2005, August). *How Two Groups of Experts Comprehend Statistics Text.* Paper presented at the annual meeting of the American Psychological Association, Washington, D.C.