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CALCULUS INSTRUCTORS' RESOURCES, ORIENTATIONS, AND GOALS IN TEACHING LOW-ACHIEVING SUTDNETS

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To my mom, the strongest woman I will ever know.

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Abstract

Teaching and learning calculus has been the subject of mathematics education research for many years. Although the literature is mainly concerned with students' difficulties with calculus, research on mathematicians' day to day activities is still scarce. Using Schoenfeld's Resources, Orientations and Goals (ROGs) framework, this study examined four instructors' ROGs in teaching calculus to low-achieving students. The findings revealed the in depth pedagogical experiences of mathematicians and their deliberation in helping students. The study suggested that building research based models and frameworks results in richer studies that would be more beneficial to both students and instructors.

Chapter 1: Introduction

1.1 Problem Statement

As a school subject, mathematics has probably the most infamous reputation for being difficult to learn. The singularity of mathematics applies not only to K-12 students but also undergraduate students. The mathematical content of courses offered in service to breadth requirements varies from beginning algebra and elementary statistics-based courses, to analytic geometry and trigonometry content, to a first course in calculus (Tsay, Judd, Hauk, & Davis, 2011).

Mathematics curricular affects students' choice of careers and majors (Ma & Johnson, 2008). Especially, calculus has been viewed as a critical - among freshmen students who are in mathematics, science, or engineering majors since it provides the foundation for understanding higher-level science courses (Willemsen & Gainen, 1995). Moreover, many researchers claim that calculus is the starting point in mathematics instruction (Sorby & Hamlin, 2001). Many of the freshman engineering students, however, fail to meet the minimum grade criterion of A, B, or C in their calculus course (Seymour & Hewitt, 1997). Thus, for a few decades mathematics educators have conducted several studies to determine factors that cause low performance in calculus among college students. Several researchers were concerned that a very large number of students that started calculus courses did not finish (or finished with a failing grade).

Artigue (2000) listed and discussed many difficulties that students have with calculus and considered the historical development of the curriculum to suggest ways of improving the current teaching. Norman and Prichard (1994) were alarmed that if the reports regarding the learning of calculus coming from various institutions around the

United States were true “this country is in an abysmal state” (p. 65). The authors used Krutetskii’s (1976) idea of flexibility, reversibility and generalization together with research on cognitive obstacles as a framework to understand students’ difficulties in calculus. They found that the particular cognitive obstacles were very much tied to the state of mathematics instruction and suggested a reform of the mathematics curricula particularly in calculus. Robert and Speer (2001) believed that students’ difficulties with calculus was universal and divided the research available in calculus into three categories of a) theory-driven, b) practice driven and c) convergence of the two. They believed that “the field will make progress on effective teaching and learning if it deals meaningfully with theoretical and pragmatic issues simultaneously” (p. 297).

More than a decade later, has the research in calculus made any progress? We still have students who change their major to one that does not require a strong mathematics background (Knott, Olson, & Currie, 2009). In addition, half of US students who declare mathematics and physical science majors switch to other fields with 90% citing poor teaching as a reason (Seymour, Melton, Wiese, & Pedersen-Gallegos, 2005). Recently a large-scale survey of Calculus I was performed by the Mathematical Association of America (MAA) (Bressoud, Carlson, Pearson & Rasmussen, 2012). Their qualitative analysis indicates that students found the teaching of Calculus 1 to be ineffective and uninspiring, the course was “over stuffed” with content and delivered at too fast a pace, and their instructor lacked connection to students and the course.

1.2 Significance of the Study

Although, there are some research available on calculus students’ difficulties, research on mathematics professor’s day to day activities is scarce (Speer, Smith, &

Horvath, 2010). In response to this need, Sofronas and DeFranco (2010) did an extensive research to explore the knowledge base for teaching (KBT) among seven college and university mathematics faculty teaching calculus at 4-year institutions in the Northeastern United States. The authors developed a KBT framework among mathematics faculty teaching calculus. One of their findings was that "in the absence of any formal knowledge of learning theory, participants developed implicit "self-created" theories of student learning which influenced their teaching practices" (p. 193).

Teachers' orientations which include dispositions, beliefs, values, and preferences about mathematics and mathematics instruction play an important factor in student learning environments (Ernest, 1989; Grossman Wilson, & Shulman, 1989; Leder, Pehkonen, & Törner, 2002; Schoenfeld, 2010). And these factors have also been found to influence teachers' instructional practices (Nespor, 1987; Pajares, 1992; Richardson, 1996; Thompson, 1992). Research thus focused on how teacher characteristics were related to their notions of effective teaching and their classroom practices in the K-12 level. Recently, a few research (Rowland, 2009; Paterson, Thomas, & Taylor, 2011; Hannah, Stewart, & Thomas, 2013) have considered the practice of university lecturers. Therefore, studies about calculus instructors' characteristics, particularly their orientations, goals, and resources to support students, especially low-achieving students, are clearly needed. It may help to minimize students' rate of drop out calculus courses and finish with satisfying results.

Aims of the Research

The aim of this research study was to investigate the calculus instructors' resources, orientations, and goals in teaching calculus at the research site university.

Furthermore, the analysis goes beyond simply identifying the variables of the instructors' resources, goals and orientations but includes by elaborating on the specific interdependencies among ROGs. This research considered some major issues, such as which knowledge and belief systems we should include to explore the calculus instructors' resources and orientations in teaching calculus. Calculus as the subject, students as recipients of lectures and pedagogical aspects such as teaching and learning of contents were contained in each column. They were chosen because they are the foundation factors when teachers decide their teaching approaches.

Research Questions

The following are the research questions for this study:

- What are instructors' Resources, Orientations and Goals (ROGs) in teaching calculus courses?
- Does knowing teachers' ROGs result in helping the low-achieving calculus students?

1.3 The Overview of the Thesis

The following is a brief description of the chapters of this thesis. Chapter 2 critically examines the related literature and the theories that have been considered as the core foundation of this thesis. This is followed by the discussion of the literature on the teaching of calculus and aspects of instructors. The detailed description of the theoretical framework is presented in Chapter 3, which is based on the suggested theories and is used to illustrate calculus instructor's foundation factors when they decide their instructional practices. The created framework addressed in this chapter are intended to help examine calculus instructors' teaching approaches toward low-achieving students. The methodology and description of the data is addressed in Chapter 4 followed by the analysis of the results in Chapter 5. The discussion of the significant findings which are strengthened by the literature appear in Chapter 6. The thesis will conclude with the final remarks in Chapter 7.

Chapter 2. Literature Review

2.1 Introduction

Calculus has been acted as a critical filter course amidst students aiming for careers in engineering, medicine, education, science, and mathematics (STEM) for many years. To earn the Bachelor of Science degree, students are required to meet the certain grades in their calculus courses whether they want to study calculus subjects. The understanding and teaching of calculus, however, in universities have long been considered subjects of great difficulty in mathematics education history. Tall (1975, p. 3) believed "Vast numbers of textbooks are available, seemingly covering every conceivable approach, but many problems remain". Therefore, with the purpose of which to improve the teaching of calculus, mathematics educators have researched regarding efficient calculus teaching environments for students.

This chapter presents relevant work from a number of areas, including efficient teaching calculus at the university level. Moreover, the chapter explores background information relating to the existing literature, theories, methodologies, evidence and conclusions, and to critically examine their strength or inconsistencies and shortcomings. Beyond this, it is hoped to show how this research contributes to expand the knowledge base in the field of teaching and learning calculus at the university level.

Structure of the Literature Review

The chapter starts with a description of the state of Calculus Reform movement, one of the impacted paradigm shifts. Since this study mainly focuses on examining instructors' calculus teaching approaches at one Midwest research university, the chapter then continues by briefly describing some theoretical frameworks teaching in context, such as the relationships between teachers' beliefs, knowledge, and attitude and their instructional practice. The next of the chapter concentrates on a theory, namely Schoenfeld's ROGs framework. Since the ROGs framework is regarding school teacher in general, some applied research using the framework at the university level mathematics courses teaching is also examined. As one of effective teaching methods and resources in the ROGs framework, employing technologies to teach calculus and its impact are devoted in the following section. Since a calculus instructor is both research mathematician and teacher, the final part of the chapter is concentrated on mathematicians.

2.2 Calculus Reform

One of vast research movements to improve the calculus teaching, Calculus Reform instruction has been under way as an organized action since about 1986 by National Science Foundation. The primary hallmarks of reform are in the areas of content (for example, the Harvard Consortium Project), pedagogy (for example, the New Mexico State Project) and technology (for example, Calculus & Mathematica, from the University of Illinois, and Project CALC, from Duke). About content area, driven by intent to improve student understanding of calculus, there were often content shifts to emphasize the main concepts and applications of calculus. Therefore, mathematics educators wanted to emphasize problem solving and modeling as the goal of the calculus contents reform. The reason Calculus Reform researched in pedagogy area is they wanted more student involvement during contact hours. Therefore, a wider variety of teaching strategies were been employed with the aim of making the student a more active participant. The third purpose of Calculus Reform is they wanted to take advantage of technology. Handheld graphing calculators or computers have been exploited as tools to enhance student learning.

Although different people may phrase it differently regarding the goal of Calculus Reform, everyone involved would agree that they were trying to improve students' conceptual understanding (Hallett, 2000).

2.2.1 Content, Pedagogy and Technology

In the 1980s, the teaching of calculus came under scrutiny for several reasons such as concern over the students' apparent lack of understanding of the subjects. Especially, when students are asked to use calculus in different settings they have learned, students often showed their deficient application ability. As Hallet (2006, p. 1) described:

> Faculty outside mathematics frequently complained that students could not apply the concepts they had been taught. In some instances, ideas were being used in other fields in ways that were sufficiently different from the way they are used in mathematics that it was not surprising that students did not make the connection. For example, the minimization of average cost has was done symbolically in mathematics, if at all, whereas it is usually done graphically in economics.

When Calculus Reform movement started to improve the teaching of calculus, there was great variation among the projects in content, pedagogy and technology. Effective components, however, in one project were adapted and incorporated by other projects in the 1990s. After Calculus Reform got underway, the most fundamental change made by the new calculus texts was the introduction of many more nonstandard problems. Smith (1994) presented that many are discovering the value of real-world problems, not as afterthoughts, but as up-front motivators, as "hooks" to capture the interest of students who have no interest in mathematics for its own sake. After all, one does not have to know much mathematics to state a substantial and interesting problem, and the problem itself can keep students focused on the task of developing mathematical tools. Newer calculus texts have a much wider variety of problems and fewer “template” problems that can be solved by mimicking a worked example in the text (Hallet, 2000).

Technology is incorporated in many current calculus courses. In fact, rapid advances in affordable technologies have provided a powerful stimulus for rethinking mathematics curricula. In the results, there are the development and implementation of numerous innovative calculus teaching methods using technology such as most texts now allow the use of technology.

In a comprehensive review, Granter (1999) found that 50% of the institutions conducting studies on the impact of technology reported improvements in conceptual understanding and other areas without loss of computational skills. Therefore, instructors’ orientations about the use of technology are required to study to improve student learning.

The use of technology, however, for calculus courses are still controversial. Many calculus textbooks include exercise problems require the use of calculators or computers, although often as an add-on, to accommodate a variety of faculty preferences. The emerging consensus recognizes the importance of using "appropriate technology," which means different things on different campuses and for different groups of students, depending on available resources, the particular focus of the course, and many other factors (Smith, 1994).

Another impact of Calculus Reform on student learning is instructors' changed expectations on students' conceptual understanding on homework and exam. Smith (1994) revealed that every calculus reform program focuses on developing thinking skills and conceptual understanding: on eliminating the possibility of students being certified as having learned calculus when all they have demonstrated is modest proficiency at memorizing formulas and manipulating symbols. Hallet (2000) also noted that changes in homework and exams have a larger effect on student learning than changing lecture content. In the 1990s, open-ended problems and extended applications are found in many books, although often as an add-on at the end of the chapter. Requiring thinking is central to establishing the idea that mathematics is more than applying formulas. Therefore, getting an answer is no longer enough to learn calculus. Along with the increase in nonstandard problems and the use of technology, many new calculus courses emphasize conceptual understanding in a rich interplay of symbolic, numerical and graphical forms what the Harvard Consortium Project have popularized as "The Rule of Three." In addition, Hallett emphasized open-ended problems that require extensive writing, often in cooperative groups so we need to call it as "The Rule of Four."

As the results of the Calculus Reform, we have experienced some changes in the teaching of calculus in the aspects of both more variety in calculus courses and more emphasis on conceptual understanding.

2.2.2 Students' Conceptual Understanding of Calculus

It is not unusual to find students who use mathematical procedures with little or no understanding of the concepts behind the procedures (Hiebert and Lefevre, 1986;

Schoenfeld, 1985). In the results, these problems have been mainly considered in Calculus Reform. As one way to improve students' conceptual understating to calculus, Hallet believed that open-ended problems requiring extensive writing are important to learn calculus. Similar research conducted by other researchers (e.g., Brandau, 1990; Doherty, 1996; Miller, 1992; Pugalee, 1997; Rose, 1990) who have suggested that one way in which students may be encouraged to see mathematics as meaningful is through the use of writing to learn mathematics (WTLM). The underlying assumption of WTLM is that writing is not simply a way of expressing or displaying what one has learned and itself a fundamental mode of learning (Stehney, 1990).

In her study on expressive writing, Rose (1989) suggested that the perceived benefits of writing in mathematics could be divided into three general categories: benefits for the student as writer, benefits to the teacher as reader, and benefits to the student-teacher interaction. Rose (1989) revealed that one of the perceived benefits to students was that the writing helped them to understand the material. Others (Gopen and Smith, 1990; Nahrgang and Petersen, 1986; Pugalee, 1997) have also proposed that WTLM may improve students' conceptual understanding.

On the other hands, Tall (2010) claimed that we need to consider how we, as individuals, think about the ideas including the notion of continuity, limit, tangent, derivative, and so on to 'make sense' of the concepts of the calculus. The first thing to make sensible of the concepts is to reflect for a moment and write down what we think these calculus concepts actually mean. Not just their definitions, but how we might describe the meaning of the ideas and their relationships in a way which makes sense to us, as individuals, and how these ideas might make sense to students. Tall (2010) also believed that when students begin to study the calculus, their success depends on their previous experience and current knowledge. Tall (2010, p.26), however, noted that:

> Mathematicians see the nature of mathematical analysis in a variety of different ways. Some seek a natural approach building on their previous experience. Such a developmental path can be seen in the earlier description of transforming the concept of continuity into the formal ε-δ limit definition. Other mathematicians see formal mathematics as a completely new start, building theorems deductively from the definitions, and constructing a new formal structure based entirely on definition and proof.

Then Tall (2010, p. 26) suggested that:

> At least two distinct routes to mathematical analysis, one prefaced by a natural transition from concepts such as natural continuity and local straightness to formal definitions, another by formal deductions within an axiomatic system. Whichever method is used, the eventual product is a knowledge structure where all the theorems are deduced from fundamental axioms and definitions. At one end of the spectrum is a knowledge structure linked to embodied images, at the other is a knowledge structure based on linguistic definitions and formal deduction.

During the 1990s essentially every math department made some changes to their calculus courses. Some of these changes have persisted, some have not, but all have made the teaching of calculus a subject of discussion in many math departments where this was not the case previously (Hallett, 2000).

2.3 Theoretical Perspectives

Even though mathematics educators have applied a number of curriculum reforms in calculus instruction, research into the teaching and learning of calculus is in an embryonic state (Frid, 1994). As noted in previous section, half of U.S. students majors in mathematics and physics science switch to other fields because of poor teaching as a reason (Seymour *et al.*, 2005). Unlike most school teachers, lecturers in universities are having conflicted roles as researchers and teachers in mathematics. Nardi, Jaworski, and Hegedus (2005, p. 285) described this problem as follows (p. 284):

> Many academic mathematicians are aware of the changing perception of their pedagogical responsibility and of experimentation with different teaching approaches, but they have limited opportunities to embrace change owing to faculty structures and organization. Often university teachers have joint responsibility for research and teaching. This is clearly beneficial, but it can cause more emphasis to be placed on mathematical research in places where that is the main criterion for promotion. Teachers of university mathematics courses, on the whole, have not been trained in pedagogy and do not often consider pedagogical issues beyond the determination of the syllabus; few have been provided with incentives or encouragement to seek out the findings of research in mathematics education. In days gone by, it was assumed that the faculty's responsibilities were primarily to present material clearly, and that "good" students would pass and "poor" ones fail. Of course, given the current climate of accountability, this is no longer the case (Alsina, 2001). Further, the relationships between mathematicians in mathematics departments and their colleagues in mathematics education are often strained, with less productive dialogue between them than could be beneficial (Artigue, 2001). The same can be said of relationships between mathematicians and engineers, economists, etc., although mathematics service teaching to students in other disciplines is an enormous enterprise (Hillel, 2001).

Therefore, Nardi *et al.* (2005, p. 285) suggested that:

> These general factors tend to work against, or delay, improvements in the teaching and learning of mathematics at the undergraduate level. In this sense, research that builds the foundations of collaboration between university mathematics teachers and mathematics educators is crucial and, given the pressure currently exercised on universities regarding the need for a scrutiny of their teaching practices, timely. But reform of pedagogical practice can only follow from developing pedagogical awareness in the first place.

In this sense, studies in the teaching of calculus are still needed of various instructional emphases and formats and their subsequent effects on learning.

2.3.1 The Foundations of the Instructional Practice of the Calculus Teacher

In the 1980s and 1990s, research in calculus had been focused on investigation of students' understandings of limits, differentiation or integration, or on students' errors, misconceptions, or inability to perform certain tasks (for example, Orton, 1983; Seldon *et al.*, 1989; Sierpinska, 1987; Tall & Vinner, 1981; Williams, 1991). After changes by Calculus Reform movement have been occurring in the approaches of calculus teaching, more research literature related to the influences on students learning of teaching strategies has appeared (for example, Alexander,1997; Allen, 1995; Brunett, 1995; Fiske, 1994; Frid, 1994; Heid, 1988; Tall, 1990). Although more mathematics educators have investigated teaching of calculus, there are considerably limited research literatures regarding calculus lecturers' psychological foundations of the practice of teaching calculus.

When a lecturer enters into a classroom, he or she is asked to make his or her lecturing decisions. What affect what that instructor does, on a moment-by-moment basis, as they engage in social environments? In other words, what factors can explain how and why lecturers determine the choices they do, while working on teaching in front of students in their classrooms.

There are many factors that influence a teacher's instructional methods. Since the structure of the subject matter and the manner in which it is taught (e.g., with integrity or improbability, contempt or respect) is extremely important to what the students learn and their attitudes toward learning and the subject matter (Shavelson & Stern, 1981), Thompson (1984) suggested that we should consider the research topics, how teachers integrate their knowledge of mathematics into instructional practice and what role their conception of mathematics might play in teaching. He noted that teachers developed patterns of behavior that are characteristics of their instructional practice. Thus, in some cases, these patterns may be manifestations of consciously held notions, beliefs, and preferences that act as 'driving forces' in shaping the teacher's behavior. In other cases, the driving forces may be unconsciously held beliefs or intuitions that may have evolved out of the teacher's experience.

Consistent with Thompson's (1984) arguments, Ernest (1989) presented a descriptive model that outlined the different types of knowledge, beliefs, and attitudes of a mathematics teacher and how these three components relate to teachers' models of teaching mathematics. According to Ernest, teacher knowledge represents the cognitive component of this model and includes the knowledge of mathematics, other subject matter, pedagogy and curriculum, classroom management, context of teaching, and education. Teacher beliefs including the conception of the nature of mathematics, models of teaching and learning mathematics, and principles of education and teacher attitudes towards mathematics and teaching mathematics represent the affective components of the model. From the model, knowledge, beliefs, and attitudes are all posited to have a direct influence on teachers' instructional practices.

About the teacher's contents knowledge issue, Thompson (1984) conducted three case studies to investigate the conceptions of mathematics and mathematics teaching. The researcher examined the relationship between conceptions and practice and then showed that the teachers' beliefs, view, and preferences about mathematics and its teaching played a significant, albeit subtle, role in shaping their instructional behaviors. Then he showed that teachers differed in their awareness of the relationships between their beliefs and their practice, the effect of their actions on the students, and the difficulties and subtleties of the subject matter. In the result, the research about instructors' beliefs and philosophy are important to improve effect learning environments.

As suggested by Ernest (1989), instructors' beliefs related about mathematics and mathematics teaching have also found to influence classroom practices (Richardson, 1996; Pajares, 1992; Patterson *et al.*, 2011; Thompson, 1992, 1984). Instructional staffing for basic math courses varies by institution: from almost all being taught by graduate students with bachelor's degrees in mathematics, to most being taught by people with advanced degrees in mathematics. Many U.S. teachers are unaware of that course enrollees may not share mathematicians' views about mathematics and may never have experienced mathematics as interesting or clear (Hauk, 2005; Ouellet, 2005). Thus the inquiry about math instructors' beliefs about course enrollees' purpose for taking their class should be done beforehand to explore their teaching methods. For example, Tsay (2011) explored the classroom discourse (i.e., connected stretches of language that make sense) between students and instructor over the course of a semester of college algebra. The main question of the research was "what is the nature of classroom discourse, and patterns in discourse, for this instructor in these two college algebra classes? (p. 209)" Additionally, the researcher inquired about how the course coordination interacts with classroom discourse. In this report they identified conflicts evidenced in the classroom through student and instructor behaviors and in the evolution of the contract for them. From the Tsay's research (2011), we understand how one instructor managed his classroom based on his beliefs and teaching philosophy while there were the environmental conflictions.

It is challenging to develop comfort and expertise in college teaching, particularly without any preparation in the pedagogy of adult learners. However, as Mason (2009) and others (Adams, 2002; Kung, 2010; Linse, Turns, Yellin, & VanDeGrift, 2004) noted, a basic disconnect between the everyday world of university mathematics, guided by the imperative for logico-deductive theorems, and of the teaching world in college mathematics is that in teaching there are “too many factors connected with the setting, the individuals, the expectations, and the practices within lectures or tutorials to be able to declare one [practice] better than another universally” and that “seeking a mathematical-type of theorem with definitive conclusions” for what constitutes “best practice” is an exercise in futility (Mason, 2009, p. 5). In that sense, Tsay provided an accessible story that might serve as an imperfect mirror for researchers and practitioners of college mathematics.

In this section, we notice that educators argued that it is necessary to consider beliefs, knowledge, attitudes to account for the differences between mathematics teachers. For example, it is possible that for two teachers to have very similar knowledge, but for one to teach mathematics with a problem-solving orientation, while the other has a more inquiry based teaching approach vice versa. Because of the potent effects of orientations, Ernest (1989) provided the framework of learning and teaching of mathematics including an extensive treatment of the mathematics teacher’s beliefs, knowledge and attitudes. More broad and recent models of a theoretical framework of teaching-in-context were explored by Schoenfeld (2010). Since the goal of this thesis is to inquire how mathematicians think of teaching calculus and students, Schoenfeld’s framework provides appropriate theoretical framework for it.

2.3.2 Schoenfeld's ROGs Framework

In the book, *How We Think* (Schoenfeld, 2010), Schoenfeld and his Teacher Model Group (TMG) at UC Berkeley have developed a theoretical framework of teaching-in-context, with a goal of explaining how and why people make the choices they do, while working on issues they care about and have some experience with, amidst dynamically changing social environments. His major claim is that (2012, p. 345):

> People's in-the-moment decision making when they teach, and when they engage in other well practiced, knowledge intensive activities, is a function of their knowledge and resources, goals, and beliefs and orientations. Their decisions and actions can be "captured" (explained and modeled) in detail using only these constructs.

The researcher provided the basic model of how things work. The basic structure is recursive: Individuals orient to situations and decide (on the basis of beliefs and available resources) how to pursue their goals. If the situation is familiar, they implement familiar routines; if things are unfamiliar or problematic, they reconsider. He argued that if we know enough about an individual's resources, goals, and beliefs, this approach allows us to model their behavior on a line-by-line basis.

Resources

Schoenfeld (2010) explored people's use of their resources with focus on knowledge during goal-oriented activity. He defined an individual's knowledge as follows (p. 25): The information that he or she has potentially available to bring to bear in order to solve problems, achieve goals, or perform other such tasks. There are various kinds of knowledge such as factual, procedural, conceptual, heuristic problem-solving knowledge and so on. Schoenfeld pointed that teaching knowledge in terms of factual knowledge is multifaceted, including not only curricular and content knowledge, but also information about particular students' mathematical performance and personalities. On the other hand, conceptual knowledge is the intellectual rationales that explain how things fit together and why things work the way they do. He provided an example regarding the conceptual knowledge in teaching mathematics situations (p. 26):

> A joint grounding in subject matter content and learning theory helps teachers make curricular decisions, both in terms of what to emphasize (how will the mathematics studied this year serve as the base for what students will learn next year or the following year?) and of how to have students experience it (for example, as a conceptually connected domain rather than as a collection of isolated facts and procedures).

Moreover, Schoenfeld argued that there are myriad rules of thumb for teachers as heuristic problem-solving knowledge. For example, teachers try to motivate students by providing interesting examples in a lesson, and vary classroom routines so that students don't get bored.

Schoenfeld provided variety examples of knowledge not only in mathematics teaching but also in cooking and medical practice. He revealed, however, the knowledge is universal, in that they are part of the knowledge base in every domain of human activity. Besides showing a lot of examples, Schoenfeld asserted that (p.27):

- Knowledge matters in problem solving. Any analysis of an individual's problem solving, or an individual's engagement in any activity, must delineate the knowledge (and more broadly, the resources) available to the individual.
- Knowledge matters in problem solving. Any analysis of an individual's problem solving, or an individual's engagement in any activity, must delineate the knowledge (and more broadly, the resources) available to the individual.

- Knowledge is associative and it comes in “packages” variously referred to as scripts, frames, routines, or schemata.
- Memory is associative. Things we perceive, or things we think of, bring to mind other things that share properties with them.
- Knowledge gets activated and accessed in ways that entail related actions and associations.
- Knowledge structures are connected, generative, and regenerative.

Schoenfeld noted that a meaningful analysis of people’s activities in many contexts must take into account the material and social resources at their disposal as well as the intellectual ones.

Orientations

Orientations are an abstraction of beliefs, including values, dispositions, tastes, and preferences in Schoenfeld’s teaching-in-context framework. He believed that (p.29):

> How people see things (their “worldviews” and their attitudes and beliefs about people and objects they interact with) shapes the very way they interpret and react to them. In terms of socio-cognitive mechanisms, people’s orientations influence what they perceive in various situations and how they frame those situations for themselves. They shape the prioritization of the goals that are established for dealing with those situations and the prioritization of the knowledge that is used in the service of those goals.

According to Schoenfeld, almost every aspect of a teacher’s classroom thoughts and actions are shaped by the teacher’s orientations toward mathematics, learning and teaching, and students. In consequence, a teacher may provide different teaching approaches depend on his or her orientations of what mathematics students should learn, how lesson should be structured to foster appropriate student engagement with mathematics, and what the teacher's role in helping students develop, both mathematically and as young people, should be. Schoenfeld provided extended discussions of the ways in which people's decisions are shaped by the ways in which situations are framed.

On Schoenfeld's model, he showed that if an individual enters into a particular context with a specific body of orientations, then the individual takes in and orients to the situation. That is, certain pieces of information and knowledge become salient and are activated in his how things work model.

Goals

Instructors are all engaged in goal-oriented activities and may have short-term, medium-term, and long-term goals operating at the same time. Some of which are determined prior to the instruction and some of which emerge as the lesson unfold. For instant, there are goals including responding at a specific moment to a particular student in an appropriate way, working through the content of the part of the today's lesson currently under discussion, building a base for future work, helping students to develop over the course of the year, preparing them for high-stakes tests, and more (Schoenfeld, 2010). Schoenfeld believed that "Goals need not be conscious: sometimes we just act, and only upon reflection (if at all) do we realize that there was an underlying reason for our actions" (p.21). Therefore, Schoenfeld suggested that most behavior can be modeled explicitly by goal-oriented structure, not that individuals consciously establish and follow a goal tree or other similar analytic structure. By providing diverse examples, his point that even a straightforward procedural solution to a mathematical exercise can be modeled in goal-oriented terms was revealed. Everything, hence, could be described as the implementation of standard goal-oriented procedures, with goals unfurling naturally into finer-grained sub goals. Even though, when unexpected or unusual events break the routine, individuals follow on the basis of their orientations, and then implemented a new set of routines for the new goals that resulted from decisions.

Schoenfeld, also, believed the near-ubiquity of goals and goal-oriented behavior and believed that most human behavior can be characterized, in minute detail, in ways that are consistent with the kind of goal-oriented structure. He showed these arguments by considering a series of examples of increasing complexity (Schoenfeld, 2010).

2.3.3 Problem Solving

As mathematicians and teachers, we use a wide range of problem solving strategies (Pólya, 1945). However, when we observe any mathematics classrooms, it is often in mathematics classrooms to see that students have not explicitly been taught those strategies which Pólya called "heuristics" in his book *How to Solve It.* Therefore, the reason, Schoenfeld (2010) learned, was that when people tried to teach the strategies described in Pólya's books, students did not learn to use them effectively. The problem is consistent with mathematics educators' challenge of what are ways we can teach students more effectively. For the purpose of efficient teaching methods, we should understand such problem solving strategies, heuristics, well enough so that we could help students learn to use them effectively. Along with the challenge, Schoenfeld (2012, p. 344) explored to find answers of the following questions:

1. Could we develop a theoretical understanding of teaching in ways that allowed us to understand how and why teachers make the choices they do, as they teach?
2. Could that understanding then be used to help teachers become more effective?

3. Could the theoretical descriptions of teaching be used to characterize decision making in other areas as well to the degree that teaching is typical of knowledge-intensive decision making?

Schoenfeld (2010) developed a theoretical framework of teaching-in-context to explain what factors influences to teachers' instructional practice in the moment decision making when they are in front of students.

To understand his theoretical framework, we need to discuss his earlier research on mathematical problem solving (Schoenfeld, 1985) which was the "bottom lines" of his theory.

Schoenfeld (1985) argued that mathematical problem solving is possible to explain someone's success or failure in trying to solve problems on the basis of these 4 things:

1. Knowledge (or more broadly, resources); Knowing what knowledge and resources a problem solver has potentially at his or her disposal is important. It includes various routines the teacher has for achieving various goals.
2. Problem solving strategies, also known as "heuristics"; Faculties use heuristics. They pick them up by themselves, by experience. Typically, students don't use the problems solving strategies.
3. "Metacognition" or "Monitoring and self-regulation"; Effective problem solvers plan and keep track of how well things are going as the implement their plans. If they seem to be making progress, they continue; if there are difficulties, they re-evaluate and consider alternatives. Ineffective problem solvers (including most students) do not do this. As a result, they can fail to

solve problems that they could solve. Students can learn to be more effective at these kinds of behaviors.

4. Beliefs; Students' beliefs about themselves and the nature of the mathematical enterprise, derived from their experiences with mathematics, shape the very knowledge they draw upon during problem solving and the ways they do or do not use that knowledge. This factor was replaced by orientations to include dispositions, beliefs, values, tastes, and preferences.

These arguments lay the groundwork for his theory that explains how and why people make the choices they do, while working on issues they care about and have some experience with, amidst dynamically changing social environments.

2.3.4 Decision Making Process

Schoenfeld described a theoretical architecture that explains people's decision-making during such activities. The main theoretical claim (2012, p. 346) is that:

> goal-oriented "acting in the moment" – including problem solving, tutoring, teaching, cooking, and brain surgery – can be explained and modeled by a theoretical architecture in which the following are represented: Resources (especially knowledge); Goals; Orientations (an abstraction of beliefs, including values, preferences, etc.); and Decision-Making (which can be modeled as a form of subjective cost-benefit analysis)

He argued that since teaching is knowledge intensive and highly social and it calls for instant decision making in a dynamically changing environment, we can think of no better domain to study than teaching. And, if we can model teaching, we can model other comparably complex, "well practiced" behaviors. All of these routine or non-routine dynamic social activities such as teaching involve goal-oriented behavior –

drawing on available resources (not the least of which is knowledge) and making decisions in order to achieve outcomes you value.

Therefore, Schoenfeld constructed the basic model of how things work, specifically when we teach. The basic structure of the model may be explained by recursive: Instructors orient to situation and determine how to approach their teaching goals based on their beliefs and available resources. In the result, we can explain an instructor's teaching approaches when we know enough about their resources, goals, and beliefs.

When a teacher enters into a classroom with a specific body of resources, goals, and orientations, he or she takes in and orients to the situation. Then goals are established based on the orientation, and activate and draw on relevant resources, particularly their knowledge. Decisions consistent with these goals are made, consciously or unconsciously, regarding what directions to pursue and what resources to use (Schoenfeld, 2010). These decisions which are the instructional practice in teaching are crucial in the classroom.

2.3.5 Effect of Using Technologies in Teaching Calculus

Consistent with teaching practice models by Schoenfeld (2010), instructors' orientations related to mathematics also influence instructional practices. Teachers with a heightened sense of teaching efficacy were more likely to use open-ended inquiry and student-directed methods of teaching (Czerniak & Schriver, 1994), whereas teachers with a lowered sense of teaching efficacy may be less willing to try innovative instructional techniques a kind of inquiry-based instruction in their lessons (Guskey, 1988). Inquiry –based mathematics instruction is characterized by students' active engagement in meaningful mathematical problems and activities that involve conjecturing, investigating, collecting and analyzing data, reasoning, making conclusions, and communicating (Jarrett, 1997; Australian Education Council, 1990; Lampert, 1990; National Council of Teachers of Mathematics, 1989). Appropriate assessment and student resources are also important aspects of inquiry-based instruction (Wilkins, 2008). The availability of appropriate tools and materials, for example, calculators, and computers serve to enhance the value of mathematical inquiry (Cobb & McClain 2006; National Council of Teachers of Mathematics, 2000; Baroody, 1998; Jost, 1992). Therefore, as one of effective teaching methods using technology should be considered. In 1992, Jost examined the process of implementation through the beliefs and practices of teachers in order to gain an understanding of the relationship between teacher constructs, contextual influences, actual use, and the meaning that teachers acquired for the change. The new curriculum which was implemented included the use of programmable graphics calculators in teaching calculus. In this research, Jost noted that the use of the calculator as an instructional tool is compatible with interactive or inquiry-oriented methodologies. One of the interesting results of the study is that the teachers who grew to view the strength of the calculator as an instructional tool have student-centered and discipline level goals for their students; interactive, inquiry-based teaching styles; and student-centered views on learning which included the view that students can learn through interactions. The researcher examined that the use of the calculator as an instructional tool in the calculus classroom requires some change in the curriculum, is a vehicle for implementing parts of the existing curriculum, and is a vehicle for reform due to things it now makes possible which could not be done without the use of technology.

Drijvers (2012) also noted that the integration of technology in mathematics education is a subtle question, and that success and failure occur at levels of learning, teaching and research. In spite of this complexity, three factors, the design, the role of the teacher, and the educational context, emerge as decisive and crucial. In this paper, he examined a number of leading studies have highlighted the potential of digital technologies for mathematics education. The first factor, Drijvers revealed, is the crucial role of design. The researcher concerned not only the design of the digital technology involved, but also the design of corresponding tasks and activities, and the design of lessons and teaching in general, three design levels that are of course interrelated. Drijvers (2012, p. 496) noted that:

> In terms of the instrumental genesis model, the criterion for appropriate design is that it enhances the co-emergence of technical mastery to use the digital technology for solving mathematical tasks, and the genesis of mental schemes that include the conceptual understanding of the mathematics at stake. As a prerequisite, the pedagogical or didactical functionality in which the digital tool is incorporated should match with the tool’s characteristics and affordances. Finally, even if the digital technology ́s affordances and constraints are important design factors, the main guidelines and design heuristics should come from pedagogical and didactical considerations rather than being guided by the technology ́s limitations or properties.

As the second factor that affects to successful technology teaching and learning environments, Drijvers (2012) emphasized the role of the teacher. He believed that integration of technology in mathematics education is not a panacea that reduces the importance of the teacher. The researcher suggested that the teacher has to orchestrate learning by synthesizing the results of technology-rich activities, highlighting fruitful tool techniques, and relating the experiences within the technological environment to paper-and-pencil skills or to other mathematical activities. To be able to do so, Drijvers (2012, p. 496) suggested that “a process of professional development is required, which includes the teacher’s own instrumental genesis … the development of his technological and pedagogical content knowledge”

The third and final factor concerns the educational context and the researcher revealed that how important it is that the use of digital technology is embedded in an educational context that is coherent and in which the work with technology is integrated in a natural way.

Besides identified the crucial factors for effective technology using in the paper, Drijvers explored trends which can be seen in retrospective. Drijvers (2012, p. 497) noted that:

> A first trend to identify is that from optimism on student learning in the early studies towards a more realistic and nuanced view, the latter acknowledging the subtlety of the relationships between the use of digital technology, the student ́s thinking, and his paper-and-pencil work. A second trend is the focus not only on learning but also on teaching. The importance of the teacher is widely recognized and models such as TPACK, instrumental orchestration and the pedagogical map help to understand what is different in teaching with technology and to investigate how teachers can engage in a process of professional development. The third and final trend I would like to mention here concerns theoretical development. Whereas many early studies mainly use theoretical views that are specific for and dedicated to the use of digital technology (e.g., Pea’s notions of amplifier and reorganizer in the Heid study), recent studies often include more general theories on mathematics education or learning in general, and also combine different theoretical perspectives.

In addition, he expressed the importance of the theoretical developments for the advancements in the field. Therefore, he showed strong relationships between the theoretical frameworks, the digital tools and the mathematical topics.

Although there are many mathematics teachers who tend to carry on the traditional teaching of mathematics as rules and procedures (Mewborn, 2001). Also, many researchers have explored the positive effect of digital technologies for mathematics teaching and learning. The U.S. National Council of Teachers of Mathematics, for example, in its position statement claims that “Technology is an essential tool for learning mathematics in the 21st century, and all schools must ensure that all their students have access to technology” (NCTM, 2008). Wilkins (2008) noted that it is quite possible that some teachers with strong mathematics backgrounds attribute their success to the ways they were taught. If they were taught using traditional methods, it is likely that they see these methods as effective for teaching mathematics and will tend to use these methods. Calculus instructors who have a mathematics doctoral degree and teaching experiences were taught calculus courses at least 10 years ago so it seems they were taught using traditional teaching methods. And there is no doubt they have strong mathematics backgrounds and success in calculus courses.

2.4 Summary

In summary, despite many efforts to improve calculus learning and teaching environments for students, students drop-out and failure rates in calculus remain high compared to many other undergraduate courses. Therefore, mathematics educators are required to study regarding efficient calculus learning and teaching environments. The necessity of mathematics education research related in calculus seems very trivial, however, their importance can hardly be overestimated. Moreover, this requirement is consistent with the ultimate goal of education research in general.

There are many factors which affect instructors' professional development. According to Schoenfeld's framework, especially, a teacher's any decision-making process involves complex interactions of the individual's resource, orientations and goals for a given situation. Teachers with different ROGs in teaching and learning calculus may likely make different instructional practice. In the sense, better understanding to calculus teachers' ROGs and their particularity as research mathematicians and calculus instructors can help students' effective learning.

Chapter 3. A Theoretical Framework

3.1 Introduction

Based on the review of the literatures in Chapter 2, I have applied Schoenfeld's model to explore the interactions between teacher beliefs and goals and their influences on the actions of teaching. That is, I inquire about calculus instructors' calculus curriculum and its subject knowledge which is how they are using and evaluating their resources. Instructors' orientations about low-achieving students, their possibility of improving mathematical ability by calculus courses, and instructors' self-evaluation as teachers for low-achieving students are explored. Furthermore, I inquire about calculus instructors' goals including expectations for their classes and their students. Then, how the instructors' resources, orientations, and goals are allocated the link the actions arising as consequence of them especially to low-achieving students.

3.2 Framework of the Calculus Instructor's Resources, Orientations, and Goals

More research related to the practice of college level courses and its quality has been conducted recently. For the last few decades, mathematics learning theorists have advised researchers and teachers on ways to improve student mathematics performance. As we noted in Chapter 2, however, we still are confronted with the fact that these messages are mostly undelivered or unaccepted by the mathematics teachers, especially calculus instructors. For example, the students' drop-out and failure percentages in calculus are higher than in many other undergraduate courses. Hence, that invoked some researchers to study to find the reasons for the disconnections between learning and teaching theories and instructional practice in general education. Though, many of the pedagogical issues in calculus teaching still need to be discussed. Creating a framework for the research regarding mathematicians' teaching decision making processes may be helpful to decrease the disconnections. In the absence of a firm theoretical framework to describe of how calculus instructors make their teaching decisions, the analysis of the data also became somewhat difficult. Therefore, in this chapter a suitable theoretical framework is discussed to identify calculus lecturers' ROGs and their functions in the foundation of instructional practice.

3.2.1 Description of the Design of the Framework

In 1985, Schoenfeld researched mathematical problem solving with goals of understanding problem solving. His book, *How We Think* (Schoenfeld, 2010), is an outgrowth of the research on mathematical problem solving. Since he believed that teaching is also a problem solving activity, the goals of the books paralleled with the goals of his previous research. In line with Schoenfeld's views on the fact that teaching can be considered as a problem solving activity, this thesis is based on that fundamental idea, even though teaching is a more complex activity. Hence, the better we can understand the nature of teaching calculus, which Schoenfeld included as a complex knowledge-intensive activity, the better we can help instructors become effective at teaching the subject. Then it may lead to students' efficient learning environments about calculus. Moreover, it can be generalized to other mathematics subjects besides calculus.

A useful theoretical framework would provide what to look at, what its impact might be and how things fit together. In the sense, Schoenfeld's framework describing the relationship of resources, orientations and goals to decision making contributes to examine how and why teaching calculus works the way it does and enlighten the situation. Furthermore, such a framework would also tell researchers how and why instructors drew on particular knowledge or strategies, or how and why they made the decisions they did.

Before describing this new framework, we will consider some examples applying Schoenfeld's ROG framework. The research given below on ROGs aimed to reveal that the framework contributes valuable information about the decision made by the lecturers at the college level during teaching.

3.2.2 Some Research regarding the ROGs Framework

At the K-12 level, the effectiveness of various approaches to instructional practice and ways in which a teacher's knowledge, beliefs and goals impact on their teaching practice have been extensively examined (for example, Thompson, 1984; Ernest, 1989; Aguirre & Speer, 2000). In contrast, research at the university level is relatively limited (Paterson *et al.*, 2011).

Addressing this need, Thomas, Kensington-Miller, Bartholomew, Barton, Paterson, and Yoon (2011) have developed a project (DATUM) which aims to examine ways in which Schoenfeld's Theoretical Framework can be used, and extended to examine university lecturing and to support the professional development of lecturers. As part of a 2-year project (DATUM) that is itself part of a larger research study on undergraduate teaching and learning, Paterson, Thomas, and Taylor (2012) presented ways in which Schoenfeld's Resources, Orientations and Goals framework of teaching-in-context can be extended to examine university lecturing. Although Calculus instructors' background, degree and research interest fields vary, there exists common characteristics between teaching mathematics. They are all research mathematicians and teachers unlike those of the K-12 level. That brings differences in their teaching practice and their goals throughout Calculus courses (Nardi, 2008; Paterson *et al.*, 2012). Therefore, the researchers analyzed how the conflict of competing goals arising from what appears to be an internal dialogue between lecturer as mathematician and lecturer as teacher. They found that there was an in-the-moment decision to be made between the competing teacher goal and the mathematician goal. For example, they noticed from the research data that one teacher decided her lecture performance between the goal, as a teacher, to stick to the course book and cover all the assigned material and the goal, as a mathematician, to explain clearly the mathematical basis of the construction and solutions of the difference equation.

Another research using Schoenfeld's ROG Theoretical Framework has been explored by Hannah, Stewart and Thomas (2011). They examined the teaching practice of university mathematics lecturers. Especially, a lecturer's pedagogical practices in a course in linear algebra were discussed via a supportive community of inquiry using Schoenfeld's ROG framework to analyze the teaching practice. The research aimed as follows (Hannah *et al.*, 2011, p.976):

1. Would the framework give us useful information about the decision made by the lecturer?
2. Would discussion of the lecturer's ROG among the participants' community of inquiry increase awareness of the orientations and goals and hence enable professional development?

With the aim of the research, they described that the lecturer's overarching goal of assisting students to see the 'big picture' and the methods he employed to do so, arising from his beliefs, values and preferences. Moreover, they found that the orientations could be grouped in clusters, along with their associated goals. To achieve the instructors' goals, the argument that they drew on many resources, primarily their own knowledge as a mathematician, and their knowledge of students, but also technology was revealed. Through an example of this approach in action, they presented along with possible pedagogical implications.

Another study using Schoenfeld's ROG framework was conducted by Törner, Rolka, Rösken and Sriraman (2010). In a workshop organized by the University of Duisburg-Essen in Germany and the Freudenthal Institute in the Netherlands for a bi-national in-service teacher training, the researchers agreed to record an exemplary classroom video on teaching on the treatment of linear functions in a German and a Netherlands classrooms. Among the whole lesson providing incitements for many aspects of analysis, the researchers restricted to explore the unexpected turning point in the videoed lesson. The reason that they focused on the unexpected turning point videoed is that although the teacher was open for new teaching approaches, well-established orientations and resources were not simply replaced but new experiences added or assimilated. According to Pehkonen and Törner (1999), "Teachers can adapt a new curriculum … and absorbing some of the ideas of the new teaching material into their old style of teaching" (p.260). Therefore, they wanted to provide answers to what extent was the sudden change in the teaching style inevitable or at least predictable by opting Schoenfeld's theory of teaching-in-context (Rolka *et al.* 2010). Hence, the main subject of the research analysis was the unexpected turning point in the videoed lesson to introduce linear functions. The researchers followed Schoenfeld's KGB framework which is the ROG framework with abbreviating knowledge, goals, and beliefs:

> Teaching processes depend on multitudinous influencing factors, but a theoretically based description calls for minimizing the variables, in order to identify the most significant ones. Thus, we follow Schoenfeld, who considers the three variables of knowledge, goals and beliefs as sufficient for understanding and explaining numerous teaching situations. (p. 403)

In order to gain a comprehensive comment of the teachers' available knowledge, beliefs, and goals and their interdependencies and structural features, the researchers collected additional data by an interview. Consequently, they found goals and beliefs can hardly be separated. That is, there exist reciprocal correspondences and argumentative relations to beliefs, going beyond the individual sections:

> … diverse goals and beliefs cannot be simply understood as a list one can pull together according to certain overriding categories. Although it makes sense to bundle them together according to general characteristics, it should also be admitted that these are not the only relations between them. In any case, one can ascertain a deductive structure given by overriding and derived goals and beliefs that is influenced finally by mutual correlations, and reminds of Green's (1971) categorization. However, the assessments and prioritizations changed in the course of the lesson… (p. 416)

In addition, the researchers argued that we might need to call subject goals and beliefs as hard and pedagogical content goals and beliefs as soft since pedagogy loses out in the game of pedagogy versus content, as Wilson and Cooney stated in 2002 (Rolka *et al.*, 2010).

By assigning Schoenfeld's KGB framework to convince explanatory power, the research was able to illuminate central focal points on the interdependencies between goals and beliefs, and document the duality of both constructs.

3.2.3 Theoretical Model of Instructional Practice

In this section the calculus instructor's essential resources, orientations, and goals to teach and the ways in which these affect the teaching of calculus are presented.

"People's in-the-moment decision making when they teach … is a function of their knowledge and resources, goals, and beliefs and orientations" (Schoenfeld, 2012, p.345). A conceptual model relating teacher's resources, orientations and goals to decision making, especially instructional practices in teaching, is presented in Fig. 1. This model will serve as the basis for addressing instructors' orientations and goals toward calculus and their students and resources such as curriculum and policy. Furthermore, it will help to understand their relations and influences on instructional practices.

Based on Schoenfeld's (2010) theory, this study hypothesizes teachers' instructional practices to be a function of their resources, orientations, and goals (see Fig. 1). In other words, these three factors are hypothesized to have a direct influence on a teacher's instructional practice.

This relationship is represented in the model with a single-sided arrow from each of these variables directed toward instructional practice. In the past, research on goals and research on beliefs have been quite isolated from one another (Aguirre *et al.,* 2000). Nevertheless, there are several interdependencies between orientations and goals (Rolka *et al.*, 2010):

> A teacher's goals are part of his or her action plan for a lesson. He or she enters the classroom with a specific agenda, in particular, with a certain constellation of goals elucidates the teacher's actions. In this respect, Schoenfeld (2006) emphasizes that a shift in a teacher's goals provides an indication of the beliefs

he or she holds. Moreover, he states that beliefs influence both the prioritization of goals when planning the lesson and the pursuance of goals during the lesson. Taken together, beliefs serve to reprioritize goals when some of them are fulfilled and/or new goals emerge. (p.406)

As it was mentioned above, Schoenfeld gave priority to orientations over goals and stated that a teacher's orientations shape the prioritization both of goals and resources employed to work toward those goals or goals teachers have for classroom interactions (Schoenfeld, 2003). Also, the interdependencies between orientations and goals are mentioned in some literature and found a few clues on a suitable internal modeling within the set of orientations and the one of goals (Cobb, 1986; Cooney *et al.*, 1998; Schoenfeld, 2003; Törner, 2002).

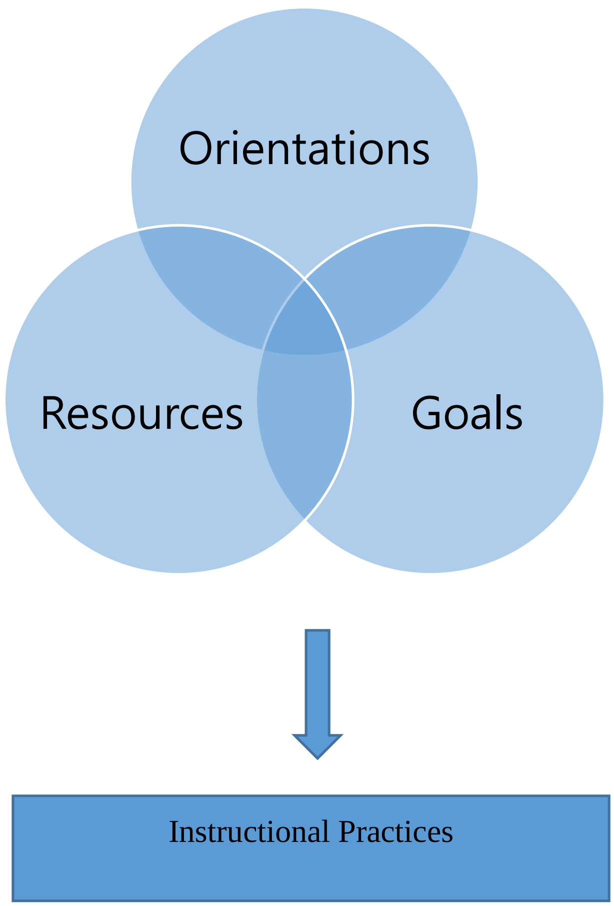

Figure. 1 Theoretical Model Relating Teachers' Resources, Orientations, Goals, and Instructional Practices.

Therefore, prioritizations and their interdependencies will be considered in the framework.

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Variables related to teachers' background characteristics are also modeled accordingly. Unlike most school teachers, calculus lecturers are both research mathematicians and teachers. For the purpose of this study, I sought to analyze how the conflict of competing goals arising from what appears to be an internal dialogue between lecturer as mathematician and lecturer as teacher was resolved. They are hypothesized to influence the system of variables outlined above. It is quite possible that these variables may exhibit direct or indirect influences on classroom practice.

The following section gives more aspects of the framework for this research in detail. The framework was constructed by creating different components of the model to examine an instructor's resources, orientations, and goals while teaching calculus courses. The formulation treats the calculus instructor's cognitive structures stored in the mind of the instructor as schemas. Table 1 shows a complete framework of instructor's ROGs for teaching calculus.

Table 1. A Framework to Illustrate Calculus Instructor's ROGs

Resource	1. Having a strategy to help low-achieving students' understanding. 2. Knowledge of different representation of the material. 3. Knowledge of time constraints during lecture. 4. Making time available for students outside classroom such as office hours. 5. Awareness of low-achieving students' academic pre-knowledge, preparation and learning difficulties for the course. 6. Realizing the low-achieving students' difficult topics. 7. Experience teaching calculus. 8. Knowledge that the instructors may gain by attending professional development programs. 9. Familiarity with the department regulations, procedures, assessment systems, and policies. 10. Text book, lecture notes, homework assignments, and exam problems resources for the courses. 11. Knowledge of available resources especially computer software programs. 12. Knowledge of how to use technology in class. 13. Awareness of available calculus curriculum including syllabus to be covered.
Orientation	1. Prototypical classroom teaching activities and strategies such as group activities, flip classroom and pop-up quiz. 2. Willingness to help low-achieving students. 3. Teaching philosophy regarding the role of the instructor. 4. Limitations as an instructor through teaching experiences. 5. View about students' appropriate learning attitudes. 6. Beliefs about the fact that low-achieving students' mathematics knowledge can be improved. 7. Acknowledging the importance of calculus contents for STEM major students. 8. Awareness of the extent of students' pre-knowledge. 9. Having a positive attitude toward improving low-achieving students' knowledge. 10. Openness to consider applying technology to teach calculus courses. 11. The instructors' management abilities in different classroom settings (e.g., class size, number of students, and number of teaching hours).
Goal	1. To encourage all students to grasp conceptual understanding in the course. 2. To provide learning motivation to the students. 3. To show connections between each concept within the course. 4. To prepare calculus students for other advanced mathematics courses. 5. To improve low-achieving students' mathematical knowledge. 6. To challenge all students to do better.

Resources

As Schoenfeld (2010) stated, the teacher's knowledge is fundamental in shaping the teacher's decision making. The term "knowledge" is used more broadly in this framework as the set of intellectual and contextual resources available to the calculus instructors. In addition, since students are one of the powerful determinants of the classroom activities, knowledge of students taught will be included.

Intellectual Resources

Intellectual resources can be divided into two areas: subject matter knowledge and pedagogical knowledge as a teacher beyond research mathematician. In general, the teacher's mathematical knowledge provides an essential foundation for the teaching. The pure subject knowledge, however, is not examined in detail in this research, because what instructors know about calculus is constructed before their Ph. D. period unlike other components. Moreover, since calculus is a lower division course which includes fundamental subjects for research mathematician without considering specialized fields, contribution of the instructors' calculus knowledge may be little. On the other hand, instructors' knowledge regarding the nature of understanding calculus is a complex conceptual structure which is characterized by a number of factors such as its extent and depth, links with other subjects, and knowledge about mathematics as a whole.

Besides the subject knowledge, the instructor needs to know how to represent contents and ideas in a way that students can grasp. The pedagogical knowledge of teaching calculus is practical knowledge of teaching calculus since it is central to the planning of instruction, and the instructor interacts with individual learners during teaching based on pedagogical grounds. Thus an instructor uses the knowledge to transform and represent teaching, which includes knowledge of different ways of presenting calculus.

Contextual Resources

The instructor has knowledge of school context such as school regulations, procedures, assessment systems and policies, curricular materials, and other teaching resources. In the research site university, the department provides the big picture of course curriculum including a textbook and subjects to cover for a semester. Thus the knowledge of context of teaching is vital to the planning and carrying out of the teaching.

Another contextual resource in this framework is the knowledge of students such as their responsiveness to learning tasks and pre knowledge as calculus learners. It also includes knowledge of the students' cultural and ethnic backgrounds and special educational needs and goals. This knowledge is important because it provides the instructors with the means to construe and interpret classroom experiences, as well as reflect on and assess a whole broad range of educational issues and experiences. In addition, meaningful instruction depends on the teacher's knowledge of students and their background, as it applies to learning and instruction.

Although instructors' knowledge is divided in this framework, it is not the main point in this research whether the instructor has the particular knowledge. For example, rather than examining what a calculus instructor in the research site university knows regarding department policies, I want to examine how and why the instructor uses knowledge to prepare and reflect on teaching in the classroom. This is consistent with Schoenfeld (2010, p.94):

> To characterize what any teacher know, the different categories of knowledge are useful and important- for example, having or not having a particular kind of pedagogical content knowledge might be the crucial difference determining the success of an instructional segments. But when one explores how the knowledge is accessed and used, these categorical differences are not consequential. The central issue at a level of mechanism is the following: given the teacher's orientations and goals at the moment, what resources does the teacher have at his or her disposal, and how and why does he or she access them?

Orientations

In addition to resources it is necessary to consider instructors' orientations to account for different teaching approaches. The importance of teachers' orientations and conceptions concerning subject matter has been noted by a number of authors not only in mathematics but also in other areas. A teacher would have variety options depending on that teacher's orientations (the teacher's beliefs, values, and preferences in this context) and what resources the teacher can bring to bear in support of the option he or she has chosen. Thus, the framework include instructors' orientations regarding teaching and learning and the nature of calculus.

What is referred here as "orientations" consists of instructors' system of orientations. According to Green (1971), orientations always occur in sets or groups and take their place in orientation system. Aguirre and Speer (2000) also mentioned the construct orientation system, which connects particular orientations from various aspects of the teacher's entire orientation system such as beliefs about learning and teaching.

Pedagogical Content Orientation

Pedagogical content orientation is an instructor's orientation system concerning the nature of teaching and learning mathematics. The importance of this orientation system is the powerful impact it has on the way mathematics is taught in the classroom (Cooney, 1985). This is teacher's conception of the type and range of teaching actions and classroom activities contributing to his or her personal approaches to the teaching of mathematics (Ernest, 1989). The effect of an instructor's principles, which can influence teaching, is also related to the extent to which the instructor's orientations describe. Thus for the effective principles, they need to be in the framework of teaching and learning calculus. Moreover, instructors' orientations regarding ideal role image and self-evaluation as a calculus instructor especially for the low-achieving students are modeled. This orientation is the associated outcome of the other orientations. Hence, based on their conceptions of the nature of calculus and low-achieving students, the instructor constructs self-image and then evaluates own identity as a teacher for students. As a result, the orientation of self-evaluation provides an essential foundation for teaching calculus.

The teacher's concepts of learning mathematics also are considered in this category. A view of learning as the active constructions knowledge versus the passive reception of knowledge is a based construction in the orientation system. Based on that, instructor's orientation to low-achieving students will be considered in this research. These include, for instance, those that need more help or time and different teaching approach methods. It also includes instructors' attitude to the students such as "there is nothing teachers can do for them." The orientations play a central role in actual practice of teaching calculus since depending on the orientations, the instructor offers extra office hours, different achievement tests or course activities for the low-achieving students. These approaches provide a vital factor to all students including the low-achieving students in learning calculus.

Conception of the Nature of Calculus

This is an instructor's orientation system concerning the nature of calculus as a whole. The orientations form the basis of the philosophy of mathematics (Ernest, 1989). In this framework the four form of orientation system are presented. First of all, there is the problem-solving view of calculus which remains open to revision of it would lead to the acceptance of students' approaches to tasks. In contrast, the view of calculus as a static immutable product, which is discovered and not created, would lead to instructors' insistence on there being only one right method. Thirdly, there is the view that calculus is a useful collection of rules and definitions. In addition, instructors' orientations toward calculus may be compounded with view of the relationship with other mathematics courses and areas.

These views play a key role in instructors' beliefs to the possibility of improving mathematical ability of low-achieving students since it would be constructed based on their orientations of the calculus. In addition, the conception of calculus as a school subject may be compounded with instructors' resources, such as the knowledge of available assistance tools to calculus instructions. Therefore, the orientations of the instructor are reflected on models of the teaching and learning of calculus and in their practices.

Such orientations mentioned above have a powerful impact on teaching through such processes as the selection of contents and emphasis, styles of teaching, and modes of learning (Ernest, 1989). According to Shulman and Richert (1987) the teacher's principles of education and orientations of its overall goals in addition to subject matter related orientations are also important. Consequently, the aim of the analysis goes beyond simply identifying the variables of the instructors' resources, goals and orientations but includes elaborating on the specific interdependencies among ROGs.

Goals

When teachers enter a classroom, most of their actions are shaped by their agenda. As Schoenfeld (2012, p.10) describes:

> If you can understand (a) the teacher's agenda and the routine ways in which the teacher tries to meet the goals that are implicit or explicit in that agenda, and (b) the factors that shape the teacher's prioritizing and goals setting when potentially consequential unforeseen events arise, then you can explain how and why teachers make the moment-by-moment choices they make as they teach.

In this framework, instructors' goals to inquire include two aspects: pedagogical content goals and subject matter goals. The instructor makes choices consistent with his or her - own broad goals when responding to issues. First of all, there are instructors' goals of lectures as the pedagogical content goal. These include motivating students to follow the lecture; providing foundations for advanced mathematics courses; acting as an introduction course for STEM field; and giving good impression about calculus itself or mathematics. Second, there are instructors' specific goals of each lecture and concept as the subject matter goal. These include conceptual understanding for each subject, more than knowing or being skilled; requiring what knowledge or procedures to recall when prompted to do; and recognizing when and where to apply a concept when working problems. Thus, based on what the instructor want to reach throughout the calculus lesson, specific content related goals are constructed and then applied to the each lecture. Moreover, the expectation toward students such as what to emerge from the calculus course influences on the teaching approach. For example, if the conceptual understanding is a prior goal to others, the practical instruction may be focused on it rather than giving a table to be memorized.

In this framework, the ways that calculus instructors approach their lectures are represented by decision making procedures. Instructors employ these decision making procedures either consciously or unconsciously when they teach. Therefore, through examining their resources, orientations, and goals, we can better understand their decision-making processes.

3.3 Summary

In summary the theoretical framework described what factors contribute to instructors' thought either as preparing or practicing lectures. Moreover, analyzing instructors' resources, orientations, and goals is a vital part of this model. Hence, I seek to identify variables of resources, orientations, and goals of calculus instructors at one Midwest research university and expound the factors' specific relationships to explore how instructor's ROGs are applied to the different teaching approaches using this theoretical framework.

Chapter 4: Methodology

4.1 Introduction

In this chapter I will describe the specific research methods and materials used in this study which was designed to examine instructors' calculus teaching resources, orientations, and goals. As Kaplan (1973, cited in Cohen *et al.*, 2007, p. 47) noted that, "the aim of methodology is to help us to understand, in the broadest possible terms, not the products of scientific inquiry, but the process itself", therefore it is critical to understand the process of phenomena.

In order to more thoroughly study instructors' thinking processes when they prepare lectures and teach students, the instructional practice experiences based on ROGs must first be explored. Hence, an exploratory qualitative study was chosen in order to "uncover and understand" those phenomena (Strauss & Corbin, 1990, p. 19).

In addition, the various research methods employed and analyses their usefulness in the context of this study will be discussed. It provides rationale for using these tools to explore instructors' ROGs.

Aim

The aim of this research study was to investigate the calculus instructors' resources, orientations, and goals in teaching calculus at the research site university. Furthermore, the analysis goes beyond simply identifying the variables of the instructors' resources, goals and orientations but includes by elaborating on the specific interdependencies among ROGs. This research considered some major issues, such as which knowledge and belief systems we should include to explore the calculus instructors' resources and orientations in teaching calculus. Calculus as the subject, students as recipients of lectures and pedagogical aspects such as teaching and learning of contents were contained in each column. They were chosen because they are the foundation factors when teachers decide their teaching approaches.

Research Questions

The following are the research questions for this study.

- What are instructors' Resources, Orientations and Goals (ROGs) in teaching calculus courses?
- Does knowing teachers' ROGs result in helping the low-achieving calculus students?

4.2 Research Design

Among the five research designs (e.g., narrative research, phenomenology, grounded theory, ethnography, and case study), defined by Creswell, I chose case study design for this research. Case study research involves the study of an issue explored through one or more cases within a bounded system. The bonded system in Creswell's definition refers to the boundaries that limit the case, such as time and place, as well as the interrelation of the part of the case to form a unified system of experience of the issue at hand (Creswell, 2007).

Although several types of case studies have been identified such as exploratory, descriptive, explanatory, Adelman *et al.* (1980, cited in Cohen, Manion & Morrison, 2007, p. 255) stated that "case studies exist in their own right as a significant and legitimate research method". According to Creswell (2007), case study research is a qualitative approach in which the investigator explores a bounded system or multiple bounded systems over time, through detailed, in-depth data collection involving multiple sources of information, and reports a case description and case-based themes. Although some researchers (Adelman, 2007; Creswell, 2007) have considered case studies as a method of study, Skate (2000) viewed case study differently. The researcher argued that as a form of research, case study is defined by interest in individual cases, not by the methods of inquiry used. Skate (2000, p. 435) stated that:

> Case study is not a methodological choice but a choice of what is to be studied. By whatever methods, we choose to study the case. We could study it analytically or holistically, entirely by repeated measures or hermeneutically, organically or culturally, and by mixed methods- but we concentrate, at least for the time being, on the case… Some of us emphasize the name case study because it draws attention to the question of what specially can be learned from the single case.

According to Skate, the main focus and emphasis is on the case and naturally the case can be studied by different research methods.

The reasons that I used a case study design are related to my research intent of the data analysis. I want to inquire the research questions within one specific site that has the same curriculum, policy, and provided resources. Moreover, because of the characteristics of the university that I chose as the research site, I expect that instructors have similar assumptions and expectations toward their students as well as students have similar levels of pre-knowledge and motivation. Therefore, with the boundary system, I tried to explore that how instructors chose their lecture methods and goals for their classes especially for low achieving students. In other words, I selected multiple cases (i.e., instructors), to illustrate different perspectives on the issue. This case study is also considered to be what Skate calls an "instrumental case study" (2000, p. 437) defined as the following:

> The methods of instrumental case study draw the researcher toward illustrating how the concerns of researchers and theorists are manifest in the case. Because the critical issues are more likely to be known in advance and following disciplinary expectations, such a design can take greater advantage of already developed instruments and preconceived coding schemes.

In this study the particular case is being explored to provide insight into an issue not because this case study has specific intrinsic characteristic, thus it is an instrumental case study according to Skate's definition.

In addition to being relevant to my research intent of the data analysis, a case study design is well engaged with my philosophy. The explanation of how I know what I know and my research topic and questions are determined by my epistemology. I identify myself as a constructionist based on objectivist. The reason that my epistemological stance is combined with two different types of epistemologies is my study experiences. I used to study mathematics which is the core of natural science area. Therefore, I believed that there was one truth and we had to try to find positive law' basis in something that was posited as researchers. And it was transparent to identify true or false and establish laws of various phenomena. I think, however, the fields of human research have different aspects with the natural science.

Now, I believe that, as Crotty (1998) mentioned, all knowledge, and therefore all meaningful reality as such, is contingent upon human practices, being constructed in and out of interaction between human beings and their world, and developed and transmitted within an essentially social context. The author added that (p. 42):

> In the constructionist view, as the word suggests, meaning is not discovered but constructed. Meaning does not inhere in the object, merely waiting for someone to come upon it. As writers like Merleau-Ponty have pointed out very tellingly, the world and objects in the world are indeterminate. They may be pregnant with potential meaning, but actual meaning emerges only when consciousness engages with them… What constructionism claims is that meanings are constructed by human beings as they engage with the world they are interpreting. Before there were consciousnesses on earth capable of interpreting the world, the world held no meaning at all.

I advocate the idea that the meanings of objects and phenomena in the world are undetermined but emerge only when consciousness engages with them especially in human science study. Therefore, my role is changed as a mathematics education researcher from finding the truth which is already posited in something to making of meaning with intentionality. Even though the view of interpretation from only one existence to liberated forms of interpretation, I still believe that there are laws whether they are posited or constructed by human beings. The definition of laws, however, is changed from abstract to conditional. When laws are built on some conditions, then they become the law. Thus, this mixed epistemological stance informs my theoretical perspective.

I consider myself as a symbolic interactionist with thinking the existence of laws. Also, I endorse the three basic interactionist assumptions: "that human beings act toward things on the basis of the meanings that these things have for them, that the meaning of such things is derived from, and arises out of, the social interaction that one has with one's fellows', that these meanings are handled in, and modified through, an interpretive process used by the person in dealing with the things he encounters" (Blumer 1969, p. 2). Therefore, it is important to symbolic interactionists to exercise sufficient discipline to ensure observed human being's intended meanings. I admit that every person is a social construction and comes to be actor in and out of interaction with our society. Thus, it is necessary to study the relationship between how we see ourselves, how we see others, and how we think others see us. However, it cannot be concluded without understanding social reality and society from the perspective of the actors who interpret their world through and in social interaction. Therefore, the research goal of this study is to explain the set of understandings and symbols that give meaning to people's interactions.

Based on my theoretical perspective, symbolic interactionism, I assume that mathematics teachers often experience conflictions about how they lecture students with diverse stages of math knowledge. I believe that potential and actual meaning of instructors' ways to drive their lecture may be pregnant with mind consciously or unconsciously. I believe that instructors' decision making process of their lecture level, goal and strategy depends on the self-definition, how they see themselves as an instructor and the interpersonal perception, how they see their students who have different math backgrounds, majors and goals. These views are developed in my research questions. A case study design meshes well with approach of my study since the goal of my research is to seek to provide an in-depth understanding of the calculus instructors in the same university and department. Moreover, this research design gives an insight into the context of a problems as well as illustrating the main point.

In order to fully explore instructors' thought processes, three types of data related to instructors' ROGs were collected: classroom observation field notes, instructor interviews, and course curriculum and information. The classroom observation field notes collected how the instructor actually manage overall class atmosphere and proceed their lectures. In addition, through the observation data I could generate more specific and relevant interview questions regarding instructors' ROGs based on instructional practices. Using instructor interviews to ask specific questions about interviewees' ROGs to provide a complementary perspective on their decision making process helped elicit a variety of viewpoints regarding instructors' ROGs on their calculus teaching. These varied viewpoint provided the most in-depth meaning at instructors' ROGs in the research site university in order to best understand their ROGs on calculus teaching especially for low achieving students. Finally, the calculus curriculum and course information in the research site university was used to provide a frame of reference for the calculus course, students, and instructors encountered in this study.

4.3 Participants

This study was designed as a reasonably small case study in order to focus on gathering in-depth information from each of the interview participants. The participants in this research were instructors including three faculty members and one lecturer who have taught calculus courses in the research site university more than two semesters. The sampling process is detailed below.

According to Morse's (1994) "cognitive process of data analysis" method, I believed that data collection should be administered from data analysis to increase validity of the research. Since data collection and data analysis are interrelated processes, the research questions, the sampling frame, and the theoretical concepts are discovered while the data are being collected.

The research was conducted in the Spring 2013. To choose participants for this phase of the study, 'criterion sampling' was used. The sampling method was introduced by Miles and Huberman (1994, p.28) as "picking all cases that meet some criterion; useful for quality assurance". Therefore, faculty invitations to participate were generated from a list of 10 instructors who were teaching Calculus 1 and Calculus 2 in the Spring 2013 semester. The fact that they were teaching calculus courses during the semester allowed me to observe their classes.

Therefore, four calculus instructors participated for this study. The first participant, Dr. F1, was a female lecturer who received her doctoral degree at the research site university. Although Spring 2013 semester was her second year as a lecturer at the university, Dr. F1 was familiar with the school system and had calculus teaching experiences as a teaching assistant. The instructor was teaching Calculus 2 which was a 75 minutes course twice weekly in the semester to 30 students.

The second participant, Dr. F2, has been teaching about 30 years at this research site university and received many teaching awards as a professor. Through long term teaching experiences, he knew valuable information regarding the department and profiles of undergraduate students of the region as well as their high school education. His Calculus 2 class was a large course for over 100 students thus he had three graduate teaching assistants who operated their discussion sessions for the students.

The third participant, Dr. F3, who was an assistant professor, had about 6 years teaching experiences at the university and 6 years at another institution as a teaching assistant in the U.S.. Furthermore, he was an international professor who grew up and educated in a foreign country. The semester was his first time teaching a large mathematics course, Calculus 2.

The last participant of this research, Dr. F4, is a male associate professor in the research site. In 2007, he started to teach in this department after having 4 years teaching experiences as a postdoctoral member in other universities in the United States. During the Spring 2013 semester, he was teaching a large Calculus 1 course.

4.4 Data Collection

Data for this study consisted of interview transcripts from interviews with instructors who have taught calculus courses before in the department. In addition, various documents such as classroom observation field notes and department websites, including faculty members and course information, were used to supplement these data and to provide background for participants' comments according to 'triangulation' defined by Cohen, Manion, and Morrison (2007). In the book "Research Methods in Education" published in 2007 by Cohen *et al.*, the authors defined 'triangulation' as the following: "the use of two or more methods of data collection in the study of some aspect of human behavior…By analogy, triangular techniques in the social sciences attempt to map out, or explain more fully, the richness and complexity of human behavior by studying it from more than one standpoint" (p.141). The following gives an overview of the data sources that have been employed in this research.

4.4.1 Interviews

This study was designed to explore participant instructors' ROGs on teaching calculus students, thus each individual's information was valuable. Therefore, among variety types of interviews such as structured, semi-structured, and unstructured interview, the semi-structured interview method was conducted for this study. Unlike the structured interview which usually contains oral forms of written surveys to obtain demographic data, the semi-structured interview delivers pre-developed core questions and then creates more proving questions. Thus these type of interview questions help in understanding what the instructor believes and their views on teaching to address the particular task rather than have rigidly structured questions as Cohen *et al.* explain (2007, p.361):

> The topics and open ended questions are written but the exact sequence and wording does not have to be followed with each respondent. The framing of questions for a semi-structured interview will also need to consider prompts and probes…Prompts enable the interviewer to clarify topics or questions, while probes enable the interviewer to ask respondents to extend, elaborate, add to, provide detail for, clarify or qualify their response, thereby addressing richness, depth of response, comprehensiveness and honesty that are some of the hallmarks of successful interviewing.

Thus four semi-structured individual interviews (Cohen *et al.*, 2007) were conducted with selected instructors. I sent emails to set up each participant's preferable meeting time and place to interview them. These options were offered to give all participants the freedom to discuss their thinking systems in a "safe" (by their own selection) environment. In the results, each one time interview was held in the individual's office to participate in a semi-structured interview session.

Interviews were structured around an interview protocol, which was designed to align with the framework and research questions of this study. Additional topics of interest not appearing on the interview protocol were discussed as the interviewee brought them into the conversation. At the end of the interview, participants were given an opportunity to ask further questions about the study or to add further comments about anything that seemed relevant to this research. Furthermore, the researcher's contact information was provided to interviewees who confirmed that email was an acceptable mode of communication with them in case additional questions arose in the future.

Each interview began with a reassurance to the interviewee that his responses would be kept confidential. In addition, interviewees were asked to read a consent form containing information about the study, e.g. the research questions, and to sign their consent to participate in the study. Participants were given a copy of the consent form to keep for future reference in case they had later questions regarding this research. They were also informed that they have the option of declining to answer, passing on, any of the questions at any time during the interview. This conversation helped interviewees to know their rights as research participants as well as what their responses were helping to achieve.

The first set of questions, which was not on the interview protocol, collected some basic information regarding each interviewee's teaching profile such as their year of attendance in the research site university. Asking straightforward, demographic questions at the beginning established a comfortable rapport and also helped the participant to feel at ease with the interview setting and with me as interviewer (Creswell, 2007; Esterberg, 2002).

The second set of interview questions were open-ended types and required deep thinking based on interviewee's previous experiences. For example, one of the interview questions was "How much effort do you think you are investing into low-achieving students?" These questions helped each interviewee develop a description of their belief system, first broadly then focused on specific follow-up areas. For a complete list of questions see Appendix 1. Painting this broad initial picture of their instructional practices helped interviewees induce in-depth thinking of their ROGs, thus opening up a broader set of the belief system for exploration in the later interview questions (Esterberg, 2002).

While participants answered the questions, I expressed my agreement about their opinions through body language and continuers. Therefore, I allowed them to feel confident in their arguments. In addition, while recording the interviewees' voice, I also took field notes to record participants' gestures, brief synopses of their responses to support the selection or probing questions, and my own reactions to their responses. These field notes aided active listening (Esterberg, 2002), helped smooth interview transitions, and promoted the flow of conversation.

The length of the average recorded interview time was 62 minutes. After finishing the interviews, I immediately transcribed what I recorded in the interview so that I would not lose any memories that were not recorded.

4.4.2 Classroom Observations

Prior to conducting interviews with each instructor, the researcher observed his or her calculus classroom during the Spring 2013 semester. It was held under the instructors' permission and the instructors also recognized the existence of the observer. While attending their calculus courses, I wrote out lecture procedures and marked singular proceedings. Through classroom observations, the researcher was able to create additional interview questions besides the interview protocol. Thus, related to what I captured from their instructional practices, personalized questions were asked.

Moreover, it provided more accurate interpretations about the instructors' interview statements.

4.4.3 Course Information

Each university follows their own calculus curriculum and course sequences. For example, the research site university adopts four semester sequences of calculus courses instead of three like others. Therefore, these objective data regarding calculus courses which the university provides served as an additional source of triangulation of instructor interview data collected for this study. Moreover, these data supplied a frame of reference for the instructor comments interviewed.

Some of these objective data were disclosed by faculty members as interviewed, while others were specifically sought in order to explain, explore, or support interview comments. These data were provided by department administrators, students, and campus website. The course information included a list of recent Calculus 1 and 2 sequence professors to use in faculty participant invitations, a list of calculus courses offered in one semester at the research site university, as well as additional information provided publicly accessible through departmental resources online.

4.5 Data Analysis

Each data explained in the previous sections contributed to this research in a valuable variety of ways. However, potential meaning is contained in each set of data and these unrevealed portions are required to work with focused analysis in the diversity and depths of ways. In this study, to analyze the data I followed the inductive analysis approach developed by LeCompte and Preissle (2003). The researchers suggested the following four steps as one of the methods to theorize qualitative data such as interview information.

After I stored the calculus instructor interview recoding files to my personal laptop, I transcribed all digital audio data from interviews into text-based computer files. Therefore, as the first step of data analysis in the perception stage, I formally and informally scanned and coded the preliminary data gathered during mapping phases. As LeCompte and Preissle mentioned, discovering or establishing units of analysis constitutes one of the primary tasks in processing ethnographic data. Therefore, I chose divisions that retain their natural integrity while providing sufficient focus for observation. The analytic units serve as perceptual divisions that guide collection of data and means for reducing raw data to divisions manageable for manipulation.

The key step to analyzing qualitative data is the tasks of comparing, contrasting, aggregating and ordering. Following these steps, I began to establish classificatory themes for organizing data. I described what I observed and divided observed phenomena into units as a categorization of the data. As the first cycle coding method, I used open coding (Straus & Corbin, 1998) which is breaking down qualitative data into discrete parts, closely examining them, and comparing them for similarities and differences. So I used invivo coding when focusing on terms that participants use in their everyday lives, process coding using gerunds to connote action in the data, simultaneous coding applying of two or more different codes to the same lines, and value coding reflecting participants' values, attitudes and beliefs. I then moved to the second step of categorization.

I indicated how units are alike and unlike each other by massing and scanning data in a systematic content analysis, in which the guiding questions asked are, "Which things are like each other?" "Which things go together, which do not?" like LeCompte and Preissle said. They also mentioned, "The bases for differentiation and sorting are used by ethnographers to define how units are used and what their significance is…. The rules or canons for discrimination the ethnographer uses are not haphazard, but are guided by certain semantic rules for aggregating single units or items (2003, p 242)." I referred to Spradley's domain analysis (1979), one type of differentiation and sorting based on the type of semantic relationship. To reorganize and reconfigure to broader categories, I followed the pattern coding (Miles & Huberman, 1994) in second cycle coding.

As the next step in categorization, or creating a domain analysis, I determined which of the described items were associated with each other and thus might be aggregated into groups. LeCompte and Preissle noted that this step requires identifying those properties and attributes that the data units of a particular category share. When I categorized the data, they were either generated directly from inspection of the data or established prior to data collection for their priori relevance to the overall research questions. Then I figured out what it means as LeCompte and Preissle identified it as themes within the story, which are built from examinations of recurrent patterns of coherence relations found within the text. The coherence relations establish a connection between an utterance and some part of the preceding discourse. I established the themes deductively, inductively, or somewhere between two extremes, abductive reasoning.

The third step of theorizing of LeCompte and Preissle is establishing linkages and relationships. Therefore, I established linkages by simply comparing and contrasting, by identifying underlying associations, by inference, or by statistical manipulation. All these steps were guided by both implicit and explicit theoretical assumptions like LeCompte and Preissle said. I engaged in detective work, following hunches, looking for and ruling out negative cases, and chasing down all suggested causes of the events being studied. When I preceded this step, I used both induction to generate statements of relationships and deduction to test working statements of relationships in the field while developing a theory or hypothesis that is grounded in data.

Speculation, the last component of theorizing, which required speculating and making inferences involved playing with ideas probabilistically. LeCompte and Preissle noted that with it, the investigator can go beyond the data and make guesses about what will happen in the future, based upon what has been learned in the past about constructs and linkages among them as well as on comparison between that knowledge and what presently is known about the same phenomena.

4.6 The Reliability and Validity of the Data

To increase the level of reliability of this research, several case studies were conducted. They were consistent with an argument of Cohen *et al.* (2007, p.146) which is “reliability is a measure of consistency over time and over similar samples. A reliable instrument for a piece of research will yield similar data from similar respondents over time”. Although there was also concern about the reliability and validity of the data, the instruments used were appropriate tools to gather the data of this qualitative study.

Moreover, the following statement from Cohen *et al.* (2007, p. 134) may help with the meaning of the term "validity" in this research.

> Maxwell (1992), echoing Mishler (1990), suggests that understanding is a more suitable term than validity in qualitative research. We, as researchers, are part of the world that we cannot be completely objective about that, hence other people's perspectives are equally as valid as our own, and the task of research is to uncover these. Validity, then, attaches to accounts, not to data or the methods (Hammersley & Atkinson, 1983); it is the meaning that subjects give to data and references drawn from the data that are important. Fidelity (Blumendfeld-Jones, 1995) requires the researcher to be as honest as possible to the self-reporting of the researched.

In order to maximize the validity of this study, the triangulation of the data was used as described in Chapter 4.4. Furthermore, for reliability of the data, the researcher contacted the interviewees to confirm the information and collect additional data.

4.7 Summary

The more we understand how an individual does knowledge intensive activities, the better we can make it effective. This is the main idea of this research as I explored the calculus instructors' ROGs and their teaching approaches. Thus, allowing the calculus instructors to tell us their belief systems including values and preferences, knowledge, experiences, and goals in their own words is the most relevant way to describe and explore the aims of this study. Through faculty members and course coordinate interviews, this case study inquired their ROGs. The interviews, along with classroom observation and course information data, contributed the basis for inductive analysis, which established the themes deductively, inductively, or somewhere between two extremes, abductive reasoning.

Chapter 5: Results

5.1 Introduction

In this Chapter, the result of the interviews that I had with four mathematicians will be presented regarding their resources, orientations, and goals (ROGs) using the Theoretical Framework described in Chapter 3. The theoretical aspects of this study are based on Schoenfeld's (2010) theory regarding ROGs. He claims that "if you know enough about a teacher's knowledge, goals and beliefs, you can explain every decision that he or she makes, in the midst of teaching"(2012, p. 343). By resources Schoenfeld focuses mainly on knowledge, which he defines "as the information that he or she has potentially available to bring to bear in order to solve problems, achieve goals, or perform other such tasks" (p. 25). Goals are defined simply as what the individual wants to achieve. The term orientations refer to a group of terms such as "dispositions, beliefs, values, tastes, and preferences" (p. 29).

Although, the theory was originally considered as applying to research on school teaching (Aguirre *et al*., 2000; Thomas & Yoon, 2011; Törner, Rolke, Rösken, & Sririman, 2010), it clearly has applicability to research on university teaching (Hannah, Stewart & Thomas, 2011; 2013; Paterson, Thomas & Taylor, 2011). Based on Schoenfeld's theory, a framework (see Table 1) was developed as described in Chapter 3 to examine instructors' ROGs while teaching calculus. Accordingly, the research participants' interview transcriptions, classroom observations field notes, and course information are delineated in order to answer the research questions:

- What are instructors' resources, orientations and goals in teaching calculus courses?

- Does knowing teachers' ROGs result in helping the low-achieving students?

Throughout the open coding procedure described in Chapter 4, observed phenomena will be described in this Chapter. In the meantime, the detected phenomena are divided into units as a categorization of the data with the intention of establish classificatory themes for organizing data with them. For instant, resources of the calculus instructors categorized as knowledge of teaching approaches, learning strategies, time constraints, and available resources. Each theme from codes such as knowledge of teaching approaches and in interview excerpts of the each participant will be presented in this Chapter.

5.2 Resources

As a teacher, each instructor has constructed his or her own effective teaching and learning acknowledgements through teaching experiences, communication with colleagues and professional development programs and even more through their experiences as a student. Since the pedagogical knowledge of the instructors influences their teaching methods to present the same content, understanding what they have built may lead us to contribute on efficient delivery ways of calculus subjects. Therefore, the following pedagogical knowledge of the instructors was explored:

- Knowledge of teaching approaches
- Knowledge of learning strategies
- Knowledge of time constraints
- Knowledge of available resources

Each theme of pedagogical knowledge will be described below by unit of individual instructor to have in-depth understanding based on their personal experiences and backgrounds.

5.2.1 Knowledge of Teaching Approaches

The contents in the calculus textbook the calculus instructors are using, Calculus seventh edition written by James Stewart (2012), are equivalent to every instructor at the research site university. But the ways they presented and the subjects they focused on were influenced by their established resources. In the following sections, the resources as knowledge of teaching approaches of the instructors will be referred followed by description of each professor’s comments. The reported order of the instructors are organized by interview date.

Case study 1: Dr. F1

This instructor received her doctoral degree at the research site university hence she had experiences both as a student and teaching assistance. Consequently, even though Dr. F1 was a novice lecturer, her teaching experiences and acknowledgements regarding the school and department policies were not lacking compared to the other faculty members. She was also attending professional development programs to provide the quality of advice and the gained information from the program influenced her way of encouraging students. Details about her resources through attending professional development programs will be discussed in the knowledge of available resources section.

As the instructor prepared daily lecture notes, she reported that the main reference was the selected textbook. Her teaching method of actively utilizing the textbook was also detected when I observed her classroom. Dr. F1 often mentioned the page, theorem and definition numbers on the textbook before she mentioned the contexts. This textbook-centered lecture approach was consistent with her knowledge of learning strategies. The instructor, however, stated that she presented not exactly like the book did in order to show varieties of approaching methods to students. This representation reflected her knowledge regarding mathematics which may contain diverse solution manuals and finding suitable ways as a few of the significant learning paths. Ultimately, it was her concern as an instructor to present multiple approaches to increase students' understanding.

> I try to keep it at the same level as basically how the book presented things. But I try to present it a little differently so that they have two aspects. If they read the book then they see the same things when I do it but I will do a little differently. So that maybe if what they read the book did not make sense but what I do make sense and vice versa. … The book did in the example I don't do that same example I might point to it and say "Hey this is how the book did this problem. I know it applies to this problem here." so that they can make those connections.

In the above quote, Dr. F1 mentioned "connections" which is her most evaluated goal of teaching calculus and details will be discussed in the section 5.4. In the meantime, the instructor proceeded from fairly straight forward to difficult topics since she was aware of students' difficulty with new topics. Her pedagogical knowledge was perceived that by more exposure to obvious and fundamental problems, the instructor would increase students' understanding.

> I try to start off something fairly straight forward. Fairly easy so they see what's happening. And then I will try to do something a little more difficult and then maybe even more difficult. … I know sometimes I think I probably break down and do a little too many steps but I just want to make sure they follow. And then sometimes after a while when they have done those steps that I have done a lot I would say "Okay, now you guys should know how to get from here to here.

> Remember." So I can just kind of drop that again. But first I make sure I do enough time so they have seen it enough now they should know next step.

Another knowledge of teaching approaches the instructor noted was differences between classroom types. During the data collection for this research, Dr. F1 taught a Calculus 2 course which met twice a week for 75 minutes. The other participant instructors' classes were operated for 50 minutes and held three times per week which were more common calculus course types. Regarding class period, she noticed differences and reported her knowledge of teaching approaches depending on the modifications.

> I think Dr. M one time told me that experts had research that have shown the 50 minutes is the ideal for lecture and after that 50 minutes some students are going to lose their concentration and everything like that. So you do have to struggle against this. And here again, I try to engage students by asking them questions.

The instructor recognized students' concentration difficulty with lengthy lectures over conversation with colleagues. In addition, Dr. F1 stated her knowledge by asking questions to help increase students' participation while she proceeded the lecture. This interacting method with students was also detected during her classroom observation. For example, as Dr. F1 proceeded to the next subject, she kept asking "Do you have any questions?" to get feedback from students.

Case Study 2: Dr. F2

Among the research participants, Dr. F2 posed a magnificent teaching experience which was 30 years as a professor at the research site university. Based on his long term experiences as a mathematics professor, the instructor represented his valuable information regarding suitable teaching strategies for each mathematics classroom the department offers. Moreover, Dr. F2 was able to have more chances to access to the materials that are released limitedly. Subsequently, the instructor was far more superior to other instructors in terms of his information through the abundance of teaching.

Dr. F2 reported that the effect of the homework scores in a sense of the grading is minuscule at the end of the semester. However, what mattered to students, that the instructor noticed, was that they complete their homework assignments. Meanwhile, he noticed based on his many years of teaching, students seemed not to recognize the impact of one homework score and were eager to increase it so that they were more likely to discuss their current homework.

> Students often come and in some sense they are asking some help for homework. Weak students who try to learn and if they could get a few extra points in this fashion, it's not terrible because in the end they have to perform on the test and this is all matters so, umm, test will override any other grades they are getting at the end so, if they can do it then that's fine.

The instructor stated that when students asked him for help on their current homework problems, he always kept in mind a bit of delicate questions regarding effective assisting methods. Based on the teaching experiences, however, he decided to use different strategies depending on students' mathematical capabilities.

> With the strong student they are asking me questions usually I will not write anything just talk and talk and they can write. With the weak student, in the end I will write answers for them and explain how to do everything if they are really weak. But during the meeting, I refuse to let them write anything. So they have to sit…in a sense I am doing the questions for them. But actually they still have to go and do the questions … and they don't have a tape recorder.

Since Dr. F2 knew that depending on students' level of prior knowledge they showed different problem solving abilities, he tried to provide appropriate ways for each situation. Hence, for the low-achieving students who are less likely to solve a problem by themselves, the instructor gave a solution at the end of their conversation. That is, the instructor provided the low-achieving students two types of available help, the verbal explanation and written notes. He knew if students had little prior mathematical knowledge, it was hard for them to complete some homework assignments even though they received extra verbal explanation from the instructor. This acknowledgement was related to his another knowledge of teaching approaches noted on the previous. He reported that increased homework scores by given solutions to students barely affected their final grades.

Besides his resources on teaching approach, pedagogical orientation toward the low-achieving students' effective learning attitudes related to his different approaching method according to students' capabilities. Dr. F2 believed that the primary goal of the assignment to the low-achieving students' learning was that they actually performed it by themselves. Though they could copy the provided solution to turn in their homework assignments, the instructor evaluated that as the first step for them to build suitable learning strategies. Therefore, he offered the solution to the low-achieving students who showed effort carrying out their assignments. On the other hand, he let the high achieving students have a chance to rethink by themselves while they see their solution memo written by themselves. Dr. F2 knew the high achieving students had enough knowledge in getting ideas and hints from what he talked to them thus they could complete the assignments.

Another teaching strategy the instructor showed to help the low-achieving students' calculus learning took place in their classroom. Since Dr. F2 knew the less physical distances between him and students, the more they could engage in their lectures, he told students who wanted to improve their low mathematical knowledge to sit in the front of the classroom. The calculus courses offered by the department are usually held in a large lecture hall which can accommodate up to 180 people. Subsequently, students were more likely to be distracted or not pay attention. This instructor recognized this problem and sought to offer the low-achieving students help to get less effected from this.

> I told her she should sit in the front and she should continue to ask me questions and try to answer questions all the time. … I try to explain to them it is much better to be in front because it is less distraction you don't see anything other going on in the class. Also, you much more engage in nothing to gap between you and me. So probably hear everything what I say clearly. And, also it means I can see how, in the front, I have 3 or 4 quite weak students and I often look at them straight in the eye and I ask them questions…in the hope that they feel a pressure.

In addition, to increase the low-achieving students' participation in lectures, Dr. F2 acknowledged that he let them feel pressure with body language. Therefore, with straight eyes, he looked at the low-achieving students who sat in the front row and asked questions hoping they were more engaged in learning during lectures.

Case Study 3: Dr. F3

Dr. F3 taught 6 years at the site and posed 6 years more teaching experiences as a graduate student at other U.S. universities. Moreover, he got Bachelor and Master degrees in foreign country. During the data collection for this research, it was noted his foundation knowledge regarding effective delivery methods. He showed that providing all possible details as the one. Dr. F3 acknowledged allowing enough exposure increases students' understanding to the explained concepts.

> When I prepare for lectures I feel, if I give any new concepts, at least one or two examples have to be simple and I have to give all possible details. Because that way they have some strong noting and they can all visit efforts to that if they want to. … The only way I think about reach out to them I maybe this is for

> everybody not just for low-achieving students. I am trying to make sure that all solutions everything at upon website they can look at and learn more.

Starting with simple and easy examples to approach the new subjects, Dr. F3 knew students could have additional resources which would act as strong foundations to build more advanced concepts. Therefore, he intentionally introduced with easier examples. Whereas this knowledge was related to his hope on students through the calculus courses. Basically, the instructor believed that they should be able to do simple calculations after completing the course which he viewed as one of the purposes of calculus. In addition, he recognized if students were exposed with capable objects they could be more engaged in their learning. Hence, Dr. F3 not only introduced easier examples, but also provided affordable first test than rest of their exams. He acknowledged that would intrigue students' active learning attitudes in calculus classrooms.

Another strategy Dr. F3 expressed was wealth of information from students and his colleagues regarding the courses. Every time he started his lecture and moved on to the next context, the instructor collected comments or questions from students. Since he realized it was hard to interact with students in a big classroom, the instructor could not receive feedback immediately without special efforts on that. Hence, Dr. F3 always invested a few minutes to gather issues from students and this method was observed through the whole semester. Besides the question and answer time, he did not plan additional review time.

> When I go there and stand and ask if you have any questions, sometimes they do. In that case I try to answer their question depending on what it is. But I don't prepare 'oh, they might have problems difficult.

Moreover, the instructor communicated with other instructors to evaluate their progress of class as the same course teachers. He knew through the information he could adjust the range of covered subjects and speed, compared to others.

> Sometimes I mean when a semester goes I have to keep track what's going on. … I talk to professor G who is doing the other thing [Calculus 2 teaching]. And we are going one section plus minus. Maybe he is ahead. Last time I talked with him was after second midterm and it was kind of very similar so. … It is good to see how they are doing how fast they are going and what they are doing. Some sections I want to stress more. So it takes more time. But maybe other professors don't think that. … Or judgment whether the student needs more help or not something like that.

Since the instructor did not have enough of his own accumulated data through same course teaching, he received it from both students and colleagues. Another notification that Dr. F3 constructed was regarding influences created by different physical environments. He noticed the distances between students and himself which significantly affected psychological interaction on them.

> In the beginning I was not interacting with students' thought. I was just lecturing. It was too big. When I was in small class, I interacted with them. Now I think after a half of the semester is done then I am trying to get them speak more. So interactions are still possible although not ideal. … Another difference between big and small class, I think the variations in students even bigger. I mean if it is a small class, there are people not prepared and people who are too prepared. There is a variation in larger class you see more. I mean ten people are getting 15% instead of 1 or 2 in a small class.

Through the first time of big classroom teaching experience, Dr. F3 reported difficulties in effective teaching method which he used to adopt for small classes. Even though the instructor evaluated interaction with students as one way of pedagogical approaches, he could not easily apply it for a large calculus course in the beginning of the semester.

Moreover, the instructor recognized students' distribution differences between two type of courses and reported it as another struggle when he evaluated them.

However, after, he accepted difficulties of operating a large classroom, Dr. F3 made changes to his original approaching methods. More details regarding his modified teaching approaches in different classroom settings will be described in the orientation section.

Since the instructor had not posed plenty of teaching experiences both at the research site university and others, he was constructing his teaching approaches knowledge through diverse routes while accumulating teaching experiences.

Case Study 4: Dr. F4

During the Spring 2013 semester, the Dr. F4 was teaching Calculus 1 which often referred to having more difficulties than the Fall course by the research site university faculty members. Since Calculus 1 courses, operated in the Spring semester, contained students who failed the same course in the Fall, the average mathematical knowledge preparedness of students was less likely to be sturdy compared to the Fall semester. Dr. F4 recognized the issue and it was reflected on his entire teaching approaches to students. More details about his notification on differences between two semesters will be described in the section 5.3.3.

Based on the expectation toward the calculus students, the instructor approached them with adjusted methods to reach goals through the course. For example, as the instructor introduced The Rolle's Theorem, he sketched graphs instead of justifying each statement of the theory which is considered as the traditional mathematics proofing process.

> The best majority of these students will get a lot of understanding out of a pictorial understanding of it than out of proof "A proof". ... If you do a bunch of

> calculations with some deltas and epsilons whatever, that might be a rigorous proof but they just feel like you are just doing one of these card games.

Through the explanation way of the theorem, the instructor showed his knowledge of teaching approaches for the low-achieving students. He revealed that calculus subjects can be presented by using either rigorous mathematical terms or student friendly procedures such as drawing graphs. Moreover, the instructor knew visualized account is more likely to convince students when theoretical contexts are introduced. Meanwhile, his acknowledgement regarding mathematical proof impacted on this representation method.

> What is the proof? Proof is something you find convincing you that something is true, right? … Even if it is not a rigorous proof by modern mathematics standard it is a proof in a sense that students find that to be convincing explanations what's going on.

Since the instructor recognized the “proof” as processes to convince students a statement is true, he was able to apply alternating representation methods to achieve the purpose. Although the instructor knew rigorous demonstration methods for calculus students, he decided to choose approachable instructional practices to help the low-achieving students' understanding.

5.2.2 Knowledge of Learning Strategies

Through their experiences as a student, the instructors established their own knowledge regarding effective learning methods and then modified them applicable to students in their classroom. The instructors' adjusted knowledge directly reflected to their instructional practices since that is what they evaluated as students should accomplish to study calculus. Therefore, in this research, the knowledge of the participants about calculus students' efficient learning attitudes will be identified in the following section.

Case Study 1: Dr. F1

As a calculus instructor, Dr. F1 emphasized that reading the textbook and practicing problems would be appropriate learning strategies which would help them to understand the contents. Through her teaching experiences, the instructor recognized that students, especially the low-achieving ones, do not read their textbook and exercise their homework assignments or examples presented during class period.

> Some other things when they say convince me that a lot of them don't read. Because they ask me something that exactly you know that is right there. That's what it says. But I think I have several they do read the text because of again, they ask questions and it will come from what the text said and that something that they didn't understand.

The knowledge about effective learning methods showed that students should read and practice as many problems as they can to improve their understanding. It was based on Dr. F1's experiences as a mathematician and educator who had taken the same courses.

> I read all my textbooks and I did all the odd number problems that at end of the chapters because that is what helped me. To me test were easy not because they were easy tests but because I prepared. I just thought that is what we are supposed to do. You are supposed to read the text. What else did I buy the book? Not just look at the problems that I had to hand in. When I was taking calculus one of my instructor did not take up any homework at all we just had tests and he told us "these are the problems you should look at to get ready for the test. Then I just did all the odd number problems because I knew that if I could do those then whatever he asked me I could do… so… yeah… I was a nerd.

Since textbook-centered studying produced positive results on her learning, Dr. F1 emphasized to students the importance of it and delivered contents. Moreover, she assigned homework problems from the textbook and then selected similar ones on tests to encourage them to be responsible for their own learning. However, the instructor perceived that students do not read and exercise as much as they are supposed to do. The notification of Dr. F1 was from students' test results since frequently she gave tests with exactly same problems from their textbook or homework assignments. Unfortunately, the results convinced the instructor that students did not prepare with those problems before the tests.

> Many of them they come to class they jot down some notes and then they only work on the problems that they have to hand in and not the problems that I say these are some problems that you should work. I had students earlier today they came in and said they were surprised by these questions on the test. But I had written questions exactly like the ones on the test that they should practice. And it just told me that students didn't even look at those to realize they might have questions pertain to finding the area or finding the volume things like that.

Her notification about the low-achieving students' inappropriate learning strategies was also persuaded by their evaluations at the end of the course.

> Now when I get my evaluation every once a while I have a student who says "Testing questions are nothing like the homework problems whatever." Even though they might actually be problems exactly like the homework problems on the test, I still get evaluations sometimes that students say things like that. So here again, that convinces me that oh they didn't do their homework.

Dr. F1 also recognized that numerous students completed their responsibilities only marginally to pass the course. Subsequently, most of students were not well prepared to study next lessons unless their tests were scheduled in near future.

> A lot of students do just basic and then when it comes to test time a day or two before the test they can't go back over at all and they don't have time to do that and really know the materials. … So there are more time and so in that I didn't assigned homework instead I had quizzes every week and with the materials we covered the week before and so they had to keep up with what we are doing as we are along.

To prevent students' unprepared learning attitudes, Dr. F1 provided weekly pop quizzes. It was one of her tempted teaching techniques to keep up students with materials they were covering.

On the other hand, the instructor also reported her knowledge regarding students who completed every homework perfectly not by themselves. She recognized availability of solution manuals and online resources to find answers thus the instructor assumed those students were utilizing the assets to finish their homework.

> You can find solutions almost anything on-line … That's out there. And then of course, they are working with another students who are strong students and then they are just more or less just writing down that students written and doesn't really understand beyond that.

Even though the low-achieving students turned in homework assignments with correct answers and solutions, Dr. F1 believed some of the low-achieving students finished it without understanding.

Case Study 2: Dr. F2

Knowledge of approaching methods of the instructor was based on his many years of teaching as described in the previous section. With varying experiments to find effective teaching methods, he constructed pedagogical methods to present to students. Dr. F2's knowledge regarding students and their academic background was also influenced by his family. As a father of two college students, the instructor had more experience in knowing calculus students' learning path.

> My own children had terrible experiences with trigonometry teachers … Because when they came home they told …it's not an option not to know this you have to know these things. They are not math students but they are scientists so…and they are quite good at mathematics. Teachers were terrible also

> telling… you don't need to know these things you can bring a sheet of paper. … So they didn't learn it.

Besides, since his spouse was a high school teacher, he acknowledged regarding students' life in high school. Therefore, through the contacts with students and information from own family, Dr. F2 was able to have significant knowledge on students' learning strategies. In his view, many students entered the calculus classroom little mathematical capabilities and pre-knowledge. He related the reason of students not having enough prior knowledge with education problems in high school.

> She [one of his current student] told me her trigonometry teacher told her explicitly there is no reason to know trigonometry identities. It just a lie [Laugh] I mean more or less impossible for me to teach calculus if you don't have this background I mean, what am I supposed to do? Where can I start? It's because maybe it's easier for this teacher who only had to give her high grade and then students move on anyway. … At the moment, one of the things that I need them to know we call it completing the square. She said "Yeah I had another teacher who told the class that. None of students never understood this technique so she stopped teaching it." [Laugh] But life in high school is different from life in university. The pressure is very different. I am married to a high school teacher so I understand a little bit where the problems come from. But students who don't know it, it is not because they cannot learn it. It's just they are brought up to believe that they didn't have to learn it. Then it is just a human nature not to learn.

Dr. F2 believed those students who did not receive appropriate education in high school, struggled with calculus courses at university. He knew some high school teachers did not teach what students needed to prepare for their future courses like calculus. In his opinion, a number of high school teachers wanted to be generous to their students to avoid being unpopular and having bad reputations. As a result, the teacher skipped materials which would be essential for calculus courses and that caused students' difficulties later at university.

In addition to that, Dr. F2 also knew that large state universities like the research site cannot only take strong students. In the meantime, he realized the university like the other state, they are more or less required to admit students. Otherwise, the state essentially refuses to fund the university. Therefore, Dr. F2 understood the reality issues that the majority of students enter calculus classroom with weak prior knowledge. Because of the fact that existence of significantly many students who were not prepared for calculus courses, he invested most of his available time for the low-achieving students.

> So based on time I am spending very little time with advanced students I send emails some time to time. At least 90% of my times is with students who are C and D ranges. That's the best thing I can probably do, particularly at this level. When it is a small advanced class, with graduate students, then it is much nicer to spend time talking to the strong ones as well.

His combined understanding of calculus students' poor prior knowledge, as a father of college students and practiced teacher, strongly influenced on his decision making process concentrating on the low-achieving students.

Case Study 3: Dr. F3

Most of the calculus instructors agreed the fact that calculus is one of the gateway courses for students in STEM majors. However, they showed slightly different opinions based on personal impression and experiences regarding taking calculus. Dr. F3 was one of the faculty members who undoubtedly expressed his recognition regarding the aims of students being in calculus classrooms as only necessity.

> If it is Calculus 1 or 2, I think quite often it's because they have to. I think their major says they have to take it otherwise they can't. And almost everyone I think they are taking calculus courses because they have to. If you are an engineer, you have to go Cal 4 maybe. I don't think the calculus courses are so much fun that you take it for fun. And I would not take it for fun also.

His knowledge was related to his view toward the courses which does not stimulate students' inquisitiveness in learning. Since he evaluated the context as technique based one, Dr. F3 established his recognition relevant to that. Therefore, he realized students were less likely to be motivated in their calculus learning activity. Dr. F3, however, knew after completing the calculus courses students are going to be aware of the usefulness and interests on the context along with studying their application courses.

> After the course is done on the parallel they are doing their engineering courses and physics courses, they see that's useful which means they have positive feeling about the course because they see it is useful. Calculus 1, well, if you are a freshman then it's very difficult to have an idea what is useful or what is not. So you just attend but I guess you are there because you have to.

Dr. F3 acknowledged when students are exposed to new subjects they need enough time to digest them. That was also noted in the previous section regarding his knowledge of presentation as starting with easier examples to provide students opportunities to follow appropriate learning paths. Moreover, similar to Dr. F2, the instructor knew a freshman especially required extra time building on suitable learning techniques.

In regards to knowledge of learning, Dr. F3's statement was consistent with his priority on the courses. He pointed out the main goal of calculus courses was students' conceptual understanding which will be described on section of his goals. The instructor provided exam problems to check if they grasp the principal idea such as the definition of derivatives. He, however, realized that many students could not handle it.

> A main thing what you learn is the definition of derivative. I think it is good for them to know all the importance of these things. And it's kind of challenging, too. So if they like it, they can play around with it. But not many of them like it. That's the fact.

On the unsuccessful outcomes, the instructor thought this was the result of students' study styles. He knew they are more likely to practice on a topic when it is connected with their homework assignments. Since Dr. F3 considered people forget after learning without immediate reviews, he wanted to induce students to strengthen their memory through giving pop quizzes.

> That was another motivation of pop-up quizzes but I don't think many of them do that. They look at their note when they work on homework. Usually, if I do a lecture on the homework for that is due two weeks later so they are not looking at that for quite sometimes. So that was another reason. Homework is due later, they will be more motivated to see later. But to motivate them to see that earlier, I have to do pop-quizzes.

However, Dr. F3 realized that unfortunately the effect of giving pop quizzes for students' preparedness was less than what he expected. Nonetheless, he highly evaluated positive aspects of the strategy hence this confirmed his willingness supporting the method.

As another difficulty on students' learning strategy, Dr. F3 revealed his notification on the effect of physical environment. Since the instructor was teaching Calculus 2 course in a large classroom with around 130 students at a time of this interview, he more evidently distinguished the differences between large and small classroom settings.

> In a big class, it is very difficult because you are left behind. … Because the semester goes by very fast, there is a new topic every week so if you are left behind then you are in big trouble.

To combat these obstacles, the instructor realized big lectures had negative effect on students' understanding of calculus subjects. He believed a teacher and students are more likely to interact in a course held in a small classroom and thought the environment was one of calculus students' hindrances in learning.

Case Study 4: Dr. F4

There are varying sources of elements which impact on student learning like the other calculus instructors in this study stated. Furthermore, depending on how the teacher recognized the factor and its effect, the issues created by them could be resolved or aggravated.

One of the difficulties that the research site university calculus courses containing is from their classroom setting. Since most of Calculus 1 and 2 are operated as large courses allowing up to 160 students enrollments, both students and instructors complained the problems provoked by the environment.

> For any smaller classes I don't do attendance only these larger one. Because I know in a larger one it is very easy for students do, I mean you should save them from themselves a little bit because in a large class it is very easy for them to think 'Well, I can just not go because no one would notice.' And you get lots of students are skipping even they shouldn't.

In instructor's experience students in a large classroom were more likely to be absent because they believed their teacher would barely notice their attendance. In his view, attending lectures is a basic step which students should be equipped by.

> They will know ahead of time. The schedules are up on d2l so they can know. And in fact, all of the, I mean they thought about it all, all of the attendance for entire semester counts as one homework problem, one homework set so it is very small. I mean the message supposed to be coming is important you should come sometimes but it is definitely not a big thing. It is definitely not an emphasis. And then for any smaller classes I don't do attendance only in these larger ones.

The impact of their attendance to the final outcome was not significant but the instructor knew students could be intrigued by the strategy which is using their desire to achieve higher grade.

5.2.3 Knowledge of Time Constraints

With the limited class time, the instructors employed distinctive teaching methods to deliver the contents on the calculus curriculum. The methods the calculus instructors showed were influenced by their knowledge of time constraints during lecture and time availability for their students outside the classroom. In the following section, each participant's knowledge of time constraints will be discussed.

Case Study 1: Dr. F1

At the beginning of calculus courses, the instructors provided a syllabus to students to introduce summary of the course contents and schedules of each subjects on that semester. That information helps instructors to consider about what and when they will cover during the semester before each class starts. Dr. F1 also made a syllabus for students who enrolled her Calculus 2 course in the 2013 spring semester. To manage the course smoothly, the instructor focused on her resources regarding the course time table. Her concerns were identified on the fact that even though she had no experience teaching in Calculus 3 and 4, Dr. F1 acknowledged what should be covered during one semester for each calculus series as the following

> The way we have broken down since we teach one book we more or less break into 4 sections and I know sometimes it seems like we have to cover stuff very quickly because of the amount that is needed to be covered … covering maybe 4 chapters of a book like Stewart's book is fairly appropriate. It is definitely enough of challenge to get through all of them but it is also doable. We can cover that.

Thus, overall indication of Dr. F1 regarding distribution of their textbook affected her knowledge of time constraints and expectations toward students' appropriate learning strategies.

> I just try to get students to realize that when they have a 3 hours course like Calculus 1, Calculus 2… the way we have set up right now they need to also set a side time probably another 9 hours in a week or they can have the time to work on reading the text, practicing the problems.

This instructor also reported her knowledge about the low-achieving students that they needed more effort from the instructor such as detailed explanation and time to understand. And all of these necessities to help the low-achieving students' learning consumed the lecture time the instructor can utilize for the entire class.

> For lower students… well…I do put in some effort to try to break things down to where even a student who is struggling at least has a chance to understand. So as I said, when I am doing the problems I break down, try to make it as easy as I can for them to follow. I encourage them to ask questions "if you have a question about it stop me just ask." … I do try to take into the count that there are some students who are struggling but I also have to be aware of the fact that I have to cover the material that they are going to be expected to know in the next class or in a class this is a prerequisite for.

Her knowledge of time constraints impacted on how Dr. F1 handled the office hours for the class to provide extra assistance to those who needed to spend more time with her.

> Now I may sure I had time that afternoon and next day and the before the test I was told them they could come in see me in my office if they have questions. … If I have a student struggling, again, I will encourage them use math center, come to me during office hours. If I don't have time to go back and teach you this this this, you are supposed to already know that. If you don't, then you need to go into the help center not ask them to do these problems for you but say "hey you know, I am having trouble understanding how to factor" and then have somebody go over with just factoring problems with you or come into my office hours. So a lot of time it is a matter of I am telling them I am available I am telling them what else out there that is available.

Particularly, before their test, Dr. F1 made time available for students to prepare their exam. On the above quote, she also stated that her knowledge regarding available resources that the calculus students can get additional service besides their instructor such as the Math Help Center the department is operating. Based on her acknowledgement, she encouraged students to utilize available resources to increase their understanding.

Case Study 2: Dr. F2

When the instructors start to teach new course, their decision regarding how to distribute appropriate time for each subject may become one of their main dilemmas. The instructors' concerns would be decreased as they pile up teaching experiences of diverse courses. As an experienced calculus instructor over 30 years, Dr. F2 well realized how to schedule and manage his calculus lectures.

> Syllabus is not so tight so you can usually take a time off and do something. … I have never faced this issues that I get so many questions from the student that I can't teach what I need to get taught. It doesn't happen to me. … Right now I can see the end of this semester is coming. And I can choose the various topics to me the important thing is to get to this numerical integrations. But then there is lots of other things I might do might not do. I want to sacrifices some of them.

Since the instructor proficiently operated in the aspect of the time management, he could handle students' questions during lectures without deficiency of covering scheduled materials. In addition, it gave him an opportunity to review a core concept to increase understanding of students who do not easily follow his lecture. Dr. F2's decision to have a flexible syllabus was related to his teaching goal.

> It is hopeless getting through the syllabus and be proud you go through the syllabus if no students are understanding anything. Anyway, to me, it's more encouraging to the student at least make… spend a reasonable time to try to answer these things.

In his view, the purpose of teaching was students' understanding. Hence, to improve their understanding Dr. F2 wanted to encourage students to ask questions which he believed was one way of learning mathematics. Therefore, he decided to schedule marginal time to proceed in one semester and this happened because of his adjustment skill through experiences.

> I probably can't spend too much time on this but to me at least this level of mathematics you can nearly always answer a question reasonably satisfactory in a short period of time or you can even avoid it if you really have to just telling them this is rather interesting questions what I'd like to do is do it next time or I would like you to come and see me during my office hours.

With entry level mathematics courses, the instructor believed that he is able to manage students' concerns more easily. Subsequently, Dr. F2 expressed he has no problem with time obstructions such as class cancellations.

His time to spare for calculus courses was contributed by the calculus courses curriculum of the research site university. Most universities within the United States operate either three or four sequence calculus courses to cover standard materials on textbooks. Since the research site university chose the four semester calculus curriculum for two years, it provides the calculus instructors and students more time to cover the contents. Dr. F2 recognized the curriculum compared to three sequences system.

> I mean, as far for me the curriculum means the content of the course so and for that I think it is fine. But I know it is very similar to every any other big universities. We use the same book we go through the same sections of the book. Umm…the place where we different is we have 4 semesters and many places have 3. … I think 4 semester sequence does very well for some of these weaker students. It is a little bit slower pace but it is also more natural in a sense that the first semester you just do differentiations and the second semester is more or less just integration. If you can get those two semesters done well students are good condition. What happen in the 3 semester, we used to have 3 semester sequence you do differentiations in semester one and a little bit of integration and different people do different amount of integration. It's just

> depends on how well you have done. It is always rush at the end and in Cal 2 nobody really knows where to start so you just start somewhere in the middle of integration and you hope they will pick it up but… so… for the good students I think it doesn't matter but for the weaker ones it's a bit unfortunate.

The instructor recollected confusions while the university operated three semester calculus curriculum. Since he acknowledged the low-achieving students were needed more time to assimilate calculus content, Dr. F2 recognized three semester curriculum provided negative influences on students. Moreover, as a merit of investing more time on calculus courses, the instructor presented low rates of failing grades compared to national average.

> I used to try to keep track of all of statistics. The grades in our calculus courses are better than national averages by a significant amount I think so…at least in a sense, we don't have very high D, F, W rates. And my fear is there is a lot of pressures for the engineers to go through this 3 semester sequence. Then the D, F, W rate would be close to national average then…and this will be a cost for weaker students. The main issue for me, when I was finishing from a chairman for Dr. M to try to keep both sequences going so there is something for weaker students who really can't handle this 3 semester sequence.

For the low-achieving students, Dr. F2 argued a necessity of four semester sequences system even though he recognized an existence of pressures from other departments for accelerated calculus sequences and necessity of their coexistence. However, because of the weaker students' requirement for more explanations and opportunities to involve in the courses, he presented his support of the four semester sequences calculus curriculum.

Case Study 3: Dr. F3

The research site university adapted only four semester sequence curriculum to cover the textbook, Calculus (2012, Stewart), but started to supplement three semester method from Fall 2013. Thus, in Spring 2013, when I interviewed Dr. F3, he was teaching Calculus 2, among Calculus 1 through 4 courses. The instructor, however, noticed that the department would apply new curriculum and expressed his positive opinion on that.

> Changing from 4 semesters to 3 semesters I think that's a good idea. Because for example, at Ohio State, they are used to do Calculus 1 through 4 in 4 quarters rather than 4 semesters. So they are much faster. Here, I think it goes slower. ... But as I said it could be shrunk as 3 semesters which we are doing.

While Dr. F3 taught calculus courses as a graduate student in another university, he went through different calculus curriculum which was proceeded quicker than the research site university. Based on the teaching experiences, he could realize issues of different paces to manage the courses. He preferred condensed course curriculum relevant to his evaluation on the course property. He recognized calculus as a technique foundation course and the reasons for students' taking those courses as a requirement. Therefore, the instructor stated that calculus courses could be managed for shorter periods since he had not felt time constraint as followed in four semester sequences.

> Sometimes I go a little slow give too many examples then I realize maybe it should be split up and then the topics which look easy maybe I give one example in class. And they have to do homework. So in general, I don't think I am going too fast right now. This is pretty okay. We will be finishing this course pretty compatibly. … As I said, I don't feel pressures [on time].

Even though Dr. F3 showed positive opinion on calculus sequences operated in three semesters, he also noticed he should adjust teaching approaches along with reduced time. For example, to proceed faster, the instructor considered giving multiple choice quiz problems instead of constructed response questions which he used to apply in four semester calculus courses.

> If this becomes 3 semesters calculus instead of 4 semesters then maybe I will rethink that. Because then you… the time is more precious. Also, one possibility

> is to make a quiz which is much like multiple choices or true or false which takes 5 minutes or something.

His preference on the accelerated calculus curriculum was founded on his evaluation on the calculus courses contents which could be concise. Moreover, it was also related to his knowledge of teaching approaches showing diverse teaching strategies to reduce time constraint.

Case Study 4: Dr. F4

The calculus curriculum which was adapted by the department at the research site university allocated the content of their textbook, Calculus 7^{th} edition written by Stewart, to four semesters. According to the subject distribution, for example, Calculus 1 course covered Chapters 1 through 3 which are about limits, derivatives, and differentiation. Since Chapter 4 starts to introduce a new concept, integrals, and faculty members disagreed about compounding these two important perceptions, they followed the division. Therefore, only three chapters were delivered through the first calculus course. Dr. F4 acknowledged the curriculum in terms of time constraints.

> When I teach calculus 1 and calculus 2, I have too much time. And when I teach calculus 3 and calculus 4 I feel like I don't have enough time. So it would be nice if it you know some of integral calculus is done…Things are compressed a little more because when I do sequences and series I feel like I have to go very fast. And when I am doing derivatives I can take all the time in the world.

Compared with Calculus 1 and 2 courses, the instructor noticed time shortage through entire course teaching experiences. Accordingly, he expressed the preferred calculus curriculum which was more compressed in the first two courses to reduce time restriction along with teaching Calculus 3 and 4. However, because of the time distribution acknowledgement, the instructor could manage Calculus 1 with flexibility.

> I feel like I have lots of time so I can be very very flexible. … I knew that Dr. P [substitution instructor] did that last week when I was gone. But I basically re-did it anyway because I know it is very theoretical on the student. … I did get a feeling that students have the idea but not 100% yet so then I do one more example.

Although the instructor knew his substitute explained the Mean Value Theorem, he accounted again due to the recognition on the sufficient available lecture time.

On the other hand, the instructor expressed time managing methods when they undergo time constraints.

> Either you might choose to not spend much time on certain materials give you more time. Or, you might if you really don't have time you might just have to say you are going to come and talk to me in office hours or something.

In order to focus on the core subjects, the instructor cut off materials which he evaluated as less important. Furthermore, he recognized another options such as utilizing outside classroom activities through office hours.

5.2.4 Knowledge of Pedagogical Resources

To teach effectively, there are essential materials that the instructor should prepare such as lecture notes, homework assignments and exam problems for the course. Moreover, depending on the instructors, they may use diverse assets to facilitate students' learning more effectively. In the following section, I will describe the instructors' knowledge of pedagogical resources.

Case Study 1: Dr. F1

To improve her pedagogical knowledge, Dr. F1 attended a professional development program that the research site university was offering to the faculty members. Throughout participating in the program, the instructor gained practical instructional knowledge for her calculus students and reported the way she applied her pedagogical knowledge in her classes.

> OU has a course about how students learn and so I am participating in that. And we are reading a book that has some research background behind it. I think that will help me also to realize that okay certain things that I do help students to keep that… like a little bit of review before I start something new those kinds of things. Trying to connect to what we are learning now the things that they already knew and make those connections. So I am trying to do what I can do to reach students of different levels low, high… whatever.

In the above quote, Dr. F1 stated that she gained extended knowledge from the course she attended, such as allowing review time before lecturing new contents and showing connections between materials.

> I actually have some booklets that talk about how successfully to study math test to things that you can do throughout so to prepare better for the test. I try to give them the information and tell them either I give them a handout and say "You know here some really good idea" or I tell them verbally "Hey! These are something you need to do be ready for the test just doing the assigned problems that you have to turn in is not enough."

The instructor also reported her usage of information regarding successful learning strategies in studying mathematics, particularly the low-achieving ones. Based on the information the instructor extended, she actively encouraged her students to use available resources.

The instructor also suggested that making study groups would be benefit to many students. She realized throughout her teaching experiences that likewise receiving assists at math lab from graduate students, would also be one of effective learning utilities for calculus students.

> I try to encourage using math center, using other tutors and using office hours. I try to encourage study groups and that's one place I have really seen some students get a lot of help. If they can get a study group going and work together

> with the group then they seem to understand so much more…. because I have seen some important improvement in my students' grades when they work together with other students. So I definitely try to pull those types of things.

In particular, to improve the low-achieving students' mathematical capabilities, the instructor encouraged them to realize the existence of available resources they could benefit from.

> mostly I encourage them to …okay outside of class… the poor students they are going to have to do a little bit more so I try to make sure they know what resources are available to them so that they don't feel like they have to do on their own.

The instructor also acknowledged that there is an outside mathematics program the research site university students can utilize when they have issues, not just mathematical, but learning in general. For example, she illustrated that students who have psychological problems may get advice and find escaping methods throughout the program.

> We have that thing called OU CARE which is… has a basic idea of helping people stay on the track to graduate. But they also are good resources for anything you want to know. They are supposed be able to… they don't have on known people right there but they know who can. So they can send people to where they can get for some help. I know a student who having test anxiety. So I can do homework fine but when I take a test I get nervous I can't just work. Well sometimes things can be done so you can either take the test and have some more time take the test in the different location so the things going on room distract you and so… I said contact the people OU CARE tell them they might even have programs of … okay you have test anxiety? Here is something you can do. So I try to direct them to resources that they maybe can help them more than what I can do as far as just mathematical. But things they are dealing with outside of math where they can get help.

Like what she stated in the above quote, Dr. F1 had abundant information on resources available that could apply to her calculus students. Based on these knowledge, she encouraged her students to actively utilize and benefit from diverse resources.

Case Study 2: Dr. F2

Throughout long-term mathematics teaching and department-directing experiences, Dr. F2 accumulated pedagogical knowledge, including the available resources and acquired great familiarity with department regulations, procedures and policies. For example, he revealed his awareness regarding the available calculus curriculum described in the knowledge of time constraint section. The instructor recognized the calculus curriculum issue that the department currently was having. For instant, he was familiar with the plan gradually changing a four semester calculus sequence to three as well as his past experiences when they ran different curriculum. Likewise, basically most of his acknowledgement was related to his long term career experiences. In addition, since he also taught in foreign country operating diverse assessment systems and procedures, the instructor learned applicable teaching resources for students.

> Essentially every English university, 70 % or something it is an A. And at the end, students are graduating and getting degrees and the degrees are classified you don't just get a degree in mathematics you get the first class degree that's the very best then there is what they call upper second class and lower second class that's the next two levels and then something else. The best majority of students get the lower second degree so that's the third group that's the C. So the C is the expected grade in a way of English universities. And nobody feels shame about getting a C but they feel shame if they get less than C. Because C is the bell curve I would say C is the expected to reach.

Based on acquired knowledge from another school curriculum, the instructor built on his teaching strategies for calculus students in the research site university.

> I use different grading scale and I more or less always use the same scale. I give students an A for 70 % and more and a B for 55% and more. So what it means is I just when I am grading something…out of 100%, I more or less use all the numbers from 0 to 100 so rather than the most standard thing 50 of something is failing grades for me it's relatively high C. But I see this in a slightly

> pedagogical because it allows me to give much finer opinion in a way of students' performances …umm…so…typically, I make each question out of either 10 or 20 points. So if it's out of 10 points I just read what they have done then I try to decide if it is basically correct they should be getting an A grade but I can give them 7 or 9 out of 10 for this piece of work. It still gives me lots of possibilities more or less I can decide if it's really A or B. I would give them 7 because it's right on this border line so I have much wider range numbers where is. For example, if you grade out of 10 points with this 90% for A as soon as you deducted the point right in the A, B border line.

Through using wider range numbers to students' test, Dr. F2 wanted to assign them precise scores. Thus it could give the instructor more open possibilities as he confirmed students' grade. As he stated, since it is often hard to decide students' grades when they are on the border line, his wide range scales could raise accuracy on students' grading.

> For me most of that efforts are not clear to catch that mostly even the better students. They would not have got a perfect solution very often but it's no doubt they knew how to do this type of questions and that performance should be A. Maybe a part of it, what I would like to do is give questions which have a lot of easy content and at the end maybe have a little bit of twisted for the better students to show that they are better students so this grading scale that doesn't prevent what I would say good students somebody are good but not excellent they could still get A quite easily. But they will not get 9 out of 10. For me, 90% score is pretty dramatically strong.

To provide fair tests according to students' problem solving capability, the instructor applied his knowledge of available resources gained through experiences of different assessment systems. In addition, Dr. F2 recognized that this grading method psychologically motivated students to improve their grading and relieved their discouragement from the possibility of failing the course.

> If you brought up this system it's hard to change. Mostly psychologically students like it. At least at the beginning they think "Oh! 70% are A." I think the truth is I am overly generous in my grade typically my grades are no higher people hopefully a lot lower but it has some sort of psychological impact. But again for weaker students see many more possibilities and tend to make a little bit less anxious.

By applying the extraordinary grading scheme for the calculus students for long periods, Dr. F2 noticed that the impact of the way was not profound. Compared to other calculus class students, the grades of his students were not different. Nonetheless, he believed that some of students were encouraged through this and that was the reason he kept utilizing the grade system.

> Even if they made 0 on two tests they still have a chance of B. But the truth is it doesn't happen very often. But they will fight for longer basically. If I give you a grade in class you know right from the beginning the best you can do is D, it changes your attitude. There is nothing you can do. You know there is no recovery that students now lost you basically. So, anyway I like it. In the end, the grade don't seem to very different because I was used to see all the grades of all the sections and I know mine are not very different from other people. So the impact is not dramatic as you think but my hope is it gives some of the student better incentives.

Not every teaching approach, though, Dr. F2 tried to help calculus students' understanding, was continued, such as his assessment system. The instructor used to heavily apply graphing calculators teaching for both regular and business calculus courses about 20 years but ceased utilizing it.

> We had these graphing calculators. We had to attach it to the device you put on a projector. I did lots of that over years. … I used it in regular calculus. But I talked with a number of my colleagues over the years and I became persuaded that at least this lower level it's not a good idea anymore. That was my feeling at the moment. Students become a bit dependent on calculator and then they don't enough evidences in my mind, know to believe some of them become so relying -they don't know any calculus so I just finished it.

Among the interview participant faculty members, Dr. F2 was the most amicable and longest user of technology, including calculators, as a tool for calculus teaching. The fact he applied it in the calculus classroom for 20 years was shown as an evidence of his positive evaluation toward technology application. However, his attitude was influenced by his colleagues to a negative position. The graphing calculators which are available for the calculus students are able to produce answers almost everything that they learn in Calculus 1 and 2 without their understanding the processes. Since the instructors noticed the issues of modern technology and its relation to students, the majority of them do not allow it in the calculus classroom for learning and tests. Though they hoped students would not receive assistance from the machine while they worked on their homework assignments, the instructors also recognized that it is out of their control. Subsequently, the instructor decided to change his teaching approaches to stop using it because he believed that it is waste of time to teach if students do not know what is beyond pushing buttons.

> You should be able to handle these techniques and even in the end you are going to…it's fine to use a calculator or computer but you see if the answer is wrong you have enough common sense to know things are done sensibly. And you will be the one who actually programming in the calculator that's the real object. I often tell them you have to be better than this calculator because you want to earn more than 200 dollars in your life and this thing only cost me 100 dollars so what you are going to do for me to make you better than calculator.

The instructor viewed that most students in calculus classrooms will be ones who create technology since they are in STEM fields. Therefore, they should learn hidden procedures related to calculus subjects instead of passively receiving what it represents. He recognized if students are allowed to use calculators they became dependent on it. The instructor, however, still viewed it as a useful tool for learning even though he evaluated the gain through using calculator is less than setback.

> But actually I like it because so many things you can do with it. Really my mind show it very useful thing … umm… I enjoyed it so there is something you can learn from technology and over the years I wrote a lot of little programs that produce what I call "movies" so which now you change some parameters very slightly and now you see how for example in Cal 1, how a curve changing and the effect of changing 1 or 2 coefficients so on so although I don't use it, I like it very much so now I am in the mood if I teach honors calculus I will use it a lot.

> And in Cal 4, I attempt to use quite a bit because they are very visual. All these partial derivatives, slicing so on so. And it's almost impossible I think the thing you can do it but I can't on the board. And there is so much available on the web so show students how they can do it for themselves and becomes a little less mysterious. Anyway, I like it but my attitude now days I would ban calculator until anything say below Calculus 4 something like that. So then start to use that mostly because it is what it does students so I don't like to use calculator or anything in this class. Although I can't prevent it on the homework. But I am sure a lot of students are using calculator. But by now, I suspect this only the better ones because the weaker ones probably know it more dangerous. On the test of course I can prevent. On the homework I just don't care anymore.

As stated in the above quote, Dr. F2 discussed that difference between lower and higher level calculus courses in terms of application of technology. He recognize the needs of more visualized subjects of Calculus 4 than 1 or 2. Since he knew that Calculus 4 contains three-dimensional graphs and functions which cannot be expressed, receiving assistance from available technology like computer software or a graphing calculator is an effective way of teaching the content. Moreover, Dr. F2 stated his different teaching approaches depended on students' level of understanding. He saw the Honors calculus course students as more eligible to control the problem of using technology and understand beyond its representation. Therefore, the instructor revealed his plan for applying these resources for higher level or Honors calculus courses.

On the other hand, Dr. F2 utilized online exercise problems for the calculus students such as the Webwork resource. He assigned another set of online homework besides the traditional one.

> The benefit of online thing is they can have multiple attempts to this questions. So you can submit an answer and it will immediately tell you if it's wrong and more or less will say why don't you try gain so that's nice. Umm…that's better than the written homework. In a sense of somebody submit something and IJ (one of TAs) sees some stupid mistake on the first line and then rest of it is waste of time. So the student gets almost nothing from it. And probably they

> would have noticed this silly mistake if they are being more cautious. So that's the aspect I like.

Since students can try multiple times by the permission of the instructor, Dr. F2 evaluated it as a benefit of online homework assignments. He liked to give students diverse types of learning opportunities, thus they could profit from each method. However, the instructor also acknowledged a detriment of using the Webwork for his calculus students. Because of the fact that he cannot see their working processes through online homework results, not like written type assignments, he recognized that it could be a disadvantage of the method.

> The aspect I don't like it is you don't know what the reason was that they got these answers because you can't see their thought processes. And that's a little bit dangerous, too. … A lot of answers are just numerical so you don't know quite well where it came from and there are usual frustrations especially with symbolic answers try to enter that accurately into the program. Mostly the program seems to work well but occasional problem with it.

In addition, Dr. F2 noticed that students often expressed their symbolic issues with entering an answer to the site. He pointed out it also was an inconvenience of using non-traditional homework assignments. Meanwhile, he realized that the troublesome issue induced the low-achieving students to visit him to resolve it. Therefore, he observed through his teaching experience that technical issues of using online homework assignment could provide another opportunity to both the low-achieving students and himself spending time to discuss their difficulties.

> One thing I have learned to get back to the weak students is they tend to like online homework. … Because students now come and ask me this is the answer I entered and online homework says it's wrong but I'm sure it's right. And in the end the only way that they can deserve this talk to me about it. And there is a way that you can give students some extra attempts. So if one of students can see me it's a clear he knew what to do and he has no attempt left. I would go ahead and sit down and give another two attempts of questions or something.

> It's just a part of processes of try to get into come and talk to me so I can see what their problems are.

Dr. F2 acknowledged that the more students engaged in their learning with his help, the better they understood mathematics subjects. Therefore, he endeavored them to talk with him through diverse intriguing methods. In that sense, giving online homework assignments acted as one of his teaching strategies to encourage the low-achieving students to visit their professor's office.

Case Study 3: Dr. F3

Instructors gain information which can be applied when they teach through various sources. For example, accumulated teaching experiences are one foundation for them to utilize at the moments of decision making. Dr. F3 also expressed how he attained resources by teaching in diverse environments.

> At least in the beginning when I was teaching it for the first time it was big difference. … I don't know single person's name. When I was in a small class, I get to know them. When I see, when I am grading 'oh, this student is responding. He or she is really understanding it.' When I was in big class, I know people talk and I know faces but I absolutely don't know their name.

Since it was instructor's first time teaching over 100 students, he obviously could recognize the differences between big and small classroom settings. Through the experience, he received new resources, such as modified approaches, required for each situation, and would apply them for his future courses.

Another knowledge of resources the instructor equipped was developed by interaction with colleagues. Communication with other teachers who taught in different universities made him notice varying calculus curricula and compare it with the research site curriculum.

> Umm…contents and curriculum. I think it is very standard. So Cal 1 trough Cal 4 cover the same stuff. It's very similar to Ohio State and all other faculty friends I have at other universities, they are teaching the exact same things I think. So it is standard stuff and it seems okay. …At Ohio State, they are used to do Calculus 1 through 4 in 4 quarters rather than 4 semesters. So they are much faster. Here, I think it goes slower

According to the knowledge of resources regarding available syllabi, the instructor supported accelerated calculus courses while the department made the curriculum change.

Besides instructor's knowledge about obtainable syllabi, he showed familiarity with accessible technology for teaching calculus courses. The instructor recognized existences and abilities of technology.

> I think there is nothing that we teach Cal 1 through 4… it can all be done with some software. You can put things in mathematica and it gives you answers almost all of them.

Based on this knowledge, Dr. F3 established his calculus teaching goals which will be described in a later section 5.4.2. In addition, he discussed his teaching experience utilizing technology as a tool for the courses.

> When I was teaching Cal 4, I was using mathematica to show surfaces. I think with the Calculus 2 this semester, I was trying to this document thing camera, document whatever projector, but I think it didn't act couple of times. I couldn't set it up so then gave up.

In the beginning of the course teaching, it was observed that Dr. F3 tried to use the classroom's installed document camera but ended in failure. Even though he was not a technology practiced person, the instructor expressed his knowledge of available technology resources including software programs which are suitable for calculus teaching.

Case Study 4: Dr. F4

Much research in education has explored students' difficulties in learning mathematics. However, some research on the college teacher and their difficulties are available. Through this research, the calculus instructors' difficulties and their sources and, furthermore, their solution methods regarding the limitations are identified. Dr. F4 presented issues created by classroom environments and time restrictions. He recognized certain obstacles from managing over 100 students with different levels of mathematical capabilities during classroom time. In order to reduce the problem, the instructor applied available resources such as office hours.

> I tell them everyone in the class repeatedly you should be coming in my office hours you should come to your GA's office hours you should go to the math center. So I say as many as times on D2L. … Next week we have an exam. I have a lot of students. Ah, normally I have 2 or 3? Normal.

Through utilizing outside classroom activities, Dr. F4 tried to help students. Moreover, the department assigns three graduate students for a large calculus course to operate discussion session meetings once a week. Beside weekly 50 minutes lecturing, each teaching assistant has chances to meet students in the Math Help Center, 3 hours per week according to the department duty policy.

> Large class is different because I have 3 graduate students and they all have hours of help center plus they have an hour of office hour they have scheduled. So I tell all students "you just have regular math questions you should go to your GA's…. So students have a lot of opportunities to get questions and answers that are not from me.

The instructor acknowledged teaching assistants' availabilities and requested them to have additional office hours for the undergraduate students. By providing students a variety of opportunities in learning, he attempted to be less affected by limitations controlling a large number of students.

In addition, Dr. F4 knew an applicable online homework problem resource, Webwork, for calculus students. Therefore, he assigned extra homework for students to practice more problems.

> This semester I am using Webwork for homework problems. I am using human graded by GA homework problems and computer graded Webwork problems. … It probably like 2/3 human 1/3 computer. Basically what I have been doing is I am giving them the normal amount of human homework that I had previous semester. Then I am just adding another set of homework each week that's computer graded which is just 10 problems and fairy easy problems but it is more practice.

By using the Webwork as an additional exercise, Dr. F4 also revealed his orientation on appropriate mathematics learning attitudes. Students can be prompted through encouraging them to as many problems as they can. Based on the knowledge of available resources and pedagogical orientations, the instructor could apply proper technology to calculus students.

5. 3 Orientations

The moments when individuals are required to decide deliberate activities, they are induced by evaluations, opinions, and favorites toward available selections he or she has. Since teaching is a knowledge intensive activity, the instructors' orientations refer to a group of terms such as dispositions, beliefs, values, tastes, and preferences defined by Schoenfeld (2010). They are considered as primary factors influencing calculus teaching approaches. Therefore, in this section, the interview participants' pedagogical orientations will be described based on the following aspects:

- Orientations on effective teaching methods
- Orientations on role of the instructor
- Orientations on the low-achieving students

Like the calculus instructors' resources, which are described in the section 5.2, orientations that they presented also were constructed through their personal teaching and learning experiences. Their orientations sill be delineated one by one to understand more deeply how each theme of the orientations they showed related to their background information.

5.3.1 Orientations on Effective Teaching Methods

Although there are plenty of options in terms of effective mathematics teaching methods, some instructors evaluate certain methods as more effective than others. It is important to inquiry on not only pedagogical approaches but also instructors' orientations on the presented methods. Consequently, in the following section, the calculus instructors' orientations on available teaching methods will be delineated related to their resources and goals in teaching calculus.

Case Study 1: Dr. F1

Since Dr. F1 finished her bachelor degree in 1970's but received her PhD in mathematics in 2010's, she has experienced with both traditional and modern teaching methods in mathematics. Subsequently, the instructor posed broader selections and views toward each method she has practiced. For an example, in the previous section about the pedagogical resources, she reported her knowledge of learning strategies that textbook-centered learning method is effective based on her learning experience in college. On the other hand, she reported her desire on interactions with students.

> I try to engage students by asking them questions. … You ask some questions and several people throw out some answers they are not worry it is going to wrong or right because if it is wrong answer so on a right tract I can give them some positive feedback and just tell them "Okay, think about this." If it is a really bad answer, I can still say "Well…no you know you are not thinking quite

> right" and then I point them out. I don't ever say "That's stupid!" you know you don't ever do that. So they feel comfortable answering so usually some people say right answer.

By both asking questions and directing them on a right track during class time, Dr. F1 intrigued students' engagement in learning activities. The instructor also noticed that the method is not easy to handle and sometimes frustrating, but this student centered teaching method would be effective to refresh calculus students' prior knowledge.

> But in other class, they just stare at you…. Some of them they move their mouth … and I like… okay come on… so it can be very frustrating sometimes… okay… how long do I wait? ... But I do try. And someday is better than others. Some days they seem more engaged and I don't know if they had more sleep the night before or the weather effect or what? That is one thing I try to be conscious at. It is not just stand up there lecture but also ask them questions as I go because there is so much that requires their prior knowledge and so I try to trigger that by asking questions. So 'wait a minute I already know this. Okay then what do we do here this is something we already know' So hopefully that will keep them a little more engaged in not getting that drowsy okay I have had enough type feeling.

As Dr. F1 stated in the above quote, she recognized different classroom atmosphere from a variety of reasons. For example, some days students seemed to be more engaged in their lectures than usual and some days they involved in more passive ways. Hence, when she noticed students' inactive actions on her student centered teaching methods, the instructor put more effort to encourage their participations with providing them more hints or paying attention to their non-verbal languages.

> Then I try to give them some other hints, clues and lead them to the right answer and as I said usually I see their mouth very quietly and I would say "Yes, that's right." Then I repeat that because nobody else could hear them. They don't have a lot of confidence…. But pretty soon you do have to go on. … Yeah… sometime it is hard and sometime it seems like you are waiting a long time when it is really been just a few seconds. And I don't know I don't have good answer for that one.

The instructor noticed students' submissive participation issues and then tried to solve the problems. Meanwhile, she reported various attempts to find more effective ways of teaching calculus. Therefore, as another teaching method she was implementing to increase students' contribution to learning activities, Dr. F1 reported her application of pop quizzes to her calculus classroom.

> Some years I tried to have quizzes during the semesters but here again that takes up time and I found this semester I am just assigning homework so we don't have the class time for quizzes and that's helping to have a little more time for review instead. … I have mixed feeling about that. I really like the idea giving quizzes to make them keep up with materials as we go. And I think a lot of students found that very helpful. Yes. So that's one of those things that I have been tempting to try for Calculus 2 also but I worry about how it is going to affect the time we have for everything that we need to cover. And so… that makes it difficult. Maybe doing online quizzes something like that might be something but there again it is more like a homework problem in that. They can just do that and not really know everything else. So…it is a struggle. I see the positive aspect of both and I see the negative aspect if I replace one with the other.

The instructor was still looking for finding suitable ways to help student's mathematical understanding. On the other hand, Dr. F1 reported her positive evaluations about effect of study groups. Like described in the previous section, one of her pedagogical knowledge based on her teaching experience informed that studying together with classmates produced good results. Hence, she encouraged her students to make study groups to help each other regardless of whether they are the low or high achieving students.

> If they can get a study group going and work together with the group then they seem to understand so much more. So I really encourage that. … There were students then I said "Try to get a study group together." They send an email because on D2L we can email. They send emails saying if anybody want to and 3, 4, 5 people would reply then they start the study group. If they want to I announce in class send a paper around for them to sign up with their contact information I am glad I do things like that and I encourage them.

Another attempt Dr. F1 presented as a teaching strategy to increase calculus students' understanding was consistent with one of modern mathematics teaching methods, applying technology to calculus classroom. Even though she had not been taught with the approach, the instructor revealed her interest about using mathematics software to teach calculus courses.

> I am a little bit interested in maybe using some computer… you know there is so much technology on the computer now. I would like to bring some of them into classroom. I am going to have to know a little bit more about it myself before I can do that so… But I definitely think that there are something it will be really great for them to see on the computer because they can see some of relationships there where I can't draw it and then they can't draw it but they can really see on the computer.

Meanwhile, the instructor reported her unfamiliarity with the available mathematics software for calculus teaching and regrets the fact that she was not exposed to the technology when she was a student. Subsequently, Dr. F1 revealed her desire to utilize the resources and operate them correctly herself first.

> I am not very familiar with it. So I have thought about trying to… I think they have online stuffs every once a while. So I have been thinking about maybe going through that and seeing it if I can do something that would be positive. I think it would good if more of us are exposed to it. I was never exposed to it when I was going through graduate school or undergraduate at all. So I kind of wish I had been.

Even though Dr. F1 expressed openness to apply mathematical computer software to teach calculus courses, she showed negative opinion regarding using calculators for general calculus students.

> Business calculus have been using calculator to see something. It was really nice. But I am not a big fan of calculator, just use of a calculator. I rather them do things that they can actually graph and stuff like that. Hopefully if they have a calculator they would understand how to use a calculator and do that too. But I am really excited about some other things that computer can do because of the more or less the 3 D kinds of graphs and seeing those kinds of things which…

> you know it is hard enough to me to do 2 dimensional on the chalk board and try to show like when we do volumes … try to show this is, point out and. But in the computer, you really can see that its volume type of problems or all that kind of stuffs so… some of these kind of things I would really need.

Since computer software have capability in showing students 3-dimensional graphs, Dr. F1 evaluated applying the mathematics software programs as a helpful method to increase calculus students' understanding. However, the instructor argued that students should use their prior knowledge first to approach new concept then assisted by technology to boost their understanding. This was consistent with her negative view toward using the calculator since it was easily accessible and applicable without deep understanding.

> I try to stick the problems that are things… they can graph because they already know what x^2 looks like. So they should know what (x-3)^2 + 2 looks like. So I try to use that knowledge rather than something they have to do with the calculator.

As in the above quote Dr. F1 stated, she evaluated using prior knowledge as a prerequisite condition when students receive additional assistance from available technology. And her orientation was consistent with one of her calculus teaching goals which provides connections between each concept within the course. More details regarding her goals will be described in the following section 5.4.

Case Study 2: Dr. F2

All teachers begin as novices, building their own pedagogical philosophies and teaching methods as they move through their career. Over the long period as a mathematician and mathematics educator, Dr. F2 also had established his theories regarding effective teaching methods and classroom management strategies. In this section, his pedagogical orientations will be described based on his long-term experiences.

First of all, Dr. F2 expressed his beliefs about effective calculus learning methods which is iterative learning. He believed that students can improve their mathematics learning results by repetition.

> I believe the only way learning mathematics is by doing questions on this topics over and over again. And seeing lots of different ways to do this same question.

Based on this belief, he provided opportunities for students to practice as many as problems before each test.

> I will set them lots of review questions but it's not a sample exam. There are massive questions, many many more than they could ever do on an exam. And usually some of them are much much harder than what we would go on exam but always go exactly right topic. So to me, it's a part of teaching.

Besides giving practice problems, Dr. F2 utilized teaching assistants (TAs) as another source. He believed that experiencing diverse problem solving methods are effective as students study calculus. In the meantime, he recognized that each TA presented varying solution manuals thus the instructor requested TAs to upload each solution. Therefore, he wanted to provide students with many solution options to approach the same problem.

> Seeing lots of different ways to do this same question so this is quite nice. IJ (TA) writes solutions every week and very often shows it to students. Okay here is a solution but there is this way you can use as well. And that's really nice. Stop seeing this 'Oh! This is a topic and this is the only way to do this' because that's nonsense.

Even though he preferred offering students various available sources to practice the course content problems, Dr. F2 expressed his negative orientation regarding the spoon-feeding technique for students' better grades. He believed that by not arranging a sample test for the final students may become actively engaged in problem solving to prepare for the test. Besides, he thought the whole reviewing process for the final would be another effective method in learning mathematics.

> I don't like this review, more or less a copy of the exam just with slight changes find a little bit of artificial so and in particular, I will not give them review for the final. Because what I am doing is I post the solutions to every exam on D2L. So at the end, they will have all the reviews with all the solutions posted all the exams, exams posted and homework with the solutions posted. There are so much to practice from and now I don't want to give them something which they would think it is just a copy of the exam. This is all they have to focus on this one review so it is force them to go back and look over the whole course again. There is no one place that they can get all information. That's a part of teaching style.

Another Dr. F2's strategies to increase students' engagement in their calculus learning utilized their psychology eager to upgrade the scores. Regardless of deep research on the impact of a few points of one test or homework on their final grade, students valued the points themselves. Thus if they noticed uncertain things on their results, they would like to confirm the results clearly to not lose any points by the grader's mistake. The instructor intrigued these to provide opportunities to work with those students, especially weaker ones.

> Graduate students grade homework every week, I tell them to enter the homework on D2L. Then tell them, they must never change homework. Once they enter it, they must not be changed. So if students want to change their grade, students need to come to me and explain it. Because it gives me a chance to know… I read everything these students doing. Just I can get to know students. So she straight after class I had one student come because she was unhappy with grade and actually I gave her few extra points but mostly I want to encourage her to keep coming back so she was seen some small incentives to come here because she is also quite weak so.

By giving small incentives which did not have effects on their final grades, Dr. F2 actively encouraged students to visit his office hours and spend extra one to one time with him. He felt if students do not attain any benefit from visiting their professor's office to understand what they have missed they would not come since they were not willing to meet with the professor. Subsequently, Dr. F2 offered small incentive to encourage his students to come to his office to get help. In addition, the instructor represented his effort to guide students on the appropriate learning path by sending emails after each test.

> I send emails to some other students but for different reasons. After each test, I send emails. One is, one type of message is for students who have done it exceptionally well. Because usually, I don't know them. They never come to talk to me. But in some sense, I want to tell them well I notice you are doing well. And the other is for students do poorly and not attending class very frequently. … With the test, I tell them everybody has to be able to do every questions one week after the test. If you can't, you need to come to me and ask questions. So I have a lot of students who come here. Umm with this class, there are 140 students. Maybe 20 of them are very poor. And of that 20, I think at least 10 of them are up here every week.

By noticing the high-achieving students' outcome, Dr. F2 cheered up their hard work and encouraged them to maintain it. On the other hand, for those who needed correction on their learning methods, he manifested required efforts to survive in the course. Otherwise, the instructor believed that they should frequently interact with their professor to acquire extra help on their learning. According to this belief, he was willing to invest his time for students' effective calculus learning. His teaching approaches were constructed based on his many years of teaching experiences but also Dr. F2 believed teaching as an interactive process hence it is comparative. In other words, the instructor was concerned that pedagogical effectiveness depended on the teacher and learners who were in the classroom. Therefore, he realized there was no one best teaching method for everyone. Thus he tried to learn about prototypical classroom teaching strategies through diverse paths.

> When I was a chairman I visited lots of all the junior faculty and new people I visited classes every semester so some of them are phenomenon and I would say almost all of them amazing to watch them teach. But I don't believe in this notion of good teaching. Well I don't think these things especially these some of younger folks do it but I could not do it in the class. For them, it's fantastic and it works really well. I think they are excellent teachers. But it will be terrible for me try to do this. It's just different way of approaching things. My belief is that teaching techniques are very much matters what students in and instructors in. In the end, it has to work for students and teacher. And it's far to simplicities to think there is just one model it works. I mean it is obvious there isn't one because it was we all use it. Most people try lots of different things that they are their careers and these things work for me and these things don't work. … You have to somehow figure out what works for you. Of course with students that's basically what I mean. I know after many years now certain things work out well with students and other will be just a disaster. So this is the part of the reasons why I stopped using calculator so much. I mean I enjoyed it but I decided it wasn't really work.

Even though Dr. F2 had many years of teaching experience, he still put his effort to find better methods for him and his students based on the pedagogical orientation. Along with change of times and situations, he adjusted his teaching procedures. The instructor also referred to students' teaching evaluations, especially written comments.

> Comments students write actually, well some of them are silly but it is enough to know that they are useful. … I hadn't thought about it and you see it has some negative impact on the student. And usually there is silly things you just stop it. Many years ago somebody told me that far too many theorems. This is more advanced class far too many theorems in the class. So one of things that I did was I only referred to something as a theorem if that's really important. And I taught the exactly same information but theorems and propositions and lemmas. And I never got the same comments again. … The words that they write if it's enough of it that is interesting thing to justify in my mind. There is a lot of nonsense but although you can't ignore all the good comments and all the very bad ones and look at the middle then they probably tell you something. That might help you a little bit.

Through students' comments regarding the course, the instructor could gather some useful feedback to improve his teaching. Therefore, his pedagogical orientations described on the above were not completed and would be accustomed along with different classroom situations and circumstances.

Case Study 3: Dr. F3

Dr. F3 had teaching experiences for 12 years at universities in U.S. However, during the time of this research, he was teaching a Calculus 2 course for the first time which was enrolled about 130 students. As noted in the previous section, the instructor reported his notification about different classroom situations as the first time teacher. In addition, after he recognized the dissimilarities, Dr. F3 modified his orientations on effective teaching methods and strategies.

> At least in the beginning when I was teaching it for the first time it was a big difference. For example, in the beginning I was not interacting with the student's thought. I was just lecturing. It was too big. When I was in small class, I interacted with them. Now I think after a half of the semester is done then I am trying to get them speak more. So interactions are still possible although not ideal. I mean sometimes for example, in a big class, there are students in the back sitting with computers that upsets me but I am thinking okay if they are not disturbing the class I will let them be. If it was a smaller class, I will not allow this.

Since the instructor realized an issue of interaction with students in a large classroom, he felt he could rarely control each individual during lectures in that setting. In addition, he believed this physical element induced difficulties on students' remedy of insufficient prior knowledge. Dr. F3 viewed that it would be hard improving mathematical capability in a large classroom because of restrictions produced by the setting unless students invested more effort. On the other hand, he thought students in a small class are more likely to get help from their teacher and success in the course.

> That special attention is very difficult in a 130 student class. … Small class's students are less hesitant to ask questions. So if I see people come to office hours and I see students doing the same stupid mistake then I think "This is crazy. You have to know these things." And even you can tell them "You know you are mixing up regarding these. Go and learn them. This is the list of back of the book. Well, see this and keep it in front of that." … I think in a smaller class it is possible to catch up on math they missed.

Based on his orientations on the difficulties of different classroom settings, Dr. F3 devised effective pedagogical methods for students in a large classroom. Therefore, to remedy the situation, he provide pop quizzes. Another reason that the instructor gave pop quizzes was that he believed it would increase students' attendance rate.

> Because we have these pop quiz things the attendance is quite high. So I am happy that strategy works. … The idea is you do well on pop up quiz if you were in the lecture, come to class. So the idea is just come to class and look through your note so when you come to next lecture you are somehow prepared for it. … In the big class, it is good for attendance as well.

On the above quote, the instructor expressed his hope that students should do for calculus learning. He thought at least students should have the responsibility to attend their class to study. In the meantime, Dr. F3 invested time and efforts to increase their understanding. Thus even though it reduced available lecture time, he continued giving pop quizzes for students. The instructor, however, expressed the mixed orientation regarding effect of the strategy, hence planned for some adjustment.

> I like pop quizzes. But I will probably next time start giving feedback and warning much earlier. Because I did that at some point, but it seems that in class… I see most students are not getting good scores some quizzes which is big lost for you guys. Probably I will say within the first few quizzes… Repeaters and reminders help… sometimes. Because sometimes it is understandable, students are busy with other courses so they want to do that. Then reminder once or twice again then they know that they have to come back and do it.

As a first time teacher of a large classroom, the instructor noticed differences between diverse environment and accompanying along with the changes. Based on the acknowledgement of diverse situations, Dr. F3 quickly altered his supported pedagogical orientations and methods according to the received feedback.

In addition to the strategy for the large calculus course students, the instructor showed his openness to apply technology for teaching calculus. Based on his resources, Dr. F3 believed use of technology as effective and applicable method for teaching calculus.

> Maybe next time if I teach something, there are things called "demonstration" from mathematica and I used it some other lectures they look very good. So I think I would like to do that. … I think for Cal 4 for example, they are doing this multi-variable for the first time it is very useful. For example, you try to find continuity of something and you want to know one thing approaches to this. So it is very useful I think to visualize these things.

The instructor thought getting assistance through using computer software would be beneficial to increase students' understanding, especially, for teaching Calculus IV which including subjects about multivariable functions. Hence, he revealed preference on the resources and plans to utilize it for future courses.

Case Study 4: Dr. F4

In front of students, each teacher should decide what he or she will do next. Even though they follow prepared lecture notes, there are moments adjusting procedures depended on feedback from students. Dr. F4 revealed his flexible standards which would influence on the course operation.

> I usually have in my mind for sure I am going to do these and then there are some other optional ones that I will add or not add I feel like I need it and I try to be flexible. Again, there is time constraint but. So like in Cal 3, when I do sequences and series, we can do infinite number of examples of various convergent tests that some students still not be happy. So you just have a certain point you have to decide I have done 5 examples of ratio test that's going to have to be good enough.

Dr. F4 constructed his own subject evaluation principle and then applied it as he distributed portions in terms of lecturing time. While he maintained core subjects, the instructor modified secondary content based on students' understanding.

> You have to pick and choose and you have to sort of figure out 'is this something that only 10% or less of students are having a problem with? Or, is it something that 50%, 60% or 70%.' Then if it is, then I will take the time when there is other ones.

The instructor also expressed his adaptability on the level of difficulty in a calculus curriculum.

> It depends totally on students what the goal of courses, where they are going to. If they are going to be math major I think they should be doing one thing. If they are going to be engineer they should do something else. They are going to be umm… sociology and just want to take calculus because it is interesting that something else and depending on their background that also depends.

Dependent on the purposes of the enrolled students and mathematical capabilities, the instructor believed the appropriate level would be determined. Dr. F4, however, recognized its reality issues. Since in a classroom there are students with different profiles and he barely noticed each one, the modification was not easy to make.

> In a perfect world, people who are doing math seriously like math majors? We have different calculus for them. Because you can't teach people who should really learn something actually about deltas and epsilons at the same time as you teach someone else how to factor polynomials degree 2. I have thought about doing this at some point trying to figure out there is a way for the department make separate track of calculus for people who want to be math majors who want to at least take advance math classes.

As one way of encouraging Mathematics majors, the instructor suggested separated calculus courses for them. However, in reality, he was only able to focus on the middle-achieving students to increase satisfaction of all students.

> In the real world? I have a room for students. I have the syllabus of materials I am supposed to cover. And I try to make these meet to middle somehow. And

> that's all. I mean in terms of, yeah I just do I think I can do to get those students to where they need to be so they learn the material they are supposed to learn in this course

By following a general syllabus and textbook, the instructor thought students could achieve the course goals. Consistent with his pedagogical orientation, Dr. F4 stated his presentation style for students having diverse levels of understanding.

> That's my guiding principle when I am choosing how to explain things. What is going to be the clearest most compelling explanations? What's going on even it is not 100% rigorous rather have them understand 100% something which is only 90% correct versus only understanding10% of something that's 100% correct.

The instructor valued the comprehensive of more students even though it is a little rough. Therefore, instead of presenting rigorous mathematical statements, he preferred to show them relaxed formats. On this approach, it was also revealed a teaching goal of Dr. F4 which is majority students' understanding.

Compared with the other research participants, Dr. F4 expressed active technology applications on calculus teaching. As noted in the previous section, he assigned online homework besides written ones. Furthermore, the instructor utilized Wolfram.com to show students demonstrations and then posted them on D2L. However, he evaluated effect of adapting technology as not powerful but helpful.

> I use it when I think it is going to be helpful in helping students learn. I don't think it does any magical. … I do not allow them to use calculators because I think it doesn't help them to learn. All they are doing is just calculating what their calculator does. And now days, a calculator can do all of Cal 1 easily. And, so they can just set and punch buttons and never understand a single thing and get an A in the class if they are good at calculators. And, but I don't think that helps to learn so I prohibit.

Although the instructor applied computer software to increase students' understanding, he did not allow using calculators. Similar to other calculus instructors, Dr. F4 thought students can solve every problems in Calculus 1 or 2 with advanced calculators such as TI-83.

5. 3. 2 Orientations on Role of the Instructor

As an educator and mathematician, each calculus instructor has built their own teaching philosophy and expressed confliction related to what they want to teach and what students want to acquire from the course. Through the teaching experiences, the calculus instructors reported their limitations as a teacher and that it significantly influenced their pedagogical philosophy especially the role of the instructor toward the low-achieving students. Hence, in the following section, the calculus instructors' orientations will be described regarding the role of the teacher.

Case Study 1: Dr. F1

Since calculus is designed for freshmen and sophomores who do not have enough studying experiences with the college level, most Calculus 1 and 2 faculty members reported that the instructors' careful concern was required for them to construct the right learning path. As a calculus teacher, Dr. F1 notified her beliefs regarding the role of a calculus instructor as the following: the teacher exists to help their students. And while the instructor assisted students, she perceived confliction between ideal and actual classroom situations.

> There is something I think as an instructor there is something you are hoping, you are learning all the time. What can I do to help students?

This instructor attended one of the professional development programs the research site university was offering at the time of this interview. Through the program, she realized useful teaching and helpful methods that would be appropriate for her classes and tried to provide that information to her students. Dr. F1, however, thought that even though she delivered as many information as she could, unless students actively utilize the available resources, there would be no improvements.

> When I found this flyer it was actually from a different university and it talks about success in math. And I read it through and “oh I might right something like this up.’ And after I read through it, it’s like “this is exactly what I would say,” so I just printed those and I told my students I have them in my office I will bring some to class if anybody wants one then I will. But when they do come in I make sure they take one when they go so they can look through that. … But here again, somebody has to take up the ball and says “okay let’s see if we can get a study group started and…” here again, there is mixed reactions. Some, in some classes I have a lot of students who are interested in doing that and in another classes it just seems like nobody will put the time and effort into doing that.

Since Dr. F1 believed that the more students pose an active learning attitude, the more they acquire assistance from accessible resources, she encouraged her students to become actively involved in their learning.

> If I can get my students to read the book that will be a big help just there because then they would see all the good examples and they can draw when they try to work problems themselves. But I have not have. I know a lot of instructors we have a hard time to convincing students they really need to read the text and to study the examples the text does. So they can see how they apply the problem that they have to do. … I try to encourage but I can’t make them sit down and force them to read it. … It becomes a decision of whether they are going to try to stick it out. And then it is just up to them to put the time and energy in. And again, I encourage them to come and see me during my office hours. Ask me some questions.

As Dr. F1 stated in the above quote, she certainly recognized her role and limitation as an instructor. Although a teacher can acts as a helper in students’ learning process but ultimately the one who essentially engages in studying calculus is the student. She expressed her limitation and established her boundary as an assistant and pointed out students’ responsibilities when they enrolled in a calculus course.

> If students would do their parts and be prepared then it is not so overwhelming. … It is up to them to do something to help themselves. I encourage them to come to my office hours. I encourage them to go to the Help Center. I encourage them to work together with other students, have a study group. And warn them that just copying somebody else's work isn't going to prepare them for the test. But what else can you do?

This instructor believed that there are many aspects that students are needed to do on their own to understand calculus. Consequently, she encouraged and motivated students to utilize available resources. Furthermore, Dr. F1 showed her effort to provide effective pedagogy methods such as attending professional development programs.

Case Study 2: Dr. F2

A teacher of a course exists to lead and help his or her students but often expresses limitations on the accomplishment of the purpose. Dr. F2 also revealed his recognition as a mathematics educator, "my attitude is you should do everything that you can help", based on students' difficulties. He viewed that calculus courses are strongly required the prior knowledge to understand and improve their established mathematical maturity.

> Mathematics is a subject in my opinion that builds on itself very much so if you, you have things that absence, low down there is no way to replace it. I mean you need to go back and fill this gap or it will perpetually hold you up.

Dr. F2 believed that support from available resources such as the course instructor is necessity. According to the view toward the course property, he constructed his role as a calculus instructor especially for the low-achieving students. The instructor, however, also noticed that it is impossible for him to teach calculus if students passively engaged in their learning. Without their appropriate learning attitudes, he believed there was no way to learn mathematics. Therefore, Dr. F2 pointed out the importance of students' attendance as the first step to improve the level of understanding and obviously delivered these views to his students.

> Because I am taking an attendance sheet every day, if I see students missing a lot of classes then I send them a relatively angry email more or less telling them they should drop the class. Because they are not trying very hard there is nothing I can do if you don't attend.

For more advanced involvement from the weak students, the instructor wanted them to work with him during his office hours since there were limitations in the classroom. However, Dr. F2 experienced students felt uncomfortableness with their professor. Hence, he managed diverse encouraging methods for students to visit his office to get extra help. For example, he accepted their complaints regarding homework scores and increased their scores. Through these strategies, if students expressed their active involvement in learning, Dr. F2 did his best to assist them.

> I can't force them to come if they don't feel benefits from it. It's not worth it. I try to be very helpful to them when they are in here so. For some of them, it is unpleasant to be with professor so I don't force it. I just try to encourage more indirectly.

Even though the instructor strived to lead the low-achieving students' achievement in calculus courses, he experienced limitations as a teacher. In other word, he was aware that regardless of his effort on the course management he met a certain number of students who failed or dropped. Since Dr. F2 evaluated success of the course related to how he dealt with the low-achieving students for example, the rate of withdrawing or failing students, he thought it as out of his control.

> Well, I hope I work really hard. To me this is how you gauge success in the class. You can't avoid a large number of students withdrawing from the class or failing or even getting Ds. I mean so that's how I judge it. And it varies from one semester to another. Occasionally classes that I get, I cannot do very much for. ... I believe I have genuine interest in helping students particularly these

> ones that you are interested in because that's the main issue. Especially in mathematics, it is a huge part of job to teach this kid and not all of them would learn. But there is a big, big difference. I don't know if you aware this but if you teach Cal 1 in spring, that's terrible in comparison with Cal 1 in fall. And I don't care what anyone tells me this is much less to do teach these students. There is obvious reasons why it is true and you cannot get in a mode of thinking these are bad teachers who are doing this. In fact, we intent to rotate people around.

The instructor, however, presented his main investments in terms of time and effort to lead the low-achieving students' survival in the courses. His teaching approach was related to the view toward learning mathematics which strongly required assistance from others to fill their prior knowledge gaps.

> Most parts of my teaching, I don't have to spend a lot of time thinking about the approach to the class in the sense of what materials should I cover? When should I cover? All that is either in notes or my mind. So all my efforts now are going to how to deal particularly with this class with huge varieties that I got.

Case Study 3: Dr. F3

Most of Calculus 1 and 2 courses taught by professors in the research site university are maintained by a type of large unit classes which allow to enroll up to 160 students. Moreover the department regularly rotates the assignment to the faculty members hence they have had a chance to teach calculus for more than 100 people. Spring 2013 was the first semester which Dr. F3 started to teach a big calculus class. Since it was new practice for him, the instructor obviously recognized differences of each environment as described in the previous section. Furthermore, the new notification influenced his construction of role as a calculus instructor. In this section, his orientations on the role for a classroom with over 100 students will be described. Before he experienced the limitations of operating a large classroom, the instructor was more likely to engage in students' learning and willing to help.

> I have taught Intro to Abstract Algebra. There I have actually got a student said "What's going on? You seemed to be talking so much in class. You look like you know things…putting exam is harder…" So I will do that in a smaller class.

As the instructor stated, his active involvement and care for each individual who seems to require additional assistance were hard to happen with a large number of students. He thought it is impossible for him to reach out for the low-achieving students because he even barely recognized students' names.

> In a bigger class, I don't even know what the scores of these students are. Well, of course, one could say I should look up and see these things but I don't. There are too many students.

Since the instructor believed that learners should strive to get support if they need it, he defined his attention with limited boundary. Hence, he desired to help students who requested additional assistance from him.

> If they have questions or if they have difficulties they have to come up that encouraged to ask. There is another part of their education I think. Things are not going to come to them. They have to come.

It was surprising when the instructor noticed nobody visited his office hours even before the exam.

> There are very few somehow. … Surprisingly, Friday when I have a midterm at 12:30. My office hours from10:30 to 12…It is big surprise. Well, I can only tell them so many times you can come.

In his view, students should notice importance of getting benefits from their professors. When they visited his office, the instructor could help the low-achieving students to fill their insufficient mathematical knowledge which cannot be accomplished during lectures.

> I think okay, because I don't think I am putting any special efforts. For example, I am not contacting students. "Oh you are doing so badly. What's going on?" I am not doing that. … This is maybe philosophy or this is just making easy for

> me. I want them to come them to realize it is important come to me. I am lazy. I will wait till they come and that is okay I think.

Consistent with the evaluation on himself as a calculus instructor, Dr. F3 answered to hesitancy on the applying additional resources such as technology. The instructor viewed it required more time for him to prepare and employ for calculus students. Therefore, although he believed utilizing computer software are appropriate for calculus courses, used passively in actual classrooms.

> I prepare lecture notes and then beyond that I don't spend more time producing more accessories for lectures. If I prepare a sheet of formula I put it on D2L and they can access to it. But I don't although I would like to. … But that will request some more pressure at this stage I don't know I don't want to bring them in. … I'd like to do more but. Usually, there is more enthusiasm the beginning of semester and later 'Okay! Yes, you do a lecture. And you do a good job and…' [Laugh] Technology, unfortunately, doesn't get too much load although I think it is useful thing and use as many as possible.

The instructor recognized detailed explanations and lecture notes for each concept as efficient resources which students can use if they desire to apply. Therefore, he did not felt strong pressure on using "accessories" for calculus lecturing.

Dr. F3 referred to the limitations by several elements such as influence of physical situations. Moreover, compounded orientations with pedagogical philosophy, personality, and knowledge regarding effective teaching methods contributed to his attitude as an instructor.

Case Study 4: Dr. F4

In the research site university, the faculty members are expected to serve both as a researcher and teacher. The calculus instructors received PhD in mathematics then keep working on their specialized research areas. Teaching undergraduate and graduate students are also primary requirement of the job. Hence, outcomes of the duty impact on their future careers. Dr. F4 recognized impotency of success in managing courses for both students and himself.

> To extent that I can. I try to do more examples, give more explanations, take more time on the things that I think it might be helpful. … I can think of other teachers who work harder, care more about those students than I do. And I can think ones who work less or care less than I do so I am somewhere in the middle.

Based on the knowledge of other instructors' performances, Dr. F4 believed he was executing his best and the "average" among colleagues. Even though he clearly recognized the responsibility and expressed a desire to help the low-achieving students, felt the limitation, too. The instructor evaluated Calculus courses strongly require certain prior knowledge in mathematics. Therefore, students showing little mathematical maturity could not survive his course.

> There isn't so much you can do. You have a certain set of materials and you have a certain set of students and kind of put them together somehow. … I can't teach four years of high school mathematics in addition to calculus.

Through teaching calculus, the instructor viewed he was not able to "solve 12 years of bad mathematics education." Especially with a large number of students in a calculus classroom, he believed it would be impossible despite all his efforts. As a result, Dr. F4 either directly or indirectly manifested the difficulty to the low-achieving students.

> If it is clear that they are completely under water then I encourage them to drop out the class, take pre-calculus or something that if it is been too long since they took their last math class something like this. You can't in a class, especially class with 150 but in most any math classes, you can't teach only for the very lower students. And you can't wait until everybody in a class understand something.

In his view, there is no time to make all students to understand the lecture materials. Meanwhile, he viewed some of the low-achieving students are not ready to learn calculus content. Subsequently, he suggested dropping the course or taking lower level courses if they still have a chance. Dr. F4's recommendation to not prepared students was:

> You should work as hard as you can. And get as much from the class as you can. So next semester you will do better.

Obviously, taking one course was not enough for the low-achieving students to fill their mathematical knowledge deficiency. He believed instructors should explicitly explain the reality issues and their options to lead students to the appropriate learning path.

5. 3. 3 Orientations on the Low-Achieving Students

How one individual acts towards a certain group influences on his or her view toward the person in the group. Of course, one's evaluations of someone are built from his or her prejudice and experiences with the people belong in the group. Likewise, in order to have a better understanding about the calculus instructor's teaching approaches to their students especially the low-achieving ones, an examination on their evaluation and views toward the low-achieving student is required. That is, if we know more about the calculus instructors' evaluations, expectations, and views toward the low-achieving students, it will help us to understand their teaching approaches and attitudes to this cohort of students. Hence, participants' orientations on the low-achieving students will be described in the following section.

Case Study 1: Dr. F1

This instructor had more opportunities having conversations with undergraduate students in comparison to the others. If students have a question, concern, or problem regarding mathematics courses, they visit her office. Moreover, most instructors at the

Department of Mathematics encouraged their students to talk with her to get advice regarding suitable mathematics courses for each student's learning path. Therefore, she had experience in hearing more stories from students compared with the other calculus instructors.

Since Dr. F1 evaluated calculus courses as challenging, she understood students' expressions about their difficulties with the courses. Especially, for those with little prior knowledge in mathematics, it was harder to learn the concepts in calculus. She realized, however, a lot of students want to take higher level mathematics courses even though they are not ready for the level.

> So many students are so desirous being into a higher level course because they think that will make their degree plan faster they don't realize if I put you in a higher level course you are going to fail it, you are going to have to retake it or go back down even lower and it is really going to slow things down.

The instructor acknowledged that students in the calculus classroom take the course because other departments require their students to take calculus courses as prerequisite to complete their major. The majority of students enroll in calculus courses instead of interest in learning the calculus material. Subsequently, to quickly reach their goals, many students revealed their desire to finish calculus sequences. As a result, she believed that students' enrollment in the unsuitable courses induced many troubles in their mathematics education.

> It is really important when they come in and get that place in the correct courses. So… thankfully OU has the testing procedures and we try to do the best we can to get them into the course they need but like anything it is not perfect. So sometimes we do have some students in calculus courses but not quite ready for it.

Dr. F1 believed that the placement test is important to the process and foundation for placing students in the correct course when they come in. She even noticed that some students have never seen certain concepts before, hence, it was hard for the instructor to decide the appropriate level of the lecture. Therefore, if she recognized they were low-achieving students, as the first step helping them, Dr. F1 directed them to areas where they could get help.

> If I have someone who is doing poorly then here again, I try to encourage them to come in, see me and talk to me. I basically say "This is what I see." I get them to talk to me what they are trying to do. I give them some ideas what I think they should be able to do.

The instructor lets them know if they want to pass the calculus course, they should put more energy into the course.

> It was the last day of drop with an automatic W so I made sure they knew that they had that option. Try to talk them about okay this is what the grade is…if you can't bring that up … you know it is going to be F at the end of the semester. "Are you going to be able to handle that? Let's be realistic." You know they would ask me "Do I have a chance to bring this up?" so I talk them about. We still have this much left. We have another test. We have the final. We still have these homework. So … you know this is kind of great you are going to make it on those in order to get a C say. These are kind of great. Now, do I think you can do this? If you will … if you have the time and take the time to do this this this. They probably say "I can't guarantee." But that will probably be helpful. … If you have that then I would have very good hope that you would get the point that where you can do better much on the test. But you have to be realistic. If you don't have that time or if you know … I have some of time but I will not be able to do this this this and I will end up not doing it then let's say hey it might be wise go ahead and drop now when you can get an automatic W and try again next semester. I try to be honest with them and let them see exactly what is going to take to do better in the class. And I try to again, I try to lead them to a place that they can get some extra help.

Like Dr. F1 stated in the above quote, as the second step helping the low-achieving students, she made sure they realize the situation they were in. Since she believed that without students' effort in learning, it was not possible to improve their knowledge and pass the courses. This belief was based on her orientations toward calculus subjects which require proper prior knowledge to acquirement of knowledge. In her orientation, she also reported that investing studying time was a necessary condition for appropriate learning attitudes. Therefore she revealed her beliefs that depending on their actual effort and accessible investments into the course, they could pass the course or it would be wise drop the course and then retake it. Hence, Dr. F1 made sure that students understood the options which were available to them, and then motivated them to put more effort into studying.

On the other hand, even though the low-achieving students failed the course, the instructor believed that it would be supportive when they retake it. She evaluated students' course failing experiences as not waste of time but one of helpful learning paths when they have a little mathematical prior knowledge.

> Because their basic knowledge has some big holes they are not really prepared for calculus. I can feel it all those big holes but hopefully some of things I do will fill it some. And maybe they will not pass calculus this semester but if they try it again then maybe they will get it. Then actually I have had that happened with students…It is because that even though they did know enough to pass the class at the first time it has started fill in some holes that they had so then they are prepared the next time they saw the materials that they are prepare to understand it better. So…one calculus course is not going to … depending on the level students to begin with it might not bring them up to the level they need to be. But it might be a start. And here again, that's why placement is so important placing student in the correct course when they come in.

Dr. F1 believed that students will struggle with calculus courses if they do not have enough mathematical ability. Hence, at the end of the semester, some of them would not earn passing grade but lay the groundwork for the next semester. Therefore, this instructor revealed her orientation regarding the fact that the low-achieving students' mathematical knowledge can be improved.

Case Study 2: Dr. F2

When people are working towards a goal, they are confronted with many challenges. Although there are different level of difficulties, teachers often conflict with their expectation toward students and actual results from them. This dissension were more likely to appear from beginner faculty members since they usually started teaching with high expectations. Because most mathematics faculty successfully completed mathematics courses, they highly expected their students based on their learning experiences. As an experienced teacher, Dr. F2 stated his conflictions and treatments as follows:

> Significant number of students have real difficulties with Pre-Calculus issues. So that one I faced it mostly in this class is a number of students who essentially know no trigonometry, don't have working on with trigonometry. Very weak on algebraic manipulations so you always hope that doesn't happen. I am afraid by now my experience it was always happened.

Even though the instructor expected students in the calculus classroom to be fully equipped with certain prior mathematics knowledge like Pre-Calculus content, he experienced a significant number of students with difficulties with it. Subsequently, he gradually decreased his expectation and adjusted the standard of each course. Moreover, the research site university operated the calculus courses with students over 100 students thus Dr. F2 realized the number of students who were not qualified for the course. This recognition induced his low expectation toward some of the calculus students.

> I am afraid that I have relatively low expectation for some of them. Unfortunately, because we teach such a lot of numbers students in any big classes for example like this one. … There will be a significant number who really can't handle it. The amazing thing is even in higher level of calculus when I taught Calculus 3 last fall and that there were some students who somehow

> survived Cal 1 and 2 it actually have difficulties with trigonometry. … Overall, this class is a little bit better than I anticipated and I am happy with them. And some, certainly, 10 or 20 are really strong out of 140 or something. That's not too bad I think and I don't, my guess is less than 20% no less than 20 students who will fail which I think it's not bad in a big size class

As an instructor, however, he confirmed his obligation to teach students with less prior knowledge and not ignore them. Moreover, as it was described in the previous section, Dr. F2 invested the majority of his effort to help the low-achieving students' understanding. The reason he was willing to spend time with the low-achieving ones was combined with his evaluation on the property of the course subject and his obligations to students. Since he believed without certain level of prior knowledge calculus is a subject hard to build up their understanding, active engagement of course leader is strongly required. In addition, he realized that some of clever students are unpleasant to the low-achieving students when they asked silly questions. Therefore, he tried to intrigue students to visit and work with him individually. On the other hand, Dr. F2 revealed his view to the high achieving students more likely to seek their solutions without extra help.

> Some of good ones always can, that doesn't matter. It's nice. It's more fun to talk to them but I don't know that I am helping them very much. They are good students anyway.

Based on his beliefs on both students groups, the instructor invested more time with the low-achieving students than the advanced ones. In addition to the different time distribution, Dr. F2 decided to substitute course subjects according to the feedback from students. For example, he recognized that impotency and necessity of exposure of the high achieving students to ε-δ limit definition. Considering the time and content limitation, he decided to replace the definition with more satisfactory topics for the majority of students, although he believed this would be a disadvantage for the high-achieving students.

> I will not teach ε-δ technique. Actually not even in Cal 3, I don't. To me, that's waste of time so that's a minority opinion I think among the faculty. … I tell it's in the calculus book they can go and read this. But I am not going to focus on that. Again, I used to but I was never happy with the outcome and in the end. … It doesn't mean I disregard ε-δ limit in my teaching. For example, I will teach Analysis in this fall. That's more or less I will focus on. But in the context of calculus, I think it is waste of time. And there are so many more important things about limit these students should know. …My reasons for not liking it in calculus is in the end what I found was if you look through all sorts of calculus books they more or less use ε-δ argument to prove something like 2x+1 approaches to 1 when x approaches to 0. Then students in the end get the feeling that well e is a half delta. This is all the things they are looking to see some expressions for delta in terms of e and they tend to focus on what to me it is a wrong issue, algebraic formulation issue. So all this effort to figure out d is a half of e to me it's giving a wrong impression. The important thing mathematically is there is some number where it works you may come up and manipulate it which shows a half e is good enough but somebody else may find 2e is good enough and both these techniques are right. And this formulation of delta in terms of e is relevant. There is such a thing it works. But there is no chance to teach this level of sophistication in a calculus class. Still students can't manipulate simple algebraic quantities so in the end, I just gave up. Because I noticed on the test I would either give them trivial examples like this because I knew they couldn't handle really difficult one so in some sense I guess I just recognized that I couldn't teach this stuffs satisfactory.

It seems like on his course subject decision procedures students' outcomes contributed as significant factor. After he taught the ε-δ limit definition which he believed as an important topic, the instructor received calculus students' misconception on that because of the combined limitations of both students and teaching aspects. Somehow students' understanding levels and his presenting methods did not provide enough evidences for him to continue teaching ε-δ method. Therefore, he concluded to teach alternating subjects such as diverse mathematical meaning about limit and gamma function instead of teaching the ε-δ limit definition. Meanwhile, Dr. F2's other beliefs on the low-achieving students influenced on this teaching method. He believed that although there were students who entered the calculus classroom with not enough mathematical abilities, they could improve their knowledge as the course progressed. Otherwise, Dr. F2 viewed teaching those students as waste of time.

> I think so. Yeah I hope so. Otherwise, it's waste of time. … For the best majority of students who enter weak they will go out with weak mathematics skills as well. But they will be quite a bit better than they were when they came in. And it's enough that you can really get to be reasonably good.

Since the instructor believed it is possible to improve students' mathematical knowledge with a calculus course when they enter the course with low mathematical knowledge, he tried to help them to achieve on the level of a higher level. His statement on students' mathematical improvement did not mean everyone should get either A or B grades. Dr. F2 knew each student showing different mathematical knowledge and goals for example, he recognized that some of students will never use that much mathematics. Therefore, he referred to them as to "be reasonably good" instead of certain objective level of success through the courses.

Case Study 3: Dr. F3

In a calculus classroom, there are two types of people, teacher and students. Both in and out of classroom, interactions between these two groups significantly affect each purpose achievement for example students' knowledge improvements. Subsequently, the attitude as a teacher and views toward students related and impacted on instructional practice. Dr. F3 conveyed his pedagogical philosophy as "things are not going to come to them they have to come." Since he believed he can help when students requested it, they should actively engaged in their learning. Especially, if they are low-achieving students who are in need of more help from diverse resources, Dr. F3 thought they have to do their best to fill their insufficient pre-knowledge.

> Low-achieving students for example, there are students come to me and talk to me about how everything is going. I am trying to encourage them I rarely tell them to drop the class. I always tell them you can do it. What is going wrong? What is the problem and but I think all of these happen from the point that they come to me.

Without enthusiastic learning attitudes, the instructor believed students would not complete the calculus courses particularly in a classroom with over 100 people. He recognized a larger variation of students' achievements in large calculus classroom than small. In other words, Dr. F3 noticed a significant number of students who were not able to follow his lecture. Because of environment limitations, however, they would be more likely to experience difficulties recovering their deficient.

> In a big class, it is very difficult because you are left behind. Unless you make a…unless students make efforts to contact to TA or the professor or math help center. If they try to do that, it is possible because the semester goes by very fast. There is a new topic every week so if you are left behind then you are in big trouble. So in general, I would say in a big class it is very difficult. If you don't know anything about trigonometry, then there is a big chunk of this whole course which is going to be blank to you and then it is not going to be easy how to do other things. … That remedial thing unfortunately has been pushed to the next course and this has not, it cannot be done. I cannot do it in calculus. Maybe somebody else can because it needs special attentions you need to recognize where they are stuck in mathematical knowledge and how you can do that.

On the other hand, Dr. F3 thought the high-achieving students in calculus courses have the capability to hold themselves up without extra help from the instructor. Since he viewed the way of teaching calculus as most tricks, students would not have significant issues in understanding the content. Therefore, he mainly focused on the low-achieving students while preparing lectures.

> There are very few students and they don't. They don't need special things for calculus. If I am teaching a graduate level course and if I know there is one student then I will give him more hard, more problems. But in calculus if you are smart and good okay don't even come to class. Save your time. … All the time to see somebody who is left behind.

Because of the difficulties that the low-achieving students maintained, Dr. F3 showed his desire to care for them more as he proceeded with the calculus courses. Furthermore, his orientation toward students affected aims of the course that he instructed.

Case Study 4: Dr. F4

According to a research constructed by Mathematics Association of America, 61% of students enrolled in undergraduate Calculus 1 course had competed a course in Calculus in high school (Bressoud *et al*., 2012). Even though significantly more students receive an A for their grades, Dr. F4 believed this does not guarantee success in college calculus courses.

> Somebody who take calculus in high school that's completely different thing. Just because they took calculus in high school and then therefore they feel like they are well prepared to take calculus in college it is not necessary true.

In his view, certain students were still not prepared unlike their self-evaluation. In a calculus classroom, the instructor recognized students having difficulties in high school mathematics by contrast to his expectation.

> They should know like whole pre-calculus things about trig. What a function is, 1-1 function and onto function and you know just be comfortable doing what I consider it high school mathematics. But I know this is not the reality. Lots of students still you see f[x] they think about as f times x treat like multiplication things like this.

Dr. F4 believed students should know Pre-calculus such as trigonometry, functions etc. prior to learn calculus in the University. Moreover, he interpreted students without a certain level of mathematical pre-knowledge as "not prepared" for calculus. He believed that it was not because they were having difficulties with calculus materials, but with the prerequisite materials. Dr. F4 also evaluated that there are more chances to meet unprepared students in the Spring semester

> People who are taking calculus now either failed in the fall or they didn't take it in the fall. So certainly on average students in the spring are not going to be as strong or well prepared has students who take it in the fall. That's certainly true.

In his opinion, the unprepared students should simply drop the course. Moreover, because of the difficulty managing a large number of students with different understanding levels, the instructor noted limitations in helping them. He expressed negative opinion in success of students having insufficient mathematical maturity even with his help.

> I don't think that is a problem of having not enough time. … It's a problem of students who we were discussing earlier people who come unprepared you don't have the right background. So we are asking them think about abstract ideas like existence of you know Mean Value Theorem says that there exist an element that has certain properties and like thinking at, why is this true, very abstract that sort of things. Spending more time on it isn't necessary helpful if students are not all students but some of students are having troubles with things like what is the composition of functions, what is, how to handle fractions things like that.

The instructor believed even if he spend a month with some students helping them to understand certain concepts, they are less likely to grasp them. The success of students depended on themselves not on the instructor he thought. Therefore, to improve mathematical understanding, Dr. F4 stated more effort from students are required.

> They may still fail the calculus class but they, their mathematical skills get much much better because they worked very very hard. I mean all things are possible if students are willing to work hard. … l can't make students learn. So it depends on. I can help them learn but all things are possible just students really really want to.

Dr. F4 noted since these students are adults, they can make their own decisions. If they choose not to invest effort in studying calculus are determined by them.

> Occasionally I tell some students you should come …talk to me in my office hours. But in general, they are adults if they choose not to come, there are lots of resources available for them. And I tell them everyone in the class repeatedly you should be coming in my office hours you should come to your GA's office hours you should go to the Math Center. So I say as many as times on D2L… and beyond that they choose not to… it is the same as attending class. If they choose not to attend… okay!

In Dr. F4's view, although calculus learning require strong mathematical background, students can reach their goals if they do their best.

5. 4 Goals

Each calculus instructor possesses his or her own goals through the courses as they teach their classes. Their goals significantly are related to their resources and orientations. Therefore, an examination regarding the calculus instructors' goals through the course will help us to better understand their teaching approaches toward the low-achieving. Hence, in this section, I explore each instructor's goals throughout the semester and classify them as the following:

- Pedagogical goals
- Subject goals

5. 4. 1 Pedagogical Goals

In this section, I will delineate instructors' pedagogical goals through the calculus courses that they were teaching.

Case study 1: Dr. F1

This instructor noted her orientations regarding the appropriate level of difficulty while she taught one calculus course in as the middle. This belief of her was affected by her low expectation to students. She assumed that students in her calculus classroom could not understand the ways their textbook (Stewart, 2012). Consequently, she showed them a bit easier than the textbook presented contents. Furthermore, Dr. F1 invested most of lecture time for the middle level of students. This instructor noticed that sometimes she broke down a little too many steps but she wanted to make sure students, specially the low-achieving ones, to follow her lectures.

> Remind them with these things that we already looked at and we already knew how to do. And I have also repeatedly told them that when I have additions and subtractions in the integral the integral can be just distribute to right through so that I can split up into pieces. But if it’s multiplication I can’t do that. And so when I have multiplications that’s when I have to think about “is there mathematics I can do?” Well, substitution work? But sometime that didn’t and then I said now we were going to have a way to do that and I introduced the integration by part. So before I do a new stuff I actually went real quickly for a review over the old stuff.

One of her pedagogical goals that she wanted her calculus students to acquire confidence in their mathematical capabilities through the course compared to when they entered the classroom. Therefore, her orientation about the calculus students and the goals affected her teaching methods, to review the foundation subjects and gave more detailed explanations. To help enhance students’ understanding in the classroom, she briefly explained what they have covered related to the new topic and then introduced what they would learn. Dr. F1 also stated that one of her goals was to develop students’ accumulation of knowledge through reviewing and repeating previous content.

> I think review and repeat is very important. Again, I want them to tie in their prior knowledge. There is thing they know they realize that they can use that still now let's use that let's go on. Now we are going to add a little bit more to that. Otherwise things are just jointed in their minds I want them to be able to connect them.

The instructor informed that she wanted her students to comprehend what they are learning related to their prior knowledge so that they could gain broad meaning of each subject and deeper understanding. Therefore, in summary, this instructor's pedagogical goals through calculus teaching were that the majority of students to improve their mathematical knowledge and connect them to their prior knowledge. To reach these goals she often reviewed and repeated the core subjects.

Case study 2: Dr. F2

The ultimate goal of every mathematics educator would be to maximize students' learning. But, how far do the instructors think they can reach the aim realistically? Dr. F2 who has served over 30 years both as a mathematician and teacher informed his modulated goals through teaching calculus courses. He believed it would not be possible for everyone in the classroom get passing grades such as A or B grades. The instructor recognized there always existed a part of students who would fail or drop the course regardless of his efforts to avoid it. In addition, the instructor noted that each student entered a calculus classroom with different mathematical prior knowledge and reasons. Thus he pointed out his relative goals through the course depended on the statuses of each student.

> I try to be familiar also with how much mathematics they are expect to know. So for her, this is the last math class. So it's real struggle to get her through this. It would be very nice if she can survive it. She will not she probably will never use that much mathematics because no matter what I do I don't think I can make it very good. But she may survive the class in a sense of getting a "C". At least that's my hope for her. At "D", probably she needs to take it again, I guess.

The instructor knew his low-achieving students and the extent of necessary mathematical knowledge for their career well. If students' prior knowledge were not enough to understand in-depth level of the subjects which would not hold them up in the future both learning paths and working careers, Dr. F2 was satisfied with their achievement of the minimum acquiring through the courses. For the better students, however, he expressed different hopes understanding the essential concept of the course such as Riemann Sums in Calculus 2.

Another pedagogical goal of the instructor was presented when he mentioned about high school teachers. As a father of two children, he experienced the impressions of students first hand. Through understanding what students received from the relationship with their teacher, Dr. F2 established his pedagogical philosophy.

> They came to respect the fact that well some of nice teachers were also good ones but some of them were just nice as an excuse not teaching what they need to teach. And they both came to understand this pretty quickly and but you only see the benefit quite along. I often tell this class in the end, either you will know the stuffs you weren't or you can go away and complain that I was a terrible teacher or good teacher.

The instructor expressed that his main goal of teaching would be students to learn what they did not know before entering the classroom. Therefore, he hoped to improve their knowledge through the courses regardless of prior capabilities. Consistent with this goal, Dr. F2 believed that teachers should teach what they are supposed to teach even though they could receive negative reputations about the challenged teaching methods.

Case study 3: Dr. F3

Dr. F3 recognized the existence of students both who are left behind and advanced as he proceeded lectures. However, he expressed limitations as an instructor for the low-achieving students because of environmental restrictions as described in the previous section. Regarding the group of students having superior capabilities, the instructor recognized existence of a few number of students. Subsequently, when he carried on calculus teaching mainly focused on middle group of students.

> So when I teach I certainly focus somewhere middle. I've never focused on top. It's impossible. There are very few students and they don't. They don't need special things for calculus. … So I am teaching somewhere middle and keeping asking questions.

Since one of his goals was to give success to a majority of students, he mainly focused on the middle part of students which he believed to be possible to expand their mathematical ability. Related to his beliefs on the role of the instructor, he hoped to concentrate on students who required his assistance more. The goal of the instructor also was revealed on his management method as he noted disturbances in a big classroom.

> In a big class, there are students in the back sitting with computers that upsets me but I am thinking okay if they are not disturbing the class I will let them be. If it was a smaller class, I will not allow this.

In order to enhance students' understanding, Dr. F3 intentionally gave the second exam with problems of the high degree of difficulties compared with the others. He believed if they are confronted with a struggling test, they would be motivated to enrich their learning.

> I think it is good to show them something which is quite complicated once in a while. Just show that it's kind of complicated. … We had the first midterm looks very easy so I deliberately made the second exam a little harder. … So 20% are D or F. Actually I expected that for the second midterm. I am not surprise. I am not. Which is I am kind of happy because it shakes them up. They have to. They can't relax too much.

By providing challenging subjects, Dr. F3 hoped to induce continuous endeavor in students. He wanted majority of students in the calculus classroom to improve their mathematical ability by actively engaging in their learning.

Case study 4: Dr. F4

In a typical calculus classroom, there are students who will become not only mathematicians but also other STEM disciplines. The management of this issue was presented as one of the difficulties for the research participants. Dr. F4 clearly recognized knowledge gaps and limitations among students. He believed it is not possible to satisfy all of students hence concentrated on the middle section.

> A lot of what I do is just for the main bulk of students but I move sort of back and forth trying to make sure that everyone is something getting useful out of the class. I don't say I am only going to teach the middle third. Of course, you know it is all you are serving a large population of students in the class and if you're heading the middle 80% most of the time then you're probably doing right. You can't get everybody all the time. So I try to move back and forth but most. That's sort of center what I think the student are at.

Since he was not able to reach to every student, Dr. F4 mainly invested classroom time focusing on the middle group. Meanwhile, he also considered advanced students hence introduced materials to stimulate their interest in learning.

> There will be times when I want to talk about something that's more advanced. I don't want to bore. Or, strong student who have no trouble with any things I want them to see some of interesting part of it. Then I would say like something like "those of you are interesting these things or thinking be a math major blah blah blah. That's for future classes so you don't need to worry about it if you do not understand." I just say. So I say things which I definitely direct to those very strong students.

Dr. F4 did not want the strong students to lose their zest by repetition of subjects. Through exposing them with content of future courses, he hoped to encourage the knowledge fulfillment of the advanced students. On the other hand, in order to lead the low-achieving students' learning, the instructor reviewed basic algebra.

> I don't like it but it is reality so you teach students you have. … I just do I think I can do to get those students to where they need to be so they learn the material they are supposed to learn in this course.

Dr. F4 hoped each student to reach the desired status through these courses. Although each one has different purposes, he expressed the goal of teaching related to responsibility as their teacher. He viewed that it is his role helping students to acquire as much as possible from the course.

5. 4. 2 Subject Goals

Through calculus series there exit certain concepts and techniques that Mathematics Educators hope college students to learn. Especially, if students are in STEM fields and they have to take more advanced mathematics course after completing calculus courses, faculty members expect them to remember and apply those foundation concepts in calculus. Hence, in this section, the calculus instructors' subject matter goals through calculus courses will be described.

Case study 1: Dr. F1

This instructor noted her central pedagogical goal is improvement of students' mathematical capabilities. Whether students started with low mathematical prior knowledge, she wanted them to level up their mathematical knowledge compared with where they began. In addition, Dr. F1 reported that the knowledge she desired her calculus students to improve in the classroom is their conceptual understanding. Since she believed students would forget what they learned if they just memorized it, the instructor considered how she could make her student to think themselves and then grasp the meaning beyond equations.

> I think a lot of us instructors really want students to learn how to “think” about things so when they see a certain problem they will be able to relate something they already know and not be afraid to try “okay I am going to try to this in this situation.” Right now we talk about just regular Anti-Derivatives, we talk about regular substitutions. Now we have integration by part now we are doing trig functions and integrating these trig functions. So they have all these rules and so it is like okay I see this I have these inventories what do I do what tools do I need to use for this situation so I want them to be able to think about these are the things I know how to apply to this. That is a difficult thing as you learning to realize what tool do I really need here? So I want them to learn how to think and of course I do want them to understand what integration is about we talk about area under a curve, what we call net area because sometimes it is negative and things like that so I want them to have basic understandings what is integration.

The instructor believed that there are some basic memorizations students really need to know and some of these things they have seen before such as strategies for integration. Hence, if she keeps reminding of the content and makes her students to use them enough then she believed that it is not memorization anymore so they are less likely to forget what they have learned. Moreover, since Dr. F1 recognized that STEM major students are more required to know theoretical basis and conceptual understanding, she tried to show them theories and application to help students’ learning.

> I try to show the theories behind what’s going on. And then show how that theory applies to different things because whether they are math majors or engineers, math majors need to know theories but they also need to understand why this is important you know because it is applied to these things. And a lot of people understand it better once they realize how something is useful or why we are even interested in it, what are we really doing with this. “Oh okay this is how it came up.” And then also for the engineers, even though they only just need to take “Okay, if I have this formula, I know this rule, I can use it in that situation.” The fact to know a little bit theory about again, will help them to understand it instead of just being “oh I memorize this! And use this” they are going to actually see “okay I know why this formula is the correct formula to use here” so it is applicable for both.

In order for her students to have conceptual understanding, Dr. F1 believed that awareness of the relations among each concepts is necessity. Subsequently, the instructor hoped students to realize connections among the pieces that they have learned through calculus courses.

> I try to let them, make them realize that if they have a list of things they don't have to memorize every little detail. Usually remember one formula and then just remember similarities and differences the other formulas can be built from that one. So the memorization get reduced. … So to me I am trying to emphasize on the importance of understanding the steps so you don't have to do the all that memorization. But they need to have nice basic foundation to build on. … But if I know one thing I can relate all the others to that. So you don't have to memorize so much. You pick and choose what you memorize then the rest of it builds on that. Then, you look at the relationships. So that is what they need to know from calculus.

The instructor's goal which is students' awareness of connections of each concept was consistent with her other goal, students' conceptual understanding. She believed that if students realized what they are learning related to their prior knowledge, then they do not need to remember plenty of formulas. Instead, they can grasp concepts through the realization of the connections. That is why Dr. F1 kept up brief reviews and repeated before she introduced new subjects to students. She believed reviewing would help students to connect with prior knowledge and thus they could apply what they already knew to the new conditions. Through calculus courses, the instructor hoped students to add a little bit more to their prior knowledge.

On the other hand, Dr. F1 recognized that there are students who will take advanced courses, requiring calculus courses as prerequisite. Therefore, for those students she wanted to use calculus as exposure courses.

> I do show them and tell them "It (ε-δ limit definition) is a really important concept and it is important to understand." But I usually don't ask it on the test

> questions or if I do it is very basic just see that they understood just basic understanding of it. So it is not something I spend a lot of time on. But I would like to expose them to it so that they are kinds of getting a little tastes. You know mathematicians they are going to see that in analysis so it is important for them to at least seen it before maybe have a little bit of understanding of it.

Because the instructor believed that if students are exposed to some mathematical ideas, then they are more likely to understand it easily in higher levels. Therefore, for those students who will use calculus contents for their future learning path, she wanted to expose them in advance. In her opinion, people understand it better once they realize how something is useful or why we are even interested in it. Hence, to help students to develop understanding, Dr. F1 wanted to provide their applications and broader views about what they are learning.

Case study 2: Dr. F2

Instructors' subject goals are significantly related to their pedagogical goals through the courses since they are derived from the main teaching goals. The calculus instructor Dr. F2 also showed his goal consistent with his pedagogical one. As noted in the previous section 5.4.1, one of his pedagogical goals was students' relative achievement. Thus, he expressed his different teaching approaches toward students. Hence, for the high-achieving students who could handle more theoretical subjects, the instructor wanted them to move forward compared to the ones who just took the courses as requirement for their majors.

> In this class, I surely hope they will be able to integrate and understand what it is. And in particular to better one's understanding in the end all the matters is Riemann Sums. The rest is just sort of trickery.

For students who posed certain mathematical ability and would apply the concept in their major fields, the instructor noted his goal for them to have conceptual understanding in the calculus courses not technical skills.

> My point of view, I want them to understand what are their really applicable parts which usually means abstract parts. Students' attitude to abstraction is its relevant for their interests the word "abstract" means if you abstract something you take away all the stuffs that doesn't matter and just see what the fundamental issues are in this question. And the advantage is this applies to lots of different settings so this word "abstract" and "applicable" should be more or less the same things because in class, you probably heard me today tell them "partial fractions are nothing to do with integration. It's just a different way of representing these ratio these rational functions which are from many purposes and much worth than original representations. ... So anyway, fundamental idea is always important.

The instructor recognized these contexts related to the fundamental concept of the course which are called as techniques of those main perception. However, he viewed them as clumsy notations that most of the textbook use and hard to avoid the language. Moreover, Dr. F2 evaluated that the techniques produce things to easier to do something for example, integration but nothing to do for it. Therefore, the instructor hoped students are able to understand the abstract parts not inapplicable representations. In his view, fundamental idea is always important.

> In Cal 1, it's different quotients. So my usual quote is there is only one resulting in Calculus 1 and this limit is one. Nothing else matters from Cal 1. … You have to use some different ideas and it leads you to the very quickly to Taylor series and all sort of things so this is tell you a little bit about my approaches. So for me, this is fundamental important in Cal 1. More or less equivalent telling me the derivatives of sine is cosine. So they should understand this limit of ratio that is difficult to handle.

The instructor confirmed the core concept of Calculus 1 is all about limit. As an analyst, Dr. F2 pointed out the impotency of understanding the limit concept related to other perceptions. Moreover, he emphasized that the calculus students who are mostly in STEM fields needed to use the applications of the limit concept.

> Actually what you have if you have data, you don't even have functions. Somehow you have to get to guess and estimate what this derivatives might be or the rate of change. You don't even have differential functions you just get some data to deal with it. You want to understand it analyze it then it is exactly the limit that's exactly what you got to do. You have to analyze the rate of this approaching to 0.

Even though the instructor taught skills that could be done by computer and spent significant time for them, he believed the fundamental thing students should know is beyond the representation. Hence Dr. F2 hoped them to have better understanding about the limit concept and application of it. It also happened in Calculus 2 course with Riemann Sum. He viewed that most of stuffs we teach in Calculus 2 are related to Riemann Sum and could be completed by computer or calculators. Therefore, the instructor believed that human should have ability to check and figure out whether it works. Consequently, he presented contexts based on the fundamental concept and wanted to spend more time on that. For example, after covering planned subjects, he considered to revisit the Riemann Sum to help students to have better understanding about it when he was teaching Calculus 2.

Case study 3: Dr. F3

Pedagogical goals of each instructor were significantly related to general views on teaching and principles and views of a teacher as described in the previous section. Equipped knowledge and philosophy affected the instructors' hope through teaching a course. On the other hand, subject goals were associated with the orientations on the courses which are calculus in this research. Along with how the instructors evaluated calculus courses and their each subject, they expressed different goals through teaching the courses.

Dr. F3 assessed current calculus curriculum intended to teach techniques relevant to a few concepts. He thought there are only one or two perceptions in each course for example, Calculus 2 containing Riemann Sum as one.

> Calculus is not condensed. I think calculus the way we teach it is maybe at least teaching most tricks other than. There is one or two concepts. I mean even in a Calculus 2 Riemann Sum is a concept. And maybe L'Hopital's Rule is a concept which we don't go deep into at all. There is nothing. There is a trick after trick after whatever. So you don't learn much of math from these things.

In addition, the instructor thought most of students enrolling calculus courses would not use the presented level of mathematical knowledge.

> I think mostly from these calculus courses for people who are not going to do their major does not involve mathematics. So there are some people who are doing this course for example, med school they have to do some calculus courses I think. But they will never use anything like this.

The instructor believed that the current syllabus of the courses rarely dealt with in-depth level of mathematics content which most of enrolled students were not required to study. Considering both the course property and students, Dr. F3 revealed his low and affordable expectation status. He believed students would acquire the desired mathematical knowledge for their majors and careers through the courses with a few difficulties. While the instructor, however, revealed the goal and its level, he exposed conflictions with foundational views on mathematics.

> So probably my idea is that they see how one has to approach problems, think about them and be very clear in your solutions so it's more way of thinking. I think it is very important. Mathematics gives you way of thinking which not many other branches so science or whatever, very structured things. I think even if they take that who cares about integral sin(x). I mean you can find a software

> do it. But I guess the basic principles are. And for people who actually will use mathematics I think for them it's good to know the basics, ideas and their background and maybe just general principles.

The purpose of teaching calculus for the instructor was conceptual understanding similar to other instructors. He viewed learning mathematics as developing ways of thinking processes. Therefore, he wanted them to absorb foundation principles which can be applied in students' future careers instead of technical skills. Since Dr. F3 believed that most of calculus materials that we are teaching can be completed by machines, he wanted them to learn core idea and its background to utilize it in further progress. Although he wanted them to grasp basic concept, he was disappointed that the current ways of teaching and presenting are mainly focused on procedural understanding.

> But unfortunately, when you do calculus courses a lot of time spend on if I change a problem this way or that way, you use this trick or that trick. That's the way it is. I don't know. That's I don't know why and I don't know how to.

Meanwhile the instructor showed his ideal subject goal as conceptual understanding of the material and pursuing direction that he showed was discordant. By testing students with slightly different problems, Dr. F3 reveled his goal of improving calculus courses.

Case study 4: Dr. F4

Calculus instructors often provide problems to check whether students can apply the content they have learned. For example, after learning derivatives of trigonometry students would be given problems like the derivative of sin(x). However, all of the exam problems are not reflected in calculus instructors' aims of the courses. Even though Dr. F4 rarely asked them a problem such as writing the meaning of Chain Rule, he wanted students to understand it. He believed one of the goals of learning mathematics is understanding theories.

> Mathematics is about you should understand why everything is true. You know the Chain Rule is not the Chain Rule because I say so because Newton said so. It is because this is why it is true. And you should understand why it is true.

Of course, the instructor recognized only a few students have abilities to attain this goal. He, however, hoped to expose his students to challenging materials.

> I show them some actual examples. Some computer software thing which you let adjust ε and then you can see δ changed things like this. So that will be exactly sort of things that I would say "this is not going to be on the test but this is something that I want you to see." And it is mostly for the strong students. I know the bottom half of the class is not going to understand what ε, δ are.

Through ε-δ limit definition teaching, the instructor revealed his subject goal. He assumed students are less likely to remember how to prove a theory. Nonetheless Dr. F4 desired them to see and then understand why the statement is right even for a while.

> Even you can't prove it later you should at least know that once you saw and understand why this is true. This is not like common down because like in high school I took math and I think for these students most things are just handed to your back this is the rule for factoring this is the rule for the product and this is the rule for the chain rule whatever. So I make a big point in this class saying "you don't understand why things are true even I don't expect you to remember, reproduce the proofs" so we spend one day at ε-δ. I want you to understand at least this for next 50 minutes what the definition limit really is.

Unlike high school mathematics courses, the instructor believed students should have chances to be represented content requiring in-depth understanding. Consistent with his orientation on mathematics, Dr. F4 hoped the students to know theory behind content. In his view, even for those students who will not take advanced mathematics courses, it would be fine for them to see some proof. Otherwise, he believed for students in Real Analysis, for instant, the experience would act as positive resource. As one of the undergraduate mathematics instructors, he wanted each calculus course to perform its duty.

Chapter 6: Discussion

6.1 Introduction

Resources, orientations, and goals of the instructors in teaching calculus courses were described in Chapter 5. The results were based on the research participants' interviews, instructional practices presented during the classroom observation, and course curriculum and information.

In order to address the research questions and furthermore suggest the ways of possible contribution to the research field, the core findings presented in the previous chapter will be discussed. As Schoenfeld (2010) stated the better we can understand calculus instructors' ROGs and their processes the better we can help instructors become effective teachers, which in return, may lead to construct successful programs in college calculus. Therefore, the applicable ROGs of the instructors, how they related to each other, and how they influenced on instructional practices will be discussed in the following section.

6.2 Understanding Calculus Instructors' ROGs

One of the main goals of this study was to answer the following research questions:

What are instructors' resources, orientations and goals in teaching calculus courses?

To understand the instructional practices, the developed framework provides one way of illustrating calculus instructors' ROGs when they manage the courses.

As a French mathematician Jacques Hadamard (1945, p.1) emphasized:

> That the subject involves two disciplines, psychology and mathematics, and would require, in order to be treated adequately, that one be both a psychologist and a mathematician. Owing to the lack of this composite equipment, the subject has been investigated by mathematicians on the one side, by psychologists on the other.

There are fundamental difficulties in discussing the nature of the psychology of advanced mathematical thinking. Consistent with his view point, estimating one's decision-making processes was not easy to figure out. However, the framework which is based on Schoenfeld's ROG Theoretical Framework leads us to have in-depth understanding regarding the procedures. This section highlights the participants' foundation resources, orientations, and goals which consciously or unconsciously influenced their teaching.

6.2.1 Ways of Helping the Low-Achieving Students' Understanding

The lecture is one of the major formats used in undergraduate mathematics education, although varying formats are introduced such as tutoring, seminars, classes, small group work and home assignments offered to students (Bergsten, 2007). Among different styles of lectures, the content-driven, context-driven, and pedagogy-driven which are identified by Saroyand and Snell (1997), content-driven lecture is considered as a traditional method type in mathematics teaching.

For example, definition – theorem – proof format (DTP) (Weber, 2004) is focused on presentation in the DTP order of within mathematics content matter. Thus, investigation into the lecturers' built knowledge of presentation was inspired to pursue in-depth understanding on their pedagogy.

It was noted that each calculus instructor posed their own strategies to help the low-achieving students. Some teaching methods knowledge for the weaker ones was consistent with the approaches for all level of students. Evidence in Chapter 5 showed that instructors started with fairly easy subjects to provide sufficient time for students to familiarize them with the new topic. Through variety of sources such as their teaching and learning experience, the instructors recognized the more students are exposed to obvious problems the better they comprehend the concepts. While they introduced detailed explanation based on the knowledge, the research participants revealed their conflict to determine the extent of the degree of the difficulty. For example, Dr. F1 stated that “Sometimes I think I probably break down and do a little too many steps but I just want to make sure they follow.” In order to increase understanding of the low-achieving students, the calculus instructors chose to invest more time on them.

This instructional practice confirmed the instructors’ implicit acknowledgement in learning difficulties of the low-achieving student. Depending on students’ level of mathematical knowledge, they require time to digest the same contents. This was also noticed on knowledge of time constraints by Dr. F2. He informed that if calculus curriculum changed to 3 semester sequence, it would negatively affect the low-achieving students. Since the courses are accelerated, instructors are not able to allow enough time for them. As a result, he scheduled flexible syllabus in order to secure extra time for students who cannot easily follow the lecture. This approach was related to his pedagogical goal of improving students’ understanding. For example, he mentioned “It is hopeless getting through the syllabus and be proud you go through the syllabus if no students are understanding anything.” By arranging additional time, each calculus instructor tried to offer opportunities for the low-achieving students to improve their mathematical understanding.

A similar knowledge of effective lecture method that the calculus instructors showed to increase the low-achieving students' mathematics ability was visualized demonstration. It seems that the instructors recognized calculus contents can be delivered by diverse methods since the level of the courses rarely require rigorous mathematics. Among other presentation options, they noticed students would construct more easily each topic with pictures. This knowledge is consistent with the theory of three worlds of mathematical thinking developed by Tall (2004, p.29):

> … the development of geometric concepts followed a natural growth of sophistication ably described by van Hiele (1986) in which objects were first perceived as whole gestalts, then roughly described, with language sophisticated so that descriptions became definitions suitable for deduction and proof. However, numbers and algebra began through compressing the process of counting to the concept of number and grew in sophistication through the development of successive concepts where processes were symbolised and used dually as concepts (sum, product, exponent, algebra expression as evaluation and manipulable concept, limit as potentially infinite process of approximation and finite concept of limit).

According to Tall, the mathematical knowledge development of students start from geometry. In his view, the first world arises from our perceptions of the world is the 'embodied world'(Tall, 2004, 283):

> If one takes 'embodiment' in its everyday meaning, then it relates more to use of physical senses and actions and to visuo-spatial ideas in Bruner's two categories of enactive and iconic representation. Following through van Hiele's development, the visual embodiment of physical objects becomes more sophisticated and concepts such as 'straight line' take on conceptual meaning of being perfectly straight, and having no thickness, in a way that cannot occur in the real world.

Regarding calculus students' level of understanding of mathematics in regards to Tall's theory of three worlds of mathematical thinking, Stewart (2008) revealed the movement of the level of difficulty as they learned Linear Algebra. Since most students who take calculus are first or second year students, their level of understanding is same as Linear

Algebra students. On the research, she concludes that Linear Algebra students are expected to build formal world thinking from embodied and symbolic. Consistent with her results, the calculus instructors in this research showed that through visualized explanation, Tall's embodied world, the low-achieving students are able to establish their complexities. For example, Dr. F4 stated that "The best majority of these students will get a lot of understanding out of a pictorial understanding of it than out of proof." Even though he recognized that the approach is not the traditional method of DTP (Weber, 2004), he knew visualized account is more effective to convince the low-achieving students when they are introduced to theoretical contexts. It was interesting to note that although the mathematicians constructed formal world for calculus contents, they played in the embodied world to help students' understanding.

6.2.2 Recognitions of Circumstances and Their Treatments

Approximately 35 percent of university undergraduate students are enrolled in large-enrollment courses (Ogawa & Nickles, 2006). Because of high demands of Calculus 1 and 2 from STEM major students, the courses are often operated in large lectures which have high rates of students per teacher. In 2013 spring semester, the research site university held three Calculus 1 courses but only one taught by a graduate student which had 35 undergraduates. The other two courses had total of 270 students. Among 4 research participants, three instructors were teaching large-enrollment courses during the semester. Each faculty member clearly distinguished differences between two types of classroom. Especially, since it was the first time teaching about 130 students for Dr. F3, he expressed some difficulties teaching large classes. First of all, the instructor noticed that the interaction method he used to apply to the class of small number of students was not appropriate for big calculus courses. Although he already had 6 years teaching experiences, the instructor recognized interaction difficulties with 130 students. For instance, he stated "In the beginning I was not interacting with the student's thought. I was just lecturing. It was too big. When I was in small class, I interacted with them." Dr. F3 posed his concerns that he wanted to connect with students but could not establish the interaction because of the environmental factor. But the issue was a little resolved along with the semester because he accepted the difficulty of interaction and then tried to modify his teaching approaches adequately for different situations. The instructor encouraged students to engage in their learning such as investing more time to hear their feedback. Therefore, after a half of the semester was done, he re-evaluated his course management by not lecturing but teaching. It seems that the quick recognition of the problem based on the teaching experiences reduced trouble created by the unfamiliar external aspect.

Furthermore, the calculus instructors recognized difficulties of students in large-enrollment courses. They knew students in large classrooms were more likely to be left behind. Because of varying obstacles generated by physical environment, the low-achieving students often skipped and less involved in the course. The instructors knew students acted as they were less connected with their teacher. This recognition was consistent with the finding of the paper (Bressoud *et al*., 2012), "Switchers repot having less intellectual connection with calculus and their instructor." Based on the recognition of students' aspects, each instructor expressed own solution method. For instance, Dr. F4 regularly checked attendance of students in a large calculus class which he did not do for small classes. Similarly, Dr. F3 provided pop quizzes for them in order to increase their attendance rate and preparation for the next lecture. However, the effects of the strategies were not clear in terms of failing and withdrawing rates in large calculus courses. Thus, it seems that both the instructors and students struggled with large-enrollment courses. Although some research showed many problems of large-enrollment courses, universities inevitably chose the option to reduce cost. Accordingly, educators recognized the issues of pedagogical impact and cost savings of the class type and then offered various solutions. For example, in 1999, a group of 20 higher education leaders gathered to participate in an invitational symposium on the topic of "Redesigning More Productive Learning Environments." The purpose of the program was to encourage colleges and universities to redesign their instructional approaches using technology to achieve cost savings as well as quality enhancements (Twigg, 1999). Despite a variety of pedagogical representation methods based on research, mathematic faculty members expressed passive attitudes for adapting it. Regarding their indifference to classroom innovation several research are available (e.g., National Science Foundation, 1996; Seymour & Hewiit, 1997; Baiocco & DeWaters, 1998; Kardash & Wallace, 2001; Marsh & Hattie, 2002; Wright & Sunal, 2004).

6.2.3 Beliefs in Effective Prototypical Teaching Strategies

According to the results showed in Chapter 5, each calculus instructor constructed his or her own pedagogical approaches. These were based on their direct teaching and learning experiences, personal familiarities, feedback from students, and formal and informal discussion with colleagues. Along with orientations built through varied sources, they viewed certain methods as more effective and then applied them to their calculus classrooms. As a common way to increase students' learning more effectively, all the research participants pointed out the importance of interaction between the instructor and student. This was because of the fact that throughout numerous research, beneficial effects of learner-centered approaches to science and mathematics instruction were well known to the mathematicians (Walczyk & Ramsey, 2003). Therefore, each instructor tried to establish the kind of instructional strategies that support students' efforts to learn. Some of them were using body language to encourage students' engagement. For example, Dr. F2 provided small incentives as follows:

> …if students want a grade change, students need to come to me and explain it. Because it gives me a chance to know… I read everything these students are doing.

By giving students the benefit of coming to his office for extra help and practice opportunities, Dr. F2 believed he could increase students' involvement and then allow them to improve their mathematical knowledge. Moreover, it was noted that the instructors preferred diverse classroom activities as one of learner-centered teaching approaches such as pop quizzes and study groups. Most instructors expressed the effectiveness of peer tutoring in learning calculus. Their orientations were also consistent with some research on the theoretical advantages of peer tutoring. For example, Topping (1996) showed the value of many different types and formats of peer tutoring within universities. He stated that because of the dual requirement to improve teaching quality while 'doing more with less' interest in peer tutoring has increased in higher and further education. Similarly, faculty members evaluated pop quizzes as a useful method to help students' learning. However, there were differences between what they believed to be effective and what they actually used. Even though calculus instructors viewed that students are more likely to improve their knowledge through peer tutoring, no one directly applied the approach. Regarding the issue, Topping (1996, p.321) claimed that it is because of external cause as follows:

> Increased student numbers coupled with reduced resources have often resulted in larger class sizes, thus encouraging a reversion to a traditional lecturing style of delivery and a reduction in small group and tutorial contact – in short, less interactive teaching and learning.

Likewise, mathematicians revealed conflictions between their orientations and instructional practices. Although it would be unwise to seize upon their decision-making process as a simple step, various research in education provides one way of understanding their selections.

Another orientation on effective pedagogical methods of the calculus instructors showed was utilization of available resources. For instance, since the department assigned three teaching assistants for a large enrollment course, calculus students had to enroll in a discussion section. Each section operated by a graduate student was a one hour meeting per week for approximately 25 students. The professors instructed the teaching assistants on what to do both inside and outside of the meetings with the students. Ways of using the additional supporters for the course were determined by the instructors' ROGs. In the meantime, the instructors recognized limitations operating a class of over 120 students, they evaluated that having some assistants may reduce the difficulties. For example, Dr. F4 asked his teaching assistants to have additional office hours for only students in the course besides 3 hours in the Math Help Center which were open for other calculus students. He expressed that one person obviously had restrictions as helping students who needed extra care from the experts. Thus, Dr. F4 believed students were more likely to acquire benefits from graduate students when they visited their office hours. Similarly, Dr. F2 also utilized the course assistants to help students in a large classroom. He asked a TA to upload each homework and test solution available on D2L available for students. By providing variety of solutions from different people, he believed students would have more opportunities to understand that there are diverse methods for one mathematics problem. Therefore it could help them to build conceptual mathematical knowledge. For example, Dr. F2 stated as follows:

> …seeing lots of different ways to do this same question, so this is quite nice. IJ (TA) writes solutions every week and very often shows students 'Okay, here is a solution but there is this way you can use as well.' And that's really nice. Stop seeing this 'Oh! This is a topic and this is the only way to do this' because that's nonsense.

Consistent with the interview participants' orientation on benefits of TAs with helping calculus students, the recent research studied by Rasmussen, Ellis, and Zazkis (2014) pointed out impact of graduate teaching assistant (GTA) training programs. While they examined the factors led the five doctoral degree granting institutions to the success of their calculus program, the researchers identified seven features. Regarding the influences, Rasmussen *et al.* (2014) highlighted GTA training program as one contribution as follows:

> The more successful calculus program had substantive and well thought out GTA training programs. These ranged from a weeklong training prior to the semester together with follow up work during the semester to a semester course taken prior to teaching. The course included a significant amount of mentoring, practice teaching, and observing classes. GTA's were mentored in the use of active learning strategies in their recitation sections. The standard model of GTA's solving homework problems at the board was not the norm. The more successful calculus programs were moving toward more interactive and student centered recitation sections.

Since GTAs act as brokers in the joint enterprise of teaching and learning calculus, Rasmussen *et al.* claimed that professional programs for them were significantly correlated with successful calculus programs such as student pass rates. Although the research site university did not operated GTA training program during the semester, the instructors revealed their thoughtful concerns and intuition about GTAs in helping the low-achieving students' success in the courses.

Besides using GTAs to acquire aids, the research participants showed their orientations on applying technology for calculus courses. The types of available technology the instructors thought about were: graphing calculators, online sources, mathematics software, and computer hardware. When the participants were asked about "technology", the first thing they mentioned was graphing calculators. Some reflected on history and effect of the tool along with teaching calculus courses for a few decades. After graphing calculators were introduced for pre-calculus and calculus, because of its easy accessibility they became very popular in many countries including the U.S. (Waits & Demana, 2000). In 1992, Demanna and Waits reported that every classroom could become a computer lab and every student could own his or her own personal computer with build-in mathematics software. They noted the same dynamics are still true today (Waits & Demana, 2000). However, there were controversy associated with graphing calculators in teaching mathematics. The finding from the case studies, which were discussed in this research, suggest that most calculus instructors had pessimism using graphing calculators in achieving aims of the courses. Because of current graphing calculators' abilities which are able to cover almost everything that students should learn in Calculus 1 and 2, the instructors viewed application of the tool as unhelpful. For example, Dr. F4 stated as follows:

> I do not allow them to use calculators because I think it doesn't help them to learn. All they are doing is just calculating what their calculator does. And now days, a calculator can do all of Cal 1 easily. And, so they can just set and punch buttons and never understand a single thing and get an A in the class if they are good at calculators. And, but I don't think that helps to learn so I prohibit.

In order to help students to grasp the presented contents, all of the calculus instructors banned using graphing calculators during lectures and tests. Although, they hoped and stated them to not utilize it for homework assignments, it was not possible to check how they did those. However, unlike the participating instructors' beliefs that applying graphing calculators disturb students' conceptual understanding, Graham and Thomas (2000) reported its benefits. They argued that the graphic calculators is an instrument for achieving a significant improvement in student understanding of algebra (e.g., Küchemann, 1981; Wagner, Rachlin and Jensen, 1984). Even though the study was for secondary school students, it is adaptable since many mathematics educators found one source of calculus students' learning difficulties from their poor prior knowledge. They believed the low-achieving students struggled with not even calculus materials but a way before subjects such as algebra and trigonometry. However, in the paper, Graham and Thomas (2000) claimed that to led conceptual improvement of students in learning mathematics, teachers should feel comfortable with using them in their own classroom. Otherwise, they are of little practical value. Consistent with the argument, evidence in Chapter 5 showed that the calculus instructors unfamiliarity with all kind of technology. While they prohibited using graphing calculators, the instructors answered in the affirmative toward other types of technology such as Mathematica program. But they rarely applied the technology and addressed insufficient management skill as one reason not using it. Since they had not taught with the method, the instructors are required to strive to learn. Therefore, it was less likely to be practiced in a classroom despite of their preferences. For example, Dr. F1 stated as follows:

> I would like to bring some of them into classroom. I am going to have to know a little bit more about it myself before I can do that so… But I definitely think that there are something it will be really great for them to see on the computer because they can see some of relationships there where I can't draw it and then they can't draw it but they can really see on the computer.

Regarding mathematics educators' confliction on using technology, Waits and Demana (2000) reported that it is human nature to not want to change. Moreover, they argued that teachers teach the way they learned. Similarly, Ralston (1999) reported that paper and pencil arithmetic and symbolic algebraic manipulative procedures were critical and very important in the past because they were the only procedures available to "compute and solve." Furthermore, he argued that if instructors examine why the traditional method exist, then it will become clear that many techniques we teach exist only because they were the only method possible in the past. Therefore, we must explain the confusion between applying mathematics algorithms and doing real mathematics (Ralston, 1999). The research and finding described in Chapter 5 are consistent with the recent result of the Characteristics of Successful Programs in College Calculus (CSPCC) project. It shows that support for instructors such as having faculty development center were common factor that have emerged from the successful institutions (Melhuish *et al.* 2014; Rasmussen *et al.,* 2014). They found that along with the influence of GTA training program, professional programs for mathematicians led their successful calculus programs. Their finding also support the source of pedagogical knowledge that the calculus instructors presented. All of them reported that they gained valuable information through both formal and informal conversation with their colleagues. Moreover, Dr. F1 who was attending a professional program during the semester expressed its helpfulness. Thus, the necessity of the program for teachers to contribute to students' effective learning are confirmed again through examining the calculus instructors.

6.2.4 Difficulties in Helping the Low-Achieving Students

It was noted that the calculus instructors wanted to help students, especially the low-achieving ones, with their best. Since the calculus instructors recognized that teaching undergraduate is one of their duties as employees and related to their future career, they tried to provide better quality service. In addition, they evaluated the weaker students are requiring more assistants to fill their insufficient mathematical knowledge. On the other hand, the high-achieving students were considered having certain level of capability to understand calculus materials without further efforts from instructors. For example, Dr. F3 expressed "They don't need special things for calculus. … In calculus if you are smart and good, okay don't even come to class. Save your time." Because of the different amounts of helping requirement depending on students' level of mathematical knowledge, the instructors were more likely to support the low-achieving students. Although they concentrated on the group, all of the participating instructors argued that two prior conditions which are students' learning desire and appropriate course enrollment. Improving students' understanding level, the teachers believe, is impossible without learners' effort. However, above all, the instructors evaluated being a right class is more important in terms of achievement. Dr. F1 stated that many students are enthusiastic enrolling into a higher course for their fast degree completion. As a result, the instructors often encountered with students who are not ready for the level. Since mathematics is a subject which strongly requires learners' prior knowledge, there are certain restrictions in helping the unprepared students as an instructor. Therefore, the calculus instructors expressed importance of the placement test to reduce unsatisfied outcomes. For example, Dr. F1 stated as follows:

> It is really important when they come in and get that place in the correct courses. So… thankfully OU has the testing procedures and we try to do the best we can to get them into the course they need but like anything it is not perfect. So sometimes we do have some students in calculus courses but not quite ready for it.

In order to avoid the failure of some students, the instructors gently suggested other options such as dropping or withdrawing before the due date. Their opinion on the reinforced placement test is consistent with the one characteristic that CSSCP found at five doctoral degree granting institutions (Rasmussen *et al.*, 2014). They found that the universities which are identified as having successful calculus programs tended to have more than one way to determine student readiness for calculus such as placement exams, gateway tests for students with lower algebra skills.

In addition, according to the evidence in Chapter 5, the calculus instructors believed that studying mathematics is completed when students actually do their homework by themselves. Besides the readiness to protect the waste of time and expense, the instructors believed that students should be aware of the fact that they have to invest certain time and actively engage in their calculus learning to fill their deficient knowledge parts. For instance, one of Dr. F3's teaching philosophy was revealed in a statement "Things are not going to come to them. They have to come." Since he believed that it depends on students whether they learn, they must do their best to achieve aims and to get support from their teachers. Besides the basic learning attitude required in mathematics education, unlike K-12 students, the instructors viewed the calculus students as mature adults who have responsibility on their behaviors. Consequently, even though they chose not studying the enrolled course, the instructors respected their decision. For example, Dr. F4 stated as follows:

> Occasionally I tell some students you should come …talk to me in my office hours. But in general, they are adults if they choose not to come, there are lots of resources available for them. And I tell them everyone in the class repeatedly you should be coming in my office hours you should come to your GA's office hours you should go to the Math Center. So I say as many as times on D2L… and beyond that they choose not to… it is the same as attending class. If they choose not to attend… okay!

Most calculus instructors expressed their limitations as supporters in leading the low-achieving students in the course to success. That is why the instructors only encouraged students by informing them about available resources such as operating office hours. On the other hand, Baiocco and DeWaters (1998) suggested reasons of passive attitude of the mathematics faculty members in helping students' learning. Such as the finding described in Chapter 5, despite variety pedagogical representation methods based on research, the instructors rarely adapted the ways. In the paper, the researchers defined it as their indifference to classroom innovation and found the following as likely sources: minimal faculty training in pedagogy, minimal or ineffective institutional faculty development centers, minimal tangible support for instructional innovation, difficulty in assessing teacher effectiveness, and minimal institutional rewards for teaching effectiveness in decisions of contract renewal, tenure, promotion, and raises (Baiocco & DeWaters, 1998). Moreover, not like teaching school, research based universities tended to view instructional innovation as a wise expenditure of their professional time (Marsh & Hattie, 2002). In order to examine faculty members' barriers to instructional innovation in STEM fields, Wright and Sunal (2004) identified nine obstacles to achieving and sustaining learner-centered instruction in college science classrooms as follows:

1. Management within institution of higher learning may not support innovation in terms of funding summer grants, allowing reassigned time for instructional innovation, and so forth.
2. Coordination across departments and colleges may not be adequate. In other words, turf wars and other cooperation failures may erupt.
3. The leaders of committees overseeing innovation may not be well respected throughout the institution and thus may be ineffective.
4. Faculty may not be brought on board as willing participants through rewards systems, tangible supports, and so forth.
5. Students may not be willing to accept innovations or may not be supported in doing so.
6. The curriculum may not be modified sufficiently to support learner-centered instruction.
7. Faculty instruction may not change enough or be sustained through ongoing workshops, summer programs, and the like.
8. Sufficient budget allocations may not be adequate to support training, technology, and assessment.
9. Changes may not meet state and national accreditation and certification standards.

Similar results about the potential obstacles directly impacting faculty were proposed by the NRC (1999) and Wyckoff (2001). These findings are consistent with the ones of the recent research project, the Characteristics of Successful Programs in College Calculus (CSPCC). Among common themes of the universities which are identified as having successful calculus programs, supporting for instructors was included such as funding for conferences and operating faculty workshops, organizations, and development center (Melhuish *et al.*, 2014; Rasmussen *et al.* 2014). Furthermore, Walczyk, Ramsey, and Zha (2007) sought to help rectify the suggested institutional barriers to innovate in STEM classrooms by uncovering perceived obstacles according to the faculty of a university. Then they describe as follows:

> … faculty had access to many supports for instructional innovation and wished to retain them, but often infrequently used them. It will be difficult for management to justify retaining existing supports or adding new ones when those in place are not used. … There were seemingly minimal rewards in terms of tenure, promotions, or raises for such innovation from management (p.97).

Consistent with the findings of CSSCP (2014), the researchers suggest that faculty who had formal training in pedagogy in graduate school were more likely to have consulted external sources of instructional innovation and to have consulted by others.

According to the numerous studies, unsatisfactory support of the university could be a reason of the participants' passive attitude of suggested instructional practices besides their orientations toward course and students. It was also supported by the fact that the research site university is a doctoral degree awarding institution thus the faculty members are required to focus on their research as mathematicians, especially during their tenure track period.

6.2.5 Efforts to Achieve Mathematical Learning Objectives

According to the ROG Theoretical Framework developed by Schoenfeld (2010), a teacher's resources and orientations toward compositions of the classroom significantly affects their in-the-moment decision making. Therefore, inquiry regarding those factors are more likely to assist on understanding about the calculus instructors' instructional practices. The evidences of Chapter 5 support his claim regarding the effects of the calculus instructors' resources and orientations. Moreover, it was noted that these two factors were related to the goals of the instructors which were also core elements having ripple effect when they operated a calculus classroom. The article that follows by Torner, Rolka, Rosken and Sriraman (2010) provides us with a richly-textured, detailed characterization of goals and orientations, including a discussion of how goal and orientation "bundles" are structured.

For most mathematics educators, one of the ultimate goals of teaching would be students' learning through courses. But, how far do the instructors think they can reach the aim along with being realistic? The participants knew not all of students are able to learn presented materials. Moreover, one of the orientations described in Chapter 5 was that some students will not use or see that much mathematics after completing the calculus courses. Based on the view toward students, the calculus instructors modified their goal through teaching. Subsequently, the finding showed that the teachers wanted them to achieve to the extent it is necessary for their degree. In other word, the goal of the instructors was consistent with the one of students. For example, Dr. F2 stated as follows:

> It would be very nice if she can survive it. She will probably never use that much mathematics because no matter what I do I don't think I can make it very good. But she may survive the class in a sense of getting a "C". At least that's my hope for her.

In reality, it was impossible for instructors to make students to learn everything they teach. However, they believed they were able to assist students to a required place and considered it as their responsibility as teachers. Accordingly, the calculus instructors hoped them to learn materials they were supposed to learn through the course to reach the desired status.

The origin of this research evolved from the question: How do calculus instructors teach students having different mathematical knowledge and aims through courses? Since there is a wide range of capability even in a small-enrollment course, it is considered a teacher's difficulty teaching a bunch of students within given resources such as lecture time. In a calculus classroom, there are students who will become mathematicians and the ones who will never use the materials after the course completion. The participants in this study recognized this issue and referred it as one of the difficulties in teaching calculus. However, the instructors' approaches were clearly revealed through one of their pedagogical goals emphasizing on the learning for the majority of students. Moreover, they referred to students with middle level of understanding as "majority". It was noted that they evaluated that there are a few high-achieving mathematics major students in a class that they more likely to learn presented subjects and solve their own difficulties by themselves. In addition, even if they have not learned in-depth level of mathematics in calculus courses, the instructor believed mathematics majors would succeed through other mathematics courses. In the meantime, to motivate their academic interest, the instructors sometimes briefly introduced certain topics such as ε-δ limit definition in Calculus 1. They did not aim for everyone's understanding but wanted some students to be exposed to advanced mathematics for their future courses. For example, Dr. F1 stated as follows:

> I do show them and tell them "It [ε-δ limit definition] is a really important concept and it is important to understand." But I usually don't ask it on the test questions or if I do it is very basic just see that they understood just basic understanding of it. So it is not something I spend a lot of time on. But I would like to expose them to it so that they are kinds of getting a little tastes. You know mathematicians they are going to see that in analysis so it is important for them to at least seen it before maybe have a little bit of understanding of it.

Although, the instructors spend some times for mathematics major or high-achieving students, most of the lectures targeted middle range of students. It was because of the calculus instructors' orientations that they account for the majority of a classroom and require more helps from teachers. Of course, the instructors recognized the low-achieving students also needed support but no matter how hard they tried it was an inescapable fact that certain number of students would drop or fail the courses. Moreover, it was related to the noted orientation which was improvement of the low-achieving students was impossible without their desire. Therefore, one of the calculus instructors' goal was mathematical knowledge progress of middle level of students. For example, Dr. F4 stated as follows:

> You know it is all you are serving a large population of students in the class and if you're heading the middle 80% most of the time then you're probably doing right. You can't get everybody all the time. So I try to move back and forth but most. That's sort of center what I think the student are at.

The decision is comprehensible when it is considering the effects of investment. On the other hand, it seems unfortunate for a minority of students especially in a large-enrollment course. Higher education scholars Slaughter and Rhoades (2014) relate this issue with academic capitalism. They state that "as colleges and universities become more entrepreneurial in a post-industrial economy, they focus on knowledge less as a public good than as a commodity to be capitalized on in profit-oriented activities (p.3)." For that reason, the calculus instructors' goal to maximize understanding for the majority of students, suggests deliberation of university level, since the disadvantage of some portions of students was hard to be reduced by an instructor's efforts. Furthermore, it requires research on pedagogical methods and change of schemes to decrease the difficulties.

6.3 The Effects of Knowing Calculus Instructors' ROGs in Teaching the Low-Achieving Students

The evidence presented in Chapter 5 suggests that the calculus instructors seem to make their instructional decisions based on their ROGs. The findings provide validation of Schoenfeld's framework describing the relationship of resources, orientations, and goals to in decision-making to analyze undergraduate mathematics teaching. While examining instructors' ROGs related to calculus teaching especially for the low-achieving students, the next research question was investigated:

Does knowing teachers' ROGs result in helping the low-achieving students?

As Dubinsky (1994, p. 114) states:

> Many people appear to believe that effective teaching is actually quite easy to achieve, if only you care enough to give it a certain amount of attention and energy. The suggestions offered by proponents of this view are, in my opinion, little more than common sense, well understood by a very high percentage of members of our profession. The analysis ignores the fact that a really large number of mathematicians are conscientious and dedicated in their teaching. Very many of us have used these suggestions in our teaching and have been doing so for many years. The important point is that, in spite of all this, our students are still not learning mathematics. For me, the inescapable conclusion is that much more is needed than common sense suggestions gleaned informally

> from experience. I am convinced that we need to reconsider and revise our pedagogy – and we need to do it in conjunction with research into what it means for a student to learn a mathematical concept.

While the research mathematicians in this study were committed in teaching, it was still considered as one of their difficulties in evaluating which methods are effective and appropriate for them and their students. The ongoing problem is also indicated in the fact that significantly many students are struggling with mathematics learning and changing their majors from STEM to others not requiring strong mathematical knowledge (Currie *et al.*, 2009; Ma & Johnson, 2008; the Higher Education Research Institute, 2010; Seymour, 2006; Bressoud *et al.,* 2012; Rasmussen, 2012). Therefore, as Dubinsky (1994) suggests we need to reconsider and revise our pedagogy in teaching undergraduate based on research. As discussed in Chapter 5, the calculus instructors gained and applied suggestions in teaching through their teaching and learning experiences and informal conversations with colleagues. However, since most mathematicians completed their mathematics courses successfully, it seemed to act as limitation in assisting the low-achieving students. Although a method that they used was effective for them to improve mathematical knowledge at times, it was not as effective for their low-achieving students. For example, Dr. F1 stated as follows:

> I read all my textbooks and I did all the odd number problems that at end of the chapters because that was what helped me. To me test were easy not because they were easy tests but because I prepared. I just thought that is what we are supposed to do. You are supposed to read the text. What else did I buy the book? Not just look at the problems that I had to hand in.

The instructor expressed that through textbook-centered learning strategy she was able to accomplish her mathematics understanding. Based on her experience, she applied the same method for her students and noticed its ineffectiveness. Even though the instructor encouraged them to read and practice problems from their textbook, students' test results and teaching evaluations convinced her they do not follow. Thus, the finding alarmed ineptness of adopting pedagogical methods through personal experiences. Similarly, the instructors' teaching experiences significantly influence their entire teaching approaches including their resources, orientations, and goals as one of pedagogical resources. Through their accumulated experiences, the calculus instructors acquired new knowledge and adjusted established beliefs. For example, Dr. F3 showed one of his main goals of calculus teaching was students' conceptual understanding and actually that was the common goal of the participants in this study. However, he realized many students still faced difficulties. Moreover, it was difficult for him to check if students understood the contents that he wanted them to learn. At the end, Dr. F3 provided test problems less related to conceptual understanding but trickier ones to check whether students could handle them. The finding informed mathematicians' conflictions based on their teaching experiences. Even though different teaching and evaluating methods based on the properties of subjects, it was hard for them to assure their efficiency. Consistent with Dubinsky's statement requiring communication opportunities through systematic forms, the mathematicians' conflictions showed another limitation of unharmonious information interchanges.

On the other hand, a little resources of the calculus instructors were available through professional development programs. It is revealed that support for instructors allowing them to acquire information via diverse routes are one of the factors of the universities identified as having successful calculus programs (Melhuish *et al.,* 2014, Rasmussen *et al.*, 2014) which is consistent with Dubinsky's view on necessity of research on how we teach mathematics. The researchers argue that instructors are more likely to help students' learning throughout structured and formal materials for study. At the same time, Dubinsky (1994, p.119) worries that major pedagogical changes are more honored in the conference report than in the classrooms:

> …the jury will still be out for a long time on deciding about their long term value. But it would be a mistake to end this note on such a negative tone. … One should not always concentrate on far there is to go, but sometimes it is helpful to look back and see how far on has come. In the case of pedagogical change in undergraduate mathematics education, it is possible to hope that our dismay at the daunting length of the former, may be overcome by the awe inspired by the substance of the latter.

In my view, discussing and knowing instructors' ROGs which impact on their instructional practices will be contributed to the substantial pedagogical change in helping the low-achieving students' mathematics learning. According to Nardi and Iannone (2004), there are benefits of joint research between mathematicians and mathematics educators and one of them is the opportunity for in-depth study of teaching and pedagogical insights leading to awareness of practice. Since instructors' cognitions and orientations are complicated and vary widely, it is still difficult to improve instruction systematically although a number of theories have attempted to characterize various aspects of them (for example, English, 2008; Lester 2007; Wood, 2008). Therefore Goldin (2010) claims that we should elucidate and address the complexity of classroom teaching instead of limiting ourselves to as simplified view. Through examining instructors' ROGs in teaching calculus and their own effective teaching methods based on experiences provided valuable information. For example, the evidence presented in Chapter 5 suggested calculus instructors' beliefs regarding the low-achieving students' learning strategies. Dr. F1 informed as the following:

> A lot of students do just basic and then when it comes to test time a day or two before the test they can't go back over at all and they don't have time to do that and really know the materials

Based on her recognition, the instructor tried to prevent students' inappropriate learning attitudes and shared her methods with the researcher of this study. That is, knowing ROGs of people who teach calculus gave education researchers the opportunity to collect their own built effective teaching approaches. Consistent with one of roles of qualitative research, providing foundations of qualitative tests for its generalization, the results of inquiry about mathematicians' instructional practices created by teaching experiences lay the groundwork for future research. Furthermore, it plays a role in the curriculum development project.

In mathematics education, theory building and empirical studies should support each other even in large-scale assessment studies. It is also pointed out by Richards (1979) that no data analysis is theory-free and the converse is true: No theorizing is data-free. Accordingly, as part of this thesis, a framework based on Schoenfeld's teaching-in-context framework was constructed. Although there has been limited data to analyze, the framework guided in interpreting instructors pedagogical thoughts. Moreover, the framework was a valuable tool in examining the ways in which instructors teach calculus by proving evidence of instructors' foundation factors on their approaches. Consistent with Kieran's argument (1998), the reporting of research results is not simply the enumeration of the observed empirical facts but also the description of a model that has been developed to explain what has been identified. Thus the theoretical framework illustrating calculus instructors' ROGs in teaching low-achieving students acted as valuable foundation and tool in examining their thought processes.

6.4 Summary

The discussion of the main results of this research highlighted instructors' equipped beliefs systems and applications on calculus teaching. The extensive evidence revealed that instructors had constructed their ROGs based on teaching and learning experiences. However, evidence showed conflictions of calculus instructors as mathematicians and teachers and their impact on instructional practices. It is suggested that reconsideration and revision of our pedagogy in teaching calculus based on research would be beneficial. Moreover, necessity of appropriate support for instructors was exposed consistent with the findings of CSPSS (Melhuish *et al.,* 2014, Rasmussen *et al.*, 2014). Thus, illustrating calculus instructors' ROGs in teaching can enrich effective pedagogical methods in helping the low-achieving students' learning.

Chapter 7: Conclusion

The aim of this research was to examine calculus instructors' ROGs and finding ways to help the low-achieving calculus students to succeed in their courses by knowing this. The theoretical framework described in Chapter 3 guided the researcher to pursue an investigation on calculus instructors' ROGs while teaching calculus. In particular, this study considered how instructors' curriculum and content knowledge, orientations toward calculus and their students, and goals in teaching mathematics affect their instructional practices, especially in regards to the low-achieving students. Based on the methodology a number of case studies were carried out by using the semi-structured interviews (see Appendix A).

The findings provided that the ways calculus instructors teach the low-achieving students differ depending on their expectations and more importantly teaching experiences. All instructors believed that if students, even with a little mathematical background, really want to improve their mathematical knowledge and invest ample time to calculus courses, they can succeed in the courses and the instructors are willing to help them.

Moreover, the results from this study showed that the calculus instructors posed their own effective teaching strategies for the low-achieving students' understanding. The approaches were based on their recognitions of students' learning difficulties mostly through teaching experiences. It was also noticed that their conflictions as instructors were primarily responsible in teaching undergraduate students. In addition, the findings showed that the calculus instructors' difficulties were created by environmental factors and those limitations from diverse reasons influenced their teaching.

Over all, through understanding instructors' ROGs in teaching calculus, necessity of appropriate support for instructors including GTAs was indicated to lead the low-achieving students' success in calculus courses. Although, most people teach the way they have learned or by experiences, more research would be beneficial. On the other hand, it is also important to assist calculus instructors to apply their own effective teaching methods in helping students' learning. This is consistent with other joint research between mathematicians and mathematics educators (Paterson *et al*., 2011; Hannah *et al*., 2011). They suggest that more mathematicians and mathematics educators forming community of practice (COP) would be one way of resolving some of current undergraduate teaching difficulties. Paterson *et al.* (2011) note that for some instructors a tension arises in their lecture between the desire to be true to the mathematics and the ways of mathematicians and the need to be a teacher who passes on the ideas. In addition, since good teaching is not innate but can be learned, and to do so the key for instructors is to encourage the development of the skills of reflective practices (Hannah *et al*., 2011). Thus, to retain STEM major students, more efforts and investigations on calculus courses are required from universities, instructors, and undergraduate mathematics researchers.

This study explored calculus instructors' resources, orientations, and goals in teaching the low-achieving students and how they construct their teaching methods based on their ROGs. It was not the intention of this study to generalize these findings for any other university, however, the results indicate strong reasons for proposing further investigations in helping the low-achieving students in a calculus course. Based on the findings of this research, the following evaluations of the research and recommendations for possible further research are presented.

A lecture is conducted through activities between instructors and students. Although they share the same space and time, interpretations about circumstances differ by own aspects. Furthermore, intention of instructors can be received differently by students, and vice versa. From that point of view, since only the instructors' aspects were inquired in this study, it is recommended to have more research on students and possibly their ROGs. As shown in the findings, most instructional practices that the calculus instructors applied were determined by their ROGs. Therefore, comparing what they believed as effective pedagogy methods with students' ROGs would contribute to build successful calculus programs. Explorations of students who study calculus courses and show poor performances are suggested for further research. In addition, effective calculus teaching methods applied to both low-achieving students and others would have been a main and continuing focus of future study, since they are ultimate target of undergraduate mathematics education. The researcher also suggests that building research based models and frameworks will lead in richer studies of calculus instructors and their students.

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Appendix A

Interview Questions

1. What do you expect students in your calculus class to know from their previous math courses?

2. In your opinion, what are students' reasons and goals for taking calculus courses in your opinion?

3. What do you think about the current calculus curriculum and the course contents in this university?

4. What would be appropriate calculus subjects to be covered during one semester?

5. What should be the appropriate level of difficulty in a calculus curriculum?

6. What do you expect students to learn from your calculus course?

7. What do you think about investing class time to review and repeat problems to help students who do not follow the lecture easily?

8. What is the level of mathematical understanding of your class? Explain why you decided the lecture level.

9. How do you evaluate yourself as an instructor in terms of dealing with low achieving students?

10. Is it possible to improve students' mathematical knowledge with a calculus course when they enter the course with low mathematical knowledge? If yes, how?

11. How much effort do you think you are investing into low achieving students?

12. Have you ever used technology to teach a calculus course? If yes, what kinds of technology have you used? And, would you please describe your experiences?

13. Do you think using technology is helpful in teaching calculus?