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Accounting for Positive Outliers

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by

Emily Shore Horton Pressman

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ABSTRACT OF THE DISSERTATION

Accounting for Positive Outliers

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Professor Louis M. Gomez, Chair

This dissertation works builds rich understanding of why some community college developmental mathematics instructors perform better than their peers. We take up this work in Statway, a community college developmental mathematics course. To identify positive outer instructors, we use Hierarchical Linear Modeling and Empirical Bayes estimation to find instructors whose results are at least one standard deviation above the mean in math achievement with underprepared students. To build theoretical understanding of what accounts for positive deviance, we explore differences in instructor knowledge, with a particular focus on mathematical knowledge for teaching. Findings from our study of eleven Statway instructors (six positive outliers and five non-positive outliers) suggest that heightened empathy and heightened pedagogical agility in anticipating and responding to student challenges may be two key factors accounting for positive outliers' successful outcomes. Our work offers several important contributions: it builds on our knowledge of mathematical knowledge for teaching by highlighting the role of instructor empathy and agility in deploying instructional knowledge; it highlights the importance of mathematical knowledge for teaching in the community college

setting, a context not yet explored in the mathematical knowledge for teaching literature; it contributes rich understanding of effective instruction in community college developmental mathematics classrooms, especially in regards to instructional empathy and agility; and it offers new ways of studying variation in educational settings, as we examine the granular nature of positive outliers, focusing on the how and the why of what they do to understand the nature of their deviance.

The dissertation of Emily Shore Horton Pressman is approved.

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CHAPTER 1: INTRODUCTION

Why Study Instructional Variation?

The study of positive outliers offers the potential to improve seemingly intractable problems where other approaches have failed (LeMahieu, Nordstrum and Gale, 2017; Pascale, Pascale, Sternin and Sternin, 2010; Singhal, 2010). Positive outliers, or positive deviants, are those who perform better than their peers given the same resources and challenges (Pascale, Pascale, Sternin and Sternin, 2010). Traditional outlier studies make sense of deviants by understanding practice: what do these people *do* differently? These studies seek to identify positive outliers and their uncommon, but successful, practices with the aim of spreading practice and replicating success (Dura & Singhal, 2009; Pascale, Pascale, Sternin and Sternin, 2010). In this proposed work, we argue that in education and across many fields, the study of positive outliers is limited (Herington & van de Fliert, 2018). While educational scholars have sought to learn about, and replicate, surface features of outliers' practice for decades (e.g. Anderson and Pellicer, 1998; Darling-Hammond, 2006; Edmonds, 1979; Pascale, Pascale, Sternin and Sternin, 2010; Phi Delta Kappa, 1980; Reeves, 2003; Stringfield, 1995; Weber, 1971; Wilder, 1977), few studies in education to-date have tried to understand outliers in detail, deeply examining what outliers do and know, and believe, to understand why positive outliers deviate from the norm. In this work, we explore individual instructors as the unit of analysis, examining the granular nature of positive outliers, focusing on the how and the why of what they do to understand the nature of their deviance.

One reason to take a more detailed approach to understanding outliers is that, sometimes, practice is not enough to see what makes outliers different. In some cases, practices are external and self-evident, but in other cases, building theoretical understanding of the conditions underlying deviant outcomes can help us see what makes outliers different. To illustrate this, we draw on an example from *The Dreamkeepers: Successful Teachers of African American Children* (Ladson-Billings, 1994) by Gloria Ladson-Billings. *Dreamkeepers* describes Ladson-Billings three-year study on excellent teachers of African American students. When the study began, Ladson-Billings expected to find some observable set of practical strategies across teachers, such as using specific discipline practices or literacy strategies that could easily be replicated elsewhere and was frustrated when she could not. Expanding her focus, she sought to explore the ideological and philosophical underpinnings of teachers' practice to understand why they perform better than others. To this end, she explored how these exceptional teachers see themselves, others, and their profession. By asking these kinds of questions, Ladson-Billings found points of similarities that explained their deviance from the norm: they *valued* community, *perceived* their highest purpose as teaching the whole child (rather than delivering curriculum), and *believed* in the importance of nurturing deep relationships with students. Because these beliefs looked different across teachers when manifested in practice, they could not easily be observed; but, by taking a look at ideological and philosophical beliefs underpinning practice, she was able to see how individual instructor differences drive practice and account for their exceptional student outcomes.

This work resulted in Ladson-Billings' theory of culturally relevant pedagogy, which has remained a dominant approach to multicultural education ever since the publication of *Dreamkeepers* (Ladson-Billings, 1994). In addition to having wide-scale implications for teacher education, Ladson-Billings' work provides a framework for others to see the practices of exceptional instructors of African American students. Building on Ladson-Billings' work, Howard (2001) sought to give descriptive accounts of how culturally relevant pedagogy is actualized in the classroom, studying four exceptional instructors of African American students.

Using Ladson-Billings' culturally relevant pedagogy as a lens for examining instructional practices, in addition to grounded theory, Howard describes specific practices related to culturally relevant pedagogy, including holistic instruction, culturally consistent communication, and skill-building practices. In cases where practice is not external and self-evident, we need ways of seeing the underlying ideas, beliefs, and characteristics that drive practice, as Ladson-Billings and Howard did, to explain differences in outcomes.

Overview of Study

The work presented here is organized around the idea that practice matters, and that sometimes, to deeply understand practice, we must conduct a more detailed outlier study to build theoretical understanding of deviance (Schoenberger, Heckert, and Heckert, 2015; Wolfzorn et al.; 2006) rather than simply looking at surface features of practice. In this dissertation work, we conduct a detailed outlier study of instructors who teach Statway, a community college developmental mathematics course, exploring how instructor individual differences account for positive deviance.

While organizational factors matter quite a lot, individual characteristics of instructors, in our case, have substantial influence on student achievement over and above what we understand of organizational-level factors (Gallimore, et al., 2009; McDougall et al., 2007; Reeves, 2003; Snow-Gerono, 2005; Thoonen et al., 2011; Yu, Leithwood, and Jantzi, 2002). Preliminary analysis of instructors in our dataset, using Hierarchical Linear Modeling and Likelihood Ratio tests, show that faculty have double the impact on student achievement in Statway than the college attended, but less so than the effects of students themselves. Additionally, we found that several colleges in our study had both positive and negative outlier instructors. We will discuss these analyses in more detail later in this dissertation.

The purposes of this research are to (1) identify positive outlier faculty members; and (2) build theoretical understanding of how individual differences in instructor knowledge drive practice, and account for differences in outcomes. To identify positive outliers, we conduct a quantitative analysis of Statway data, accounting for the nested structure of the data using Hierarchical Linear Modeling, and adding stability to varying, and sometimes small sample sizes, using Empirical Bayes estimation to find instructors whose results are at least one standard deviation above the mean in math achievement with underprepared students. Then, we explore how instructor individual differences in instructor knowledge account for differences between the positive outlier instructors and non-positive outlier instructors. An underlying assumption of this work is that instructor knowledge shapes practice (Ball, Thames, and Phelps, 2008). Thus, we posit that exploring differences in knowledge may have tremendous explanatory power to help us see the nature of mathematics practice, to help us better understand how individual differences in instructor knowledge account for positive deviance.

Our work offers several important contributions to the field. Our study builds on our knowledge of mathematical knowledge for teaching by highlighting the role of instructor empathy and agility in deploying instructional knowledge; it highlights the importance of mathematical knowledge for teaching in the community college setting, a context not yet explored in the mathematical knowledge for teaching literature; it contributes rich understanding of effective instruction in community college developmental mathematics classrooms, especially in regards to instructional empathy and agility; it offers new ways of studying variation in educational settings, as we examine the granular nature of positive outliers, focusing on the how and the why of what they do to understand the nature of their deviance. In what follows, we provide a review of literature on outlier studies in education, discuss the landscape of community college developmental mathematics, in general, and Statway in particular, and describe, in more depth, how instructor knowledge shapes practice, highlighting why we believe this is an important analytic lens for exploring individual differences.

CHAPTER 2: LITERATURE REVIEW

Outlier Studies in Education

Why Study Positive Outliers?

The study of positive outliers offers the potential to improve seemingly intractable problems where other approaches have failed. Positive outliers help us understand the nature of variation in performance, or the naturally occurring condition of things being different from each other (e.g. student to student outcomes; changing student outcomes over time). However, traditionally, education research attends to variation in outcomes narrowly, focusing primarily on averages within a distribution, asking questions centered on average performers, or those within one standard deviation of the mean (see orange section in *Figure 2.1)* while ignoring the smaller percentages that fall to either extreme (see red and yellow section *Figure 2.1*). This kind of work that focuses on averages is useful because it allows us to quickly assess performance, and determine, broadly, what is and is not working, so that we may make decisions about how to improve.

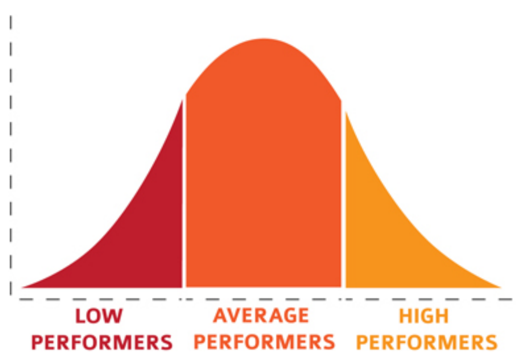

Figure 2.1: The Bell Curve

While we recognize that averages are useful, we argue, in this work, that studying the nature of deviations from the norm produce important, but often overlooked, knowledge about what is, and is not, working. In our study, we seek to examine high performers, those who are one standard deviation above the mean (highlighted in yellow in *Figure 2.1* above). More specifically, we must probe the *conditions* underlying deviations from the norm to better understand how to improve quality of performance overall (e.g. Anderson and Pellicer, 1998; Darling-Hammond, 2006; Edmonds, 1979; Pascale, Pascale, Sternin and Sternin, 2010; Phi Delta Kappa, 1980; Reeves, 2003; Stringfield, 1995; Weber, 1971; Wilder, 1977). Rather than simply asking questions about broad data, to see the whole picture, we must ask more granular questions that help us see the conditions producing varying outcomes: *What are sources of variation? Why do some perform better than others? Why did something go wrong? How can we repeat this success?*

In this work, we posit that studying positive outliers, those who deviate positively from the norm, offers an important, asset-based lens to study variation. Understanding positive outliers helps us see what is working, for whom, and under what conditions (Bryk, Gomez, Grunow and LeMahieu, 2015). The contributions of this kind of knowledge are twofold. First, from a practical perspective, this knowledge can be used to identify and spread successful strategies and behaviors (Bryk, Gomez, Grunow and LeMahieu, 2015; Deming and Edwards, 1982; Langley et al., 2009; Shewhart, 1931). Second, from a theoretical perspective, it has great potential to contribute knowledge about the dynamics which undergird the variability we see (Herinton and van de Fliert, 2018). Together, this kind of knowledge helps us identify the facilitators and barriers to quality performance so that we may effectively respond and improve overall outcomes (see *Figure 2.2* below) (Bryk, Gomez, Grunow and LeMahieu, 2015; Deming and Edwards, 1982; Langley et al., 2009; Shewhart, 1931).

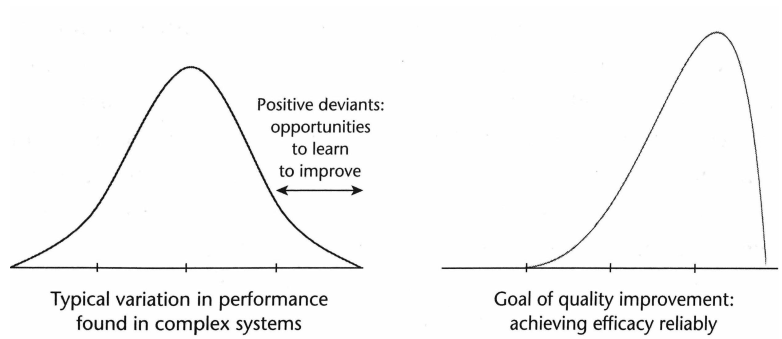

Figure 2.2: Typical Variation in Performance and Improved Variation in Performance (Bryk, Gomez, Grunow and LeMahieu, 2015)

While scholars have studied positive outliers for decades, we argue that in education and across many fields, the study of positive outliers has commonly taken a narrow lens (Herington & van de Fliert, 2017). For example, while educational scholars have sought to learn about, and replicate, surface features of outliers' practice for decades (e.g. Weber, 1971; Edmonds, 1979; Phi Delta Kappa, 1980; Reeves, 2003; Wilder, 1977; Anderson, 1992; Stringfield, 1993; Darling-Hammond, 2006; Pascale, Pascale, Sternin and Sternin, 2010), few studies in education to-date have tried to understand outliers in detail, deeply examining what outliers do to understand why positive outliers deviate from the norm. Yet, sometimes, practice is not readily observable; and in these cases, we must see the individual differences that drive practice to build theoretical understanding of deviance. In what follows, we provide an overview of practice-oriented outlier studies in education, and argue that, sometimes, to understand why outliers deviate from the norm, we must take a *deeper* look to understand what outliers do differently.

W*hat* do Outliers *do* Differently?

Most commonly in educational research, outlier studies ask questions of "what" rather than questions exploring "why" positive deviance occurs. This kind of work commonly seeks to identify positive outliers, or the people or entities who "beat the odds", those who perform better than their peers given similar resources and challenges. The aim, then is to identify the surface features of uncommon, successful practice, and spread unique practice elsewhere, with the hope of replicating success (Dura & Singhal, 2009; Pascale, Pascale, Sternin and Sternin, 2010).

There is long tradition of these kinds of outlier studies in educational research. Weber (1971), who is often credited as a founding father of the modern school effectiveness field, conducted one of the earliest positive outlier studies in education. He studied exemplary high schools in the U.S. serving high percentages of low-income students of color. Following Weber's work, a handful of school effectiveness researchers probed educational outliers in the 1970s, 1980s, and early 1990's, including Edmonds (1979) "Effective Schools for the Urban Poor", a response to the Coleman Report, which sought to identify characteristics of schools where low-income students were successful; Phi Delta Kappa's (1980) inquiry into why some schools are exemplary; Reeve's 90/90/90 schools, and research on exemplary school programs; Wilder's (1977) research on effective reading programs; Anderson and Pellicer's (1998) study on 'high-flying' programs; and Stringfield's (1995) work on 'promising programs'. In the mid-1990's, a number of government policies, reports, and funding initiatives called for research on "evidence-based practice", which led to a flurry of studies employing averages and effect sizes to determine "what works" (Biesta, 2007; Farnsworth and Solomon, 2013; Slavin, 2002), many of which are published in the What Works Clearinghouse[1].

One of the most widely cited of such studies is Doug Reeves "90/90/90 Schools" research. Reeves' (2005) 90/90/90 research examines U.S. schools where 90% of students are eligible for free and reduced lunch, 90% are of ethnic minority groups, and 90% met or exceeded high academic standards (Accountability in Action, Reeves, 2005). Reeves' work sought to identify a set of behaviors common among teachers and administrators in these unexpectedly successful schools to pinpoint "what works", with the goal of replication in other places. To do

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[1] https://ies.ed.gov/ncee/wwc/

this, Reeves controlled for attendance and mobility, which ultimately provided a positive bias for 90/90/90 schools. How, for example, would Reeve's "replicable" strategies work in a school with exceptionally high rates of student mobility? While Reeve's work, and others like it, are powerful, because they provide evidence that some strategy or behavior has potential in the realm of improvement, their narrow focus on "what works" limits transferability of findings. In other words, to foster uptake of exceptional practice in a new place, we need nuanced understanding of the different variables that drive specific action, and granular insight into how those variables interact. Only then, can we attend to the adaptive challenges of innovation to ensure fit within a local context (Heifetz and Laurie, 1997). While work like Reeves helps us see the readily observable, surface features of successful practice, they often lack the nuance to encourage spread of practice to other places.

Not surprisingly, traditional outlier studies, which seek to identify easily-observable features of successful practice, and try to spread solutions to other communities, have faced criticism in recent years for ignoring the need for fit between innovation and local culture (Heifetz and Laurie, 1997). The problem with this traditional approach is that education is a complex system of interrelated variables. We can make changes that make sense on their own (reduced class sizes, for example), but when introduced to the complex setting of a school, often fail to align with the needs of the local setting (e.g. the California Class Size Reduction program[2]). In response, in recent years, a handful of scholars in education have become interested in the Positive Deviance[3] approach put forth by Pascale, Pascale, Sternin, and Sternin

[2] https://www.cde.ca.gov/re/pr/csrk3.asp

[3] It should be noted, here, that, hitherto, we use positive outliers and positive deviants as synonyms in our discussion. However, here we use (capital P, capital D) Positive Deviance, to describe the specific approach to studying positive deviants developed by Pascale, Pascale, Sternin and Sternin.

(2010), healthcare practitioners, which attends to some of the adaptive challenges of implementation.

Like traditional positive outlier approaches, the Positive Deviance approach is concerned with identifying *what* deviants do. In contrast to traditional approaches, however, the Positive Deviance approach is designed to uncover deviants, and make their successful practices visible *within* the local community, rather than spread innovation elsewhere (Heifetz and Laurie, 1997). In this way, Positive Deviance attends to the adaptive challenges of implementation, where traditional approaches of simple scaling that is not adaptive often fail to take hold. The Positive Deviance approach, which consists of six systematic phases (see Table 2.1 below), also focuses largely on understanding and spreading successful practice.

Table 2.1: Phases of the Positive Deviance Method

Phase	Description
Phase 1	Define the problem and desired outcome.
Phase 2	Determine common practices.
Phase 3	Discover uncommon but successful behaviors and strategies through inquiry and observation.
Phase 4	Design an action learning initiative based on findings
Phase 5	Discerns (monitor) progress of the initiative by documenting and evaluating regular
Phase 6	Disseminates results through sharing, honoring, and amplifying success stories.

To illustrate what the Phases outlined in Table 2.1 look like in practice, we describe the work of Monique and Jerry Sternin, healthcare practitioners tasked with reducing malnutrition in Vietnam (Pascale, Pascale, Sternin, and Sternin, 2010). This work become codified into the systemized approach of Positive Deviance that is used today. Save the Children, a U.S.-based non-governmental organization, was invited by the government in Vietnam to develop a program to solve the wide-scale problem of child malnutrition in the country. The Sternins were invited to lead the charge, but, because of tense political conditions between the U.S. and Vietnam, were given only six months to demonstrate success. While the problem of malnutrition was previously tackled in Vietnam through programs providing supplemental food, once supplies ran out, malnutrition quickly returned. The Sternins faced the challenging task of finding a new kind of solution, one that would be sustainable in the long-term using only resources existing within the community.

Drawing on the positive deviance work of Zeitlin, Ghassemi & Mansour (1990), the first to use the term "positive deviant" to describe statistical outliers who perform better than the norm, the Sternins began investigating the behaviors related to food preparation of all the families in the community, as well as families of positive outlier children, who, despite having access to the same resources as others in the community, were of healthy weight. The Sternins identified three common practices among families with positive deviant children: 1) washing children's' hands often, especially after contact with something considered unclean; 2) supplementing food with sweet potato greens, smalls crabs, and shrimp, despite the local cultural belief that these foods are unhealthy for children; and 3) feeding children the same amount of food, but more frequently throughout the day (i.e. 4 meals instead of 2), thus increasing calorie absorption.

Once the uncommon but successful practices were identified, the group created a training program where interested villagers would practice PD behaviors at a neighbor's house for two weeks. During these training sessions, the families practiced collecting and cooking with sweet potato greens, shrimp, and crabs, and learned about the hand-washing practices of positive deviant families and the benefits of more frequent feeding habits. At the end of six months, 40% of participants were at a healthy weight, and an additional 20% had put on enough weight to move from severe malnutrition to moderate. After two years, 93% of more than 1,000 children participating in the program were at a healthy weight (Pascale, 2010). This method, developed and used by the Sternins in Vietnam, building off ideas developed by Zeitlin and colleagues, became codified into the classic positive deviance approach, consisting of the six systematic phases described in Table 2.1.

In the past five years, Pascale, Pascale, Sternin and Sternin's (2010) Positive Deviance approach has been taken up successfully, by a handful of researchers in education to address some of the field's seemingly intractable problems, including reducing dropout rates and increasing student graduation rates (Ayala, 2011; Dura & Singhal, 2009; Singhal, 2013), reducing absenteeism (Niederberger, 2011), attending to district-wide low student achievement (Richardson, 2004), and improving educational outcomes of specific groups of traditionally marginalized students, including students with learning disabilities (Kallman, 2012) and black males (Harper, 2012).

These studies are premised on the idea that in every community, there are people, despite having access to the same resources, who find better solutions to problems than their peers. Using this asset-based and community-driven approach, the studies above attend to the adaptive challenges of implementation by finding solutions which already exist within the communities. As a result, they are evidence of success in driving educational improvement, suggesting that the study of positive outliers in general, and the Positive Deviance approach, in particular, holds important implications for education reform, having been used effectively in K-12 contexts, and with adult learners, to tackle a variety of education's most complex problems. Yet, like other studies that focus on identifying *what* outliers do differently than their peers, it's difficult to generalize findings beyond the specific community of study.

To summarize, outlier work in education research commonly tries to understand the practices of outliers, as described in this section. Fewer studies in education to-date have tried to understand outliers in detail, exploring what accounts for positive outliers' deviance from the mean. In the next section, we describe, in more detail, applications of outlier research that have taken a more detailed approach to understanding what drives outlier success.

Why do Outliers Perform Differently?

Positive outlier research that seeks to explore questions of *why*, often make sense of outliers by exploring social phenomena underlying deviance or using existing social theories as an analytic lens (Herington & van de Fliert, 2018; Schoenberger, Heckert, and Heckert, 2015; Wolfzorn et al.; 2006). For example, some work has examined positive outliers through the lens of labeling theory (Schoenberger, Heckert, and Heckert, 2015), social bond theory (Wolfzorn, Heckert and Heckert, 2006), naturalization (Schoenberger, Heckert, and Heckert, 2012), and in education research specifically, culturally relevant pedagogy (Howard, 2001), to name a few. Why go beyond surface-level features of practice, as these studies have done, to build theoretical understanding of deviance?

One reason to take a more detailed approach to understanding outliers is that, sometimes, practice alone does not hold enough explanatory power to see what makes outliers different as individuals. In these cases, building theoretical understanding of the conditions underlying deviant outcomes can help us understand deeply what outliers are doing and give some insight into why, as exemplified earlier in this paper by Ladson-Billings (1994) *Dreamkeepers* work. As described earlier, Ladson-Billings was unable to identify the "what", easily-observable practices or behaviors shared among the exceptional teachers in her study. As a result, she expanded her study to explore why some teachers performed better than others. To do this, her inquiry focused on how these exceptional teachers see themselves, others, and their profession, asking: *How did the teachers think of themselves as teachers? How did they think about students, parents, administration, other teachers? How did they structure social relations within and outcome of the classroom? And how did they conceive of knowledge?* By asking these questions, Ladson-Billings sought to understand teachers' ideological and philosophical beliefs which underpin practice. This work resulted in Ladson-Billings' theory of culturally relevant pedagogy, which has remained a dominant approach to multicultural education ever since the publication of

Dreamkeepers (Ladson-Billings, 1994). Further, (Howard, 2001) later used this framework as a lens to see the observable practices of exceptional instructors. Thus, we argue that taking a deeper look into what accounts for deviance, beyond surface-features of practice, is necessary where practice is not external and easily observable, and, in all cases, has potential to enrich our ability to see and understand outliers on a much deeper level.

In this study, we conduct a detailed outlier study on community college developmental mathematics instructors. We seek to identify positive outlier faculty, those whose results are at least one standard deviation above the mean in math achievement with underprepared students, explore their uncommon, but successful practices, where possible, and build theoretical understanding of individual differences that drives practice. We believe that this will help us identify, and deeply understand, what accounts for the deviance from the norm. In the next section, we provide a brief description of community college developmental mathematics, in general, and Statway, in particular, and discuss variation in Statway instruction.

Community College Developmental Mathematics and Statway

Each year, over thirteen million students enroll in community colleges across the U.S. Community colleges are an essential access point for minority, low-income, and non-traditional students to the higher education and workforce training (Cohen & Brawer, 2008). Yet, for 59% of these students, the dream of graduation is quickly shattered when they are placed into developmental, or remedial mathematics courses (Bailey, Jeon, & Cho, 2010). With a 30% success rate (Levin & Calcagno, 2007), developmental mathematics have been called the "graveyard of dreams and aspirations" (Merseth, 2011). Students are often doomed to take and retake courses, resulting in prolonged enrollment, increased debt, and in many cases, evental dropout (Stigler, Givvin & Thompson, 2010).

In 2009, the Carnegie Foundation for the Advancement of Teaching launched the Community College Pathways (Pathways) program in response to the developmental mathematics crisis in community colleges in the U.S. The Pathways program consists of two courses, Statway and Quantway, which are taught in place of traditional developmental mathematics courses in participating community colleges across the U.S. (Van Campen, Sowers, Strother, 2013). Since its formation, the Pathways program has achieved significant success in addressing the developmental mathematics crisis. For example, 49% of students now complete their Statway course in the first year of taking it, compared to the 6% of students enrolled in traditional developmental mathematics courses (Van Campen, Sowers, Strother, 2013). Even with this remarkable success, there exists a great deal of variation in student outcomes, in Statway, as 51% of students do not complete the course in the first year of taking it.

An underlying assumption of the work proposed here is that Statway instructor variability may be a key factor contributing to poor student outcomes. Efforts to increase the quality of teaching are gravely needed in community college developmental mathematics; yet this problem receives relatively little attention in traditional developmental mathematics courses (Boylan, 2002; Stigler, Givvin & Thompson, 2010). Further, our previous experiences working in Statway, and preliminary analysis of Statway data, point to instructional quality as an important site for improvement. We believe that understanding the nature of instructor variation, in general, and of positive outliers, in particular, will help us better understand how to support developmental instruction, and, in turn, improve student outcomes in Statway. In the next section, we describe what instructional variation in Statway looks like, based on our previous experiences, and our preliminary data analysis of instructor variation.

Faculty Variation in Statway

Between 2013 and 2016, a small team of professors and doctoral students took up the task of developing new curriculum for Pathways using improvement methods. During three years on this project, we worked closely with 25 Pathways faculty in 15 community colleges around the country, collaboratively developing, testing, and refining curriculum together. Spending a substantial amount of time talking and observing instructors through surveys, interviews, classroom observations, we began to see a great deal of variation in instructional knowledge, beliefs, strategies, and behaviors.

What does this variation look like? Consider, Aiyana for example: *Aiyana, a 21-year-old student, enrolled in Borough of Manhattan Community College (BMCC), is excited to obtain a nursing degree. She moved from Somalia to the U.S. with her family during high school and she has struggled to transfer her strong literacy skills from Arabic to English. Aiyana has failed BMCC's traditional developmental math course twice, and she is now trying Pathways as an alternative. Hopeful in her ability, she is dismayed when, on her first day of class, she encounters her first Pathways lesson text on the first day of class:*

Voting for the House of Representatives

The U.S. Congress consists of two bodies, the Senate, and the House of Representatives. For legislation to be enacted, it must pass in both of these bodies. The House of Representatives consists of a fixed number of 435 voting representatives. These representatives are allocated to each state proportionally, based on population; however, each state must have at least one representative. In a simple sense, this means that the higher a state's population, the more representatives it will have. The aim of this method of allocation is that U.S. voters have relatively equal representation in the House.

Aiyana, who reads at a 7th grade level, is actually only able to read this:

Voting for the House of Representatives

The U.S. Congress consists ____ two ______the Senate, and the House of Representatives.
_____, it must pass________. The House of Representatives consists ______ fixed number
____435 voting representatives. __________ proportionally
________population__________________. _________, this means ___ higher a state's

population, ___ more representatives ___. The aim __________________U.S. voters have ________ equal representation in the House.

Before even getting to the challenging mathematics in the lesson, Aiyana is faced with a challenging text. Further, she is not familiar with U.S. government, and doesn't feel this context is relevant to her own career goals or interests. Some instructors may use strategies and tools to support literacy, such as explaining terms like 'legislation' in the above passage to improve text readability for students who struggle, but many do not (Gomez, Rodela, Lozano, 2013). Further, while 2-3 instructors in our project indicated that they believed providing instructional support around literacy is important in supporting mathematics achievement, most instructors indicated that they do not believe it is their role to teach language in mathematics, regarding it as a skill completely separate from mathematics (Gomez et al., 2015). While literacy in mathematics was certainly divisive among instructors, we saw significant variation in instructional knowledge, beliefs, and practice in other areas as well: ideas about when to offer instructional support versus encouraging students to persist, knowledge and beliefs about the use of specific pedagogical strategies to support differential student needs, knowledge and beliefs about the role of group work as an instructional tool, and fidelity to the curriculum versus adaptation, to name a few.

Given the high degree of variability in instructional knowledge and practice we saw in preliminary work, it is, perhaps, not surprising that there is also a great deal of variation in student performance in Statway. *Figure 2.3* below, which displays the distribution of student end grades in Statway from the first three years of implementation (2011, 2012, and 2013), illustrates this variation.

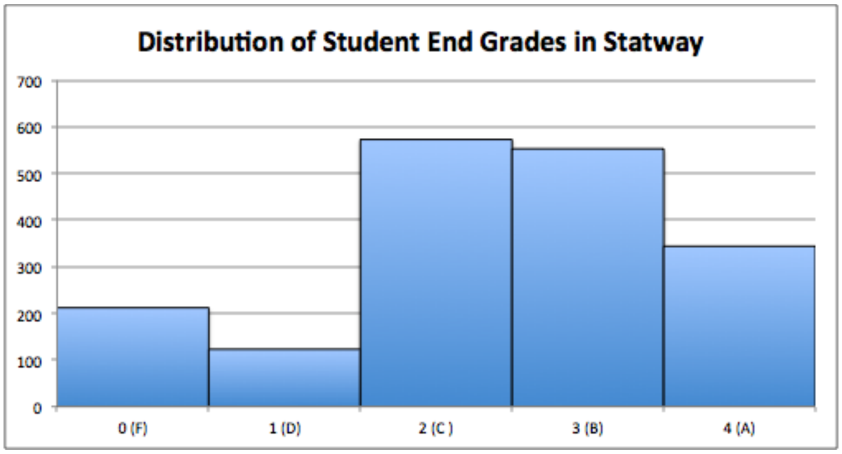

Figure 2.3: Distribution of Student End Grades in Statway
**It is important to note that this data includes students who took Statway for the first time as well as students who have previously taken, and failed, the course.*

To pass Statway, students must earn a C or higher. *Figure* 3 shows that in the first three years of implementation, 81% of students passed Statway with a C or higher, which is significantly better than the 30% pass rate of traditional developmental mathematics courses. Further, 19% of students did exceptionally well in Statway, earning an A. While this demonstrates the significant success of Statway in comparison to traditional courses, an alarming 19% of students (those who earn an F or D) did not pass Statway at all in the first three years of implementation. Given that Statway is an alternative to the problematic traditional developmental mathematics courses, the reality for the one-fifth of Statway students who do not pass in three years is grim, as the cycle of taking and re-taking developmental courses commonly leads to student drop out (Stigler, Givvin & Thompson, 2010).

In this work, we argue that that variability in some aspects of Statway instruction is a key factor contributing to varying student outcomes. We posit that individual instructors, in our specific case, have more influence on student achievement than organizational-level factors; although we do recognize that organizational-level factors matter, in regard to instruction and student achievement (Gallimore, et al., 2009; McDougall et al., 2007; Reeves, 2003; Snow-Gerono, 2005; Thoonen et al., 2011; Yu, Leithwood, and Jantzi, 2002;) Preliminary analysis of instructors in our dataset, using Hierarchical Linear Modeling and Likelihood Ratio tests, show that faculty (variance = .9411, $p<.05$) have double the impact on student achievement in the Pathways than the college attended (variance=.04940, $p <.05$), but less so than the effect of students themselves (variance=1.33726, $p <.05$). Additionally, we found that several colleges in our study had both positive and negative outlier instructors. We will discuss these analyses in more detail in the Methods and Findings sections, however, we felt these results are important in supporting our primary focus on individual faculty, rather than colleges.

To this end, in the preliminary stages of this work, we sought to understand what was already known about the relationship between instructional variation and student outcomes. We found that preliminary data analysis conducted by researchers at the Carnegie Foundation supported our hunch: there is high variation in success rates among Statway faculty (see *Figure* 2.4 below).

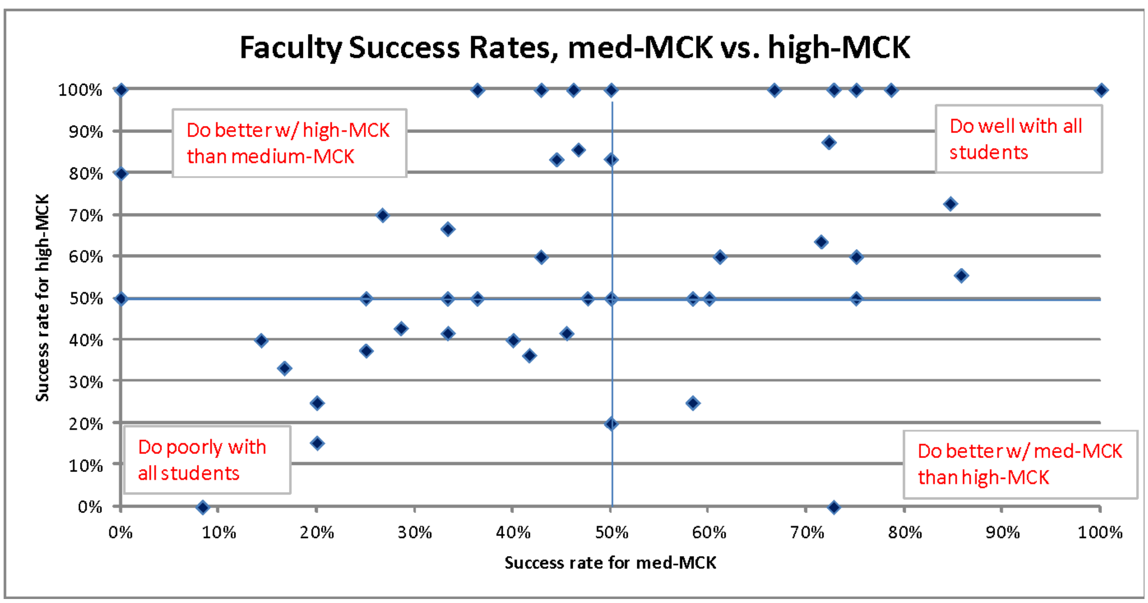

Figure 2.4: Variation in Faculty Success Rates

Incoming Statway students are required to take a common assessment called the Math Conceptual Knowledge (MCK) assessment. This analysis groups students into med-MCK (those who do average on the MCK assessment), and high-MCK (those who do well on the MCK assessment) to analyze how faculty perform with the two groups of students. *Figure 2.4* illustrates that faculty success rates vary greatly. Perhaps disheartening, the analysis illustrates that over 20% of instructors "do poorly with all students", but it also offers a bright spot in the upper right quadrant: roughly the same number of instructors (20%) "do well with all students".

Thus, given our previous experiences working in Statway, and the results of these preliminary analyses, we posit that Statway instructional variation contributes to variation in student outcomes. In the work presented here, we seek to understand why some instructors have better outcomes, in regards to student achievement, than others, and to explore the nature of their positive deviance. In cases where practice is not easily observable, we explore how instructor individual differences drive practice, asking: how do instructor individual differences account for positive deviance? In the next section, we discuss the analytic lenses we use to explore instructor individual differences.

Exploring Individual Differences

We explore instructor individual differences using the lens of instructor knowledge. In the past several decades, a great deal of work has been done to expand our understanding of mathematics teachers' knowledge. For example, Hill, Rowan, & Ball's (2005) concept of mathematical knowledge for teaching builds our understanding of instructor mathematics knowledge. Mathematical knowledge for teaching (MKT) includes an emphasis on both subject matter knowledge and pedagogical content knowledge, such as how and why specific mathematical procedures work, how to best define mathematical terms for particular students, and having a sense of the types of errors students are likely to make with particular content. The authors argue that an important element of knowing appropriate pedagogical strategies includes knowing students: having the ability to anticipate what students are likely to think and what they may find confusing or challenging; selecting examples that draws on students frame of reference and interest; knowing how to motivate students; knowing how to interpret and support student mathematical thinking; and knowing how to shape assignments based on what they know students are likely to do (Ball, Thames, and Phelps, 2008).

Mathematical knowledge for teaching includes four domains: *common content knowledge*, or the mathematics knowledge and skill used in settings other than teaching; *specialized content knowledge,* or the mathematics knowledge and skill unique to teaching; *knowledge of content and students,* or knowledge that combines knowing students and knowing about mathematics; and *knowledge of content and teaching* or knowing about teaching and knowing about mathematics. In this work, we focus the last two domains, *knowledge of content and students (KCS)* and *knowledge of content and teaching (KCT)*, rather than the first two, which are more subject-matter focused. The KCS domain suggest that key areas of teacher knowledge needed to promote student learning include a teacher's ability to anticipate students' conceptualizations and mis-conceptualizations of mathematics concepts. In this way, teachers must know students in order to be able to anticipate, hear, and interpret students' mathematical thinking, in planning, and as it emerges in the classroom. The KCT domain highlights the importance of instructor knowledge in attending to differing student needs. In other words, KCT includes specific teaching strategies used in response to students' conceptualizations and mis-conceptualizations of content. For example, this may include the ways in which an instructor chooses to sequence a lesson plan, where the instructor chooses to provide additional scaffolding, or use modeling in specific ways, to name a few (Ball, Thames, and Phelps, 2008).

We focus our inquiry on the KCS and KCT domains because we posit that these domains may be particularly important for community college developmental mathematics teaching and learning. Community college developmental mathematics students often come into the classroom from a wide range of academic backgrounds and skills. For example, a preliminary analysis of reading level in Pathways mathematics classrooms range shows that students range from a third-grade reading level to collegiate (Gomez, Lozano and Rodela, 2012). Thus, we believe that an instructor's' knowledge and skill in anticipating, and attending, to diverse student needs may be a key factor of effective instruction.

While scholars have found that MKT impacts instructor practices, and student outcomes (Hill, Rowan, & Ball, 2005), one limitation is that it is developed primarily for the K-12 context, with a particular focus on elementary mathematics. Thus, while it heavily guides our conceptual framework, as outlined in the following section, but we do not use the measures developed specifically for MKT.

Conceptual Framework

As described above, this study is organized around the idea that mathematics instructors' individual differences shape practice and have a significant impact on their success with students. Specifically, the goal of this work is to understand how instructor differences in knowledge, especially at the intersection of content, teaching, and students, account for instructor positive deviance. While most positive outlier studies in education to-date ask "what do positive outliers *do* differently on the surface?", in this work we bring relevant theoretical lenses to bear in interpreting positive outlier cases. We believe, that in cases where practice is not external and easily observable, a theoretical perspective focused on teacher knowledge, in general, and mathematical knowledge for teaching, in particular, will help us more deeply understand how individual differences drive practice and account for deviance. In this sense, in this work, in addition to examining what instructors *do* differently, we ask *why* outliers perform differently.

To explore this question, we focus our inquiry on instructor knowledge, exploring, and comparing, how instructors anticipate, and attend to "trouble spots" in a Pathways lesson. Trouble spots are areas in a lesson likely to present a barrier to student learning. One example of a trouble spot in a Pathways lesson is the concept of *concentration* (i.e. the amount of a substance contained in a solution). The lesson assumes that students understand the concept of concentration. Yet, when asked to perform simple mathematics calculating the concentration of a specific solution, many students struggle with understanding the concept of concentration. We explore how instructors differentially anticipate trouble spots in a lesson plan.

We are also interested in examining how instructors vary in how they attended to such trouble spots in practice. For example, while some may try to explain the concept of *concentration* using the problem in the lesson, others may use additional examples (e.g. laundry detergent) or manipulatives (using an infant's medicine syringe) to explain concentration. *Figure 2.5* below illustrates our conceptual framework.

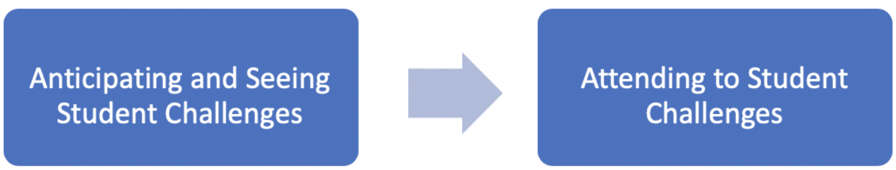

Figure 2.5: Conceptual Framework for Exploring Instructor Knowledge about Student Challenges and Attending to Challenges Through the Lens of Trouble Spots

We posit that focusing on how instructors anticipate and attend to students' mathematical responses will help us explore teacher knowledge. For nearly three decades, scholars have pointed to "anticipating" student responses to cognitively demanding mathematical tasks as a key instructional practice in advancing mathematical understanding (Stein et al, 2008). Anticipating student mathematical responses involves predicting how students may interpret a problem, the varying strategies (correct or incorrect) students may employ to tackle a problem, and how those strategies relate to larger mathematical concepts and procedures (Lampert, 2001; Schoenfeld, 1998; Yoshida, 1999; Stigler & Hiebert, 1999). This kind of "anticipating" requires that instructors consider how students of different mathematical sophistication will engage with the mathematics in the lesson in order to recognize trouble spots, and plan for attending to trouble spots in practice (Stein et al, 2008).

Anticipating and Seeing Student Challenges in the Pathways

As described above, trouble spots are any areas in the lesson with which students may struggle. These may include the mathematics of the lesson, formatting issues within the lesson, the language and literacy requirements of a lesson, personal feelings about ability to "do" mathematics, to names a few. Researchers have identified several areas related to classroom instruction that may impede student success in developmental mathematics: student interest and engagement in mathematics content (Carnevale & Desrochers, 2003); student mindset related to previous negative experiences with mathematics and feelings of not "belonging" in mathematics classrooms (Blackwell, Trzesniewski, & Dweck, 2007; Haynes, Perry, Stupinsky, & Daniels, 2009); and, the language and literacy demands of mathematics (Gomez, Rodela, Lozano, & Mancevice, 2013). While Statway was developed in response to these barriers to student success, we believe, that even within Statway, these may continue to be trouble spots for students.

We hypothesize that positive outlier instructors may anticipate and attend to such trouble spots in lessons differently than their peers. More specifically, we hypothesize that positive outliers' expertise in anticipating and planning for trouble spots, allows them to attend to trouble spots to meet diverse student needs, as described in the following section.

Attending to Student Challenges in the Pathways

Drawing on literature about mathematics instruction, in general, and community college and developmental mathematics instruction, particular, we anticipate that this line of inquiry will shed light on instructor use of specific pedagogical strategies and instructional decision-making, as well as other factors that support effective Statway instruction. The Pathways are designed to promote the use of specific teaching strategies, primarily centered in fostering productive persistence in students, or building a set of skills, mindsets, and strategies that encourage better study skills, habits of mind, and tenacity to succeed through challenges. We posit that positive outliers, in this vein may use pedagogical strategies that encourage growth mindset (Dweck, 2006), may prioritize establishing positive student-teacher relationship (Nieto, 1992; Noddings, 1992) where teachers have high expectations of all students (Muller, Katz and Dance, 1999), and practices are likely rooted in ideas of participatory democracy, engaging with the interests and capacities that are unique for every learner (Dewey, 2007).

Study Purpose & Research Questions

The purposes of this research are to (1) identify positive outlier faculty members; and (2) build theoretical understanding of how individual differences in teacher knowledge drive practice and explain positive deviance. To elaborate on these topics, the study is guided by the following research questions:

1. Can we identify positive deviant faculty members, in the Statway data, who are statistically different from other faculty? If so, who are these faculty?
2. How do differences in instructor knowledge explain positive outliers' successful outcomes?
    a. How do instructor differentially anticipate and see the challenges developmental mathematics students face in succeeding in Statway?
    b. How do instructors differentially attend to student challenges in order to effectively teach developmental mathematics?

In the following chapters, we describe our study and present our findings. In Chapter 3, we provide a description of the methodology. In Chapter 4 we present descriptions of our statistical analysis, using Empirical Bayes Estimation and Hierarchical Linear Modeling, to identify positive outlier instructors. In Chapter 5, we describe our qualitative analysis of interview data, examining how individual differences account for positive outliers. We begin Chapter 6 with a discussion of our findings and conclude the chapter with significance of our study and implications for teaching and learning in developmental mathematics and future research.

CHAPTER 3: METHODOLOGY

Study Design

To address the research questions, the study is conducted in two stages. In the first phase, we use Hierarchical Linear Modeling and Empirical Bayes estimation to identify positive outlier developmental mathematics instructors, those instructors whose results are at least one standard deviation above the mean in math achievement with underprepared students. In the second phase, we conduct 1 to 1.5 hr, semi-structured interviews centered on artifact-prompted analysis with instructors. The goal of the interviews is to examine how instructors think about, and attend to, student challenges.

Phase I: Identifying Positive Outliers

In the first phase of our study, data analysis focuses on exploring the following research question:

- Can we identify positive deviant faculty members, in the Statway data, who are statistically different from other faculty? If so, who are these faculty?

Phase I setting and participants.

Statway is part of a program developed by the Carnegie Foundation for the Advance of Teaching, which includes two developmental mathematics courses: Statway (statics) and Quantway (quantitative reasoning). These are accelerated courses that are taught in place of traditional developmental mathematics courses in participating community colleges across the U.S. Pathway courses aim to offer students meaningful, relevant, authentic, and useful mathematics that students can use in their daily lives. Since its launch in 2011, over 222 Pathways faculty have taught more than 20,000 students in 36 higher education institutions across the U.S. In this work, we focus specifically on Statway faculty.

We conduct our work in Statway for three primary reasons. First, this work grew out of a previous project working in the Pathways to develop new curriculum. Working closely with faculty, including classroom observations and instructor interviews, we saw a great deal of variation in practice (as described in the preceding chapter). Thus, this dissertation takes up the question of how to explore this variation to drive improvement. Second, while Statway has had tremendous success in the developmental mathematics landscape, pushing how we think about community college mathematics teaching and learning, there is still room for improvement. Further, we believe that developmental mathematics courses, in general, are a critical area in need of improvement, as community college students' failure of development courses has great impact on academic and lifelong success. We believe that the work we conduct here will shape our understanding of how to improve Statway, in particular, and developmental mathematics generally. Our third, and most practical reason for conducting this work in Statway is that we had access to very detailed data about Statway faculty, which afforded us the ability to use quantitative analysis to identify positive outlier instructors.

Phase I data sources and analysis.

To identify study participants, we use Hierarchical Linear Modeling (HLM) (Raudenbush & Bryk, 2002) and Empirical Bayes (EB) estimation (Krutchkoff, 1972) to identify positive outlier faculty, average faculty, and negative outlier faculty. HLM accounts for the nested structure of the data (students within faculty, faculty within colleges). That is, we use HLM because students share faculty and faculty share colleges; we expect, for example, that there is some correlation between students under the same faculty, and some correlation between faculty at the same colleges. We use empirical bayes estimation to estimate teacher effects (see, e.g., Chetty, Friedman, & Rockoff, 2014; Corcoran, Jennings, & Beveridge, 2011; Jacob & Lefgren, 2005, 2008; Kane & Staiger, 2008; and McCaffrey et al., 2004). The use of Empirical Bayes estimates is critical to our study because instructors have varying, and sometimes limited number of students. Using other methods to estimate effect sizes would not allow us to take into account these varying sample sizes, thus impacting the individual faculty estimates. EB estimations shrink faculty estimates toward the average, accounting for variation in the number of students per instructor. This add stability to the data, so that our estimates are more accurate.

Our analysis centers on student-level data from the first three years of Statway. Drawing from a larger data set of 3,008 students, we created a sample of Statway students who are likely to struggle in the Statway course based on certain characteristics. This sample includes students who (1) took at least one developmental reading or writing course; (2) who had a typical high school mathematics grade of C or lower; or (3) who had a math placement level of at least one level below college. We pulled students across cohorts for each instructor, giving each student a unique identifier. That is, a student who repeated the Statway course with the same instructor, or a different instructor, would be treated as a unique student for each year of enrollment. Our final sample includes 1341 students, 91 faculty, and 25 schools. In what follows, we describe our Hierarchical Linear Modeling analysis and Empirical Bayes Analysis. *Table 3.1* below represents the variables used in our analysis.

Table 3.1: Variables used in teacher effectiveness analysis

Outcome Variable

Variable	**Description**
End GP (*gp_end)*	Each student's grade point average at end of SW sequence

Level 1 Student Variables

Variables	**Description**
Student ID (*stu_id)*	Individual student IDs

Level 2 Classroom Variables

Variables	**Description**
Instructor ID (*facul_id)*	ID linking students to Instructor

Level 3 School Variables

Variable	**Description**
School Id (*ipeds_id)*	ID linking student and faculty to school

Findings of this statistical analysis will be discussed in Chapter 4 of this manuscript. To give a brief overview, we found eleven positive deviant instructors, whose results are at least one standard deviation above the mean in terms of student achievement. Ten of the instructors are one standard deviation above the mean, while one instructor is two standard deviations above the mean. Instructors teach at ten community colleges across the U.S., as shown in Table 3.2 below.

Table 3.2: Positive Outlier Statway Faculty

Instructor ID	**Stand Deviation**	**School**
Instructor 68	+2	College 1
Instructor 34	+1	College 2
Instructor 1636	+1	College 3
Instructor 1642	+1	College 4
Instructor 1645	+1	College 5
Instructor 3620	+1	College 6
Instructor 1623	+1	College 7
Instructor 31	+1	College 8
Instructor 29	+1	College 8
Instructor 1706	+1	College 10
Instructor 3609	+1	College 13

Phase II: Accounting for Positive Outliers

In the second phase of our study, we explore the following research questions:

- How do differences in instructor knowledge explain positive outliers' successful outcomes?
    - o How do instructor differentially anticipate and see the challenges developmental mathematics students face in succeeding in Statway ?
    - o How do instructors differentially attend to student challenges in order to effectively teach developmental mathematics?

Phase II setting and participants.

For Phase II of the study, we recruited participants found in Phase I, by contacting faculty directly via email. We reached out to all of the positive outlier instructors, twenty "average" instructors, and twenty "negative" outliers (those instructors whose results in the Empirical Bayes analysis is at least one standard deviation below the mean). Our resultant sample, after recruitment, includes six positive outlier instructors, two average instructors, and three negative outlier instructors, as evidenced in Table 3.3 below.

Table 3.3. Statway Faculty Participants

Instructor ID	Standard Deviation	College
Instructor 34	+1	College 2
Instructor 1636	+1	College 3
Instructor 1645	+1	College 5
Instructor 3620	+1	College 6
Instructor 1623	+1	College 7
Instructor 1706	+1	College 10
Instructor 1637	0	College 3
Instructor 3207	0	College 15
Instructor 66	-1	College 1
Instructor 70	-1	College 17
Instructor 61	-2	College 14

Phase II data sources and analysis.

Data sources. In Phase II, data collection includes a single 1 to 1.5 hr, semi-structured instructor interview. The interview begins with a brief survey about instructor background and is followed by artifact-prompted analysis exploring how instructors differently anticipate and attend to student challenges. Artifact-prompted analysis centers on Quantway contextualized lesson 3.1 and two short (<4 min) videos of instructors teaching Quantway contextualized lesson 3.1. The rationale for using Quantway for this study is threefold: (1) it is based on the same instructional design principles; (2) it is likely that none of the instructors have taught the contextualized Quantway lesson 3.1, so the lesson will be new to them but allows for a common point of talk; and (3) we have access to video of instructors teaching the video that do not show exemplary or below-average teaching. Our rationale for using artifact-prompted analysis is to give instructors a way to connect the practice they see in the video to their previous Statway practice (without feeling like we are evaluating either their practice or that of the instructors' in the video), and help us connect knowledge to practice by illuminating how instructors think about, and describe, what they do.

Interviews are documented through interview notes. After each interview, field notes were typed and initial impressions and interpretations were recorded in the form of an analytic memos. Analytic memos are used to uncover emergent themes and note participant reactions and impressions (Strauss & Corbin, 1990). Interviews are transcribed.

Data analysis. Coding, both planned and emergent, focuses on understanding how instructors differentially anticipate and see student challenges, and attend to them. Our first three cycles of coding focus only on the lesson analysis portion of the interview, as these cycles of coding seek to explore how instructors anticipate student challenges. The first cycle of coding focuses on identifying trouble spots, areas in the lesson which may present a barrier to student learning. The second cycle of coding focuses on identifying the area in the lesson where each instance of a trouble spot occurred using second-level categorical codes (Objectives, Problem Situation, Question 1, Question 2, Question 3, Question 4, Question 5, Question 6, General Lesson). In the third cycle of coding, we identified third-level codes using open-codes to identify the area of focus for each instance of a trouble spot. *Tables 3.4* and *3.5* below illustrate this coding, described above, of trouble spots.

Table 3.4: Coding of Trouble Spots (Location of Trouble Spot)

Level One Code	**Level Two Code**	**Examples of Coding from Lesson Analysis**
Trouble Spot	Area in Lesson of Trouble Spot	
	Problem Situation	The illustration in the problem situation isn't clear, and students may have trouble. I would have a picture of each of the infants' and the childrens' only with the drug facts directly underneath them. It would make it clearer what the choices were. - Instructor 5
	Question 1	I would not be confident in students' ability to do this question [Question 1] in small groups. There's going to be one group that does super well, and the rest of the groups are going to sit staring at each other and then need help. - Instructor 6

Table 3.5: Coding of Trouble Spots (Focus of Trouble Spot)

Level One Code	**Level Two Code**	**Examples of Coding from Lesson Analysis**
Trouble Spot	Focus of Trouble Spot	Example of Coding from Lesson Analysis
	Language and Literacy	In question 2, they will probably ask, What does the word concentration mean? That may take a little but of an explanation. People, even at the higher levels, have a hard time with the concept of concentration of something. - Instructor 8
	Ratios and Units	This is a trouble spot... The instructor really has got to make sure that everybody is understanding why the mL is on the bottom here and on the top here. Why is the mg on the bottom here and on the top here? What is the goal? The goal is to get teaspoons at the end and so everything is revolving around that. It's like, 'Hey, where did this come from? Let's look back at Figure 3. Where did this come from? Let's look back at Figures 1, 2.' The instructor will have to help students see that these numbers are coming from somewhere, so that these are all referenced. - Instructor 1

In the first three cycles of coding, we noticed that the way in which instructors talked about student challenges differs. Some instructors reflect on students' point of view (e.g. "students might think"; "here, students might ask"; "students probably will say") when describing student challenges. We call this empathetic talk. On the other hand, some instructors are broader in their discussion of student challenges. The standard instructor talk description of a trouble spot might sound like Instructor 3 discussing scaffolding:

> ***Instructor 3:*** *I think students might find 6 a bit difficult. I don't think it's bad or that the lesson should be changed. I think the teacher shouldn't jump in too quickly to offer support.*
>
> ***Interviewer:*** *What specifically might students struggle with in questions 6?*
>
> ***Instructor 3:*** *The lesson doesn't give them the scaffolding here to go from milliliters to ounces and dollars, all that sort of stuff.*

To inquire into this more deeply, our fourth cycle of coding focuses on identifying instances of instructors using empathy statements, instances when instructors discuss trouble spots in terms of how the students may be experiencing them (e.g. "students might think"; "here, students might ask"; "students probably will say"). This cycle of coding focuses on the entirety of the interview, including lesson and video analysis. The goal is to gain insight into instructor empathy as they anticipate student challenges in the lesson analysis and see student challenges as they unfold in the video. Table 3.6 below illustrates examples of empathy statements in our coding.

Table 3.6: Coding of Empathy Statements

Level One Code	Examples of Coding from Lesson and Video Analysis
Empathy Statement	So, they read that it's called unit analysis. The types of students, they'll be confused between unit analysis and dimensional analysis. They might read unit analysis later in the lesson and think, "well, what's that? We're talking about dimensional analysis. -Instructor 5
	On 5B where it says, "compare the portion of a teaspoon dosage." I know my students would be like "well, what do you want us to do? What do you mean compare?". I don't think my students would understand the word compare. - Instructor 10

Like coding cycle four, our fifth cycle of coding focuses on the entirety of the interview (including both lesson analysis and video analysis), as we explore how instructors attend to student challenges. In the fifth cycle of coding, we identify all instances of pedagogical strategies discussed. In the sixth cycle of coding, we use open coding to identify second-level codes describing the type of pedagogical strategy discussed. Table 3.7 below illustrates examples of coding of pedagogical strategies.

Table 3.7: Coding of Pedagogical Strategies

Level One Code	Level Two Code	Examples of Coding from Lesson and Video Analysis
Pedagogical Strategy	Type of Strategy	
	Direct Instruction	I might expect to point out, in question 3, th" this is what you're starting with, this is your goal, and this is walking you through the steps" because I think there would be questions and confusion about the way this is written in question 3. - Instructor 4
	Feedback	If you ask a student "Hey, what's two plus two?" and a student goes "four", and you go "Good. Who else has an answer?" Nobody else is going to answer, because you already judge that one to be good right? But if you go, what's two plus two and the student goes, "four", and then without any sort of change or tone, you go, "does anybody else have another suggestion?": you elicit more responses and so like, just getting different perspectives is a change in how we should be giving feedback. -Instructor 1

We noticed, in our fifth and sixth cycles of coding, one pedagogical strategy, *adapting curriculum* fell into two categories: "on-the-fly" modifications which happened during class, and premeditated changes to printed lesson materials, which we call "printed alterations". We used second-level codes to code each instance of *adapting curriculum* as "on-the-fly" or "printed alternation". Table 3.8 shows examples of coding for curricular flexibility below.

Table 3.8: Examples of Curricular Flexibility

Curricular Flexibility	Examples from Interview
'On-the-fly' Modifications	I would probably use another example, something like sugar to total content of cookie recipe, or something like that, to get them into the mindset of proportional thinking a little bit at the beginning of the lesson – Instructor 4
Printed Alterations	I would make another worksheet that I'd have them work on in small groups. – Instructor 6
	I would have a couple of questions written so that if a group finishes early, maybe I could give them that, or if I felt like they weren't understanding I could give them another one to work on, but I'd want to have 2-4 more of these types of questions ready. - Instructor 4

Additionally, in our fifth and sixth cycles of coding, we noticed that that some instructors described their pedagogical strategies differently than others. While some said things like, "Here, I would write on the board to show students how to set up ratios", other instructors showed less certainty in the pedagogical strategy they would use in the moment. In our seventh cycle of coding, we code each instance of *pedagogical flexibility* described in the lesson and video analysis. Table 3.9 illustrates examples of coding for pedagogical flexibility.

Table 3.9: Coding of Pedagogical Flexibility

Level One Code	Examples of Coding from Lesson and Video Analysis
Pedagogical Flexibility	I would try to explain it my best, but, if it didn't work, I would probably… Instructor 8 If I felt like they weren't grasping it, or if the discussion wasn't as productive, I would… Instructor 4 Depending on if the students are getting it....I might..- Instructor 7

Limitations

We suggest the following limitations within this study: the sample of instructor participants, and my role as a researcher. Two limitations of our sample of instructor participants relate to limitations of available methods used to collect data, and the small sample size of instructors we study. Second, while my previous work in Statway carries some affordances in carrying out this work, it does raise some issues with objectivity in data collection and analysis. We end our Limitations section with a discussion of some ways that we attempt to mitigate these limitations in the work described in this dissertation.

Sample of Instructor Participants

Our quantitative dataset used to identify positive outlier instructors is comprised of data collected in 2011, 2012, and 2013. As a result, many of our instructor participants no longer teach Statway, which limited our data sources. For example, we could not observe practice by observing instructors teach a Statway lesson. While we were able to to use artifact-prompted analysis as a proxy for understanding instructors' knowledge and practice, we believe our findings, especially as they relate to practice, may be less granular than what in-class observations may have produced.

A second limitation of the sample of instructor participants was the small sample of six positive outlier instructors, three negative outlier instructors, and 2 average instructors. The benefit of this sample was that I was able to conduct detailed qualitative data collection and analysis draw comparisons across the type of instructors. However, the small sample size limits ability to run quantitative analysis, and, compromises generalizability.

Role as Researcher

My first three years as a doctoral student working in the Pathways as a researcher proved to be beneficial and challenging in regard to this work. On one hand, this experience gave me in-depth knowledge of the program, teaching knowledge, beliefs and practices, and student learning. The benefit of my experiences working in Statway prior to my dissertation work is that it gave me better insight into the work of instructors to develop an appropriate research lens. On the other hand, I came into this work with some preconceived hunches about why some instructors have better results than others. To mitigate this, I tried to be as objective as possible when collecting data. Further, data analysis is designed to unveil what instructors themselves bring to light in the study, rather than focus primarily on my own analytical lens.

Mitigating Limitations

Because we are only drawing on qualitative data analysis of a small sample size to answer our second research question, in addition to the limitations imposed by my previous experience as a researcher in the Pathways, we use interrater reliability scores (Miles and Huberman,1994) to ensure that the data analyzed in the study are correct representations of the variables measured. Given the breadth of codes, and length of interviews, we focus our reliability analysis on two instructor interviews (one positive outlier and one non-positive outlier) as coded by two individuals. Additionally, since the number of observations for each individual code is somewhat small in some cases, we calculate a reliability score that incorporates five codes (trouble spots, empathy statements, unique pedagogical strategies, total pedagogical strategies, curricular flexibility and pedagogical flexibility). Table 3.10 below shows the interrater reliability score (reliability = number of agreements/number of agreements and disagreements) below.

Table 3.10: Interrater Reliability of Codes

	Inter-Rater Reliability Score
Positive Outlier Instructor	79%
Non-Positive Outlier Instructor	82%

Both scores indicate good to substantial agreement between coders.

In summary, the limitations discussed here compromise generalizability of our findings, preventing us from making broad claims about positive outlier developmental mathematics instructors, generally. However, the value of our study is in our exploration of variation on a granular level, to illuminate developmental mathematics teaching and learning at the classroom level, examining potential barriers for students, and uncovering the knowledge and practice that underlies impactful instruction.

CHAPTER 4: IDENTIFYING POSITIVE OUTLIERS

In the next two chapters, we examine the question: how do differences in instructor knowledge account for positive deviance? To explore this question, in our first phase, we use quantitative analysis of Statway data to identify positive outlier developmental mathematics instructors, those instructors whose results are at least one standard deviation above the mean in math achievement with underprepared students. In this chapter, we discuss the findings from our analysis to identify positive outlier instructors, which we conducted in RStudio and replicated findings in SPSS. We begin by discussing our results from our Hierarchical Linear Modeling analysis, followed by a discussion of our results of the Empirical Bayes estimates for positive and negative school and faculty outliers.

Overview of Findings

In this chapter, we explore the first of our research questions.

- Can we identify positive deviant faculty members, in the Statway data, who are statistically different from other faculty? If so, who are these faculty?

We hypothesized that using Hierarchical Linear Modeling and Empirical Bayes estimation we could identify positive outlier faculty in the Statway data. We found this to be true. We identified fourteen positive outlier faculty who are at least one standard deviation above the mean in terms of student achievement, and twelve negative outlier faculty who are at least one standard deviation below the mean in regard to student achievement. Additionally, in this section, we discuss positive and negative outlier colleges, as well as report more detailed findings about positive outlier instructors.

Hierarchical Linear Modeling

We use Hierarchical Linear Modeling (HLM) to analyze variance in the student, faculty, and college variables. We use HLM because of the hierarchical nature of our data set. In our data, students are nested within faculty, and faculty are nested within colleges. In other words, students in our study share variance according to their teacher and college. HLM accounts for this shared variance, allowing us to see the effects of student-to-student, teacher-to-teacher, and college-to-college variation on student grades. Table 4.1 shows results from this analysis below.

Table 4.1: Variance

Groups	Name	Variance	Std. Dev
Faculty	intercept	.09411	.3068
College	intercept	.04940	.2223
Residual (student)		1.33726	1.1564

Our results in *Table 4.1* show that faculty-to-faculty level variance is .09411, and the college-to-college variability is .04940. The residual, or the student effects are 1.33726. This suggests that individual student-to-student variation has the most impact on student grades, and college has the least.

Additionally, we tested the significance of the college-level and faculty-level variance components using using Likelihood Ratio Tests (Anderson et al., 1958). To test significance of the college level variance component, we compare the combined model and the faculty-level model. We found the variance component to be significant, $p < .05$. To test significance of the faculty level variance component, we compare the college-level and the faculty-level models. We also found the variance component to be significant here, $p < .05$. Thus, our findings suggest that faculty have a more significant impact on student achievement in Statway than the college attended, but as you would expect less than the effect of student themselves. It is not unexpected that student-to-student variation would be the highest. These findings, which show that faculty effects are greater than college effects support our preliminary analysis described in Chapter 2 of this manuscript, pointing to faculty variation being a key factor in varying student outcomes.

Additionally, we examine scaled residuals and the intercept estimate of the data in Tables 4.2 and 4.3 below.

Table 4.2: Scaled Residuals

Min	1Q	Median	3Q	Max
-2.5446	-.5538	.1471	.7662	1.7720

Table 4.3: Fixed Effects

	Estimate	Standard Error
Intercept	2.39198	.06859

Our scaled residuals (see Table 4.2) help us diagnose normality of the data, calculating the probability that the sample was drawn from a normal population. While they are a bit skewed to the left, we are not concerned due to the large sample size. The intercept estimate in Table 4.3 shows that the grand mean of student end-grade in the Statway sequence is 2.39.

Empirical Bayes Estimation

To identify positive outlier instructors, we use Empirical Bayes (EB) estimation. Our data focuses on a subset of students (struggling students) within a classroom. Thus, in the data, some teachers have a limited number of students, creating a small sample size. EB estimations shrink college and faculty effects toward the mean, while accounting for the number of students per college and per faculty. This adds important stability to the estimates of faculty and college effects.

College Effects

In this section, we discuss the effects of individual colleges on student outcomes.

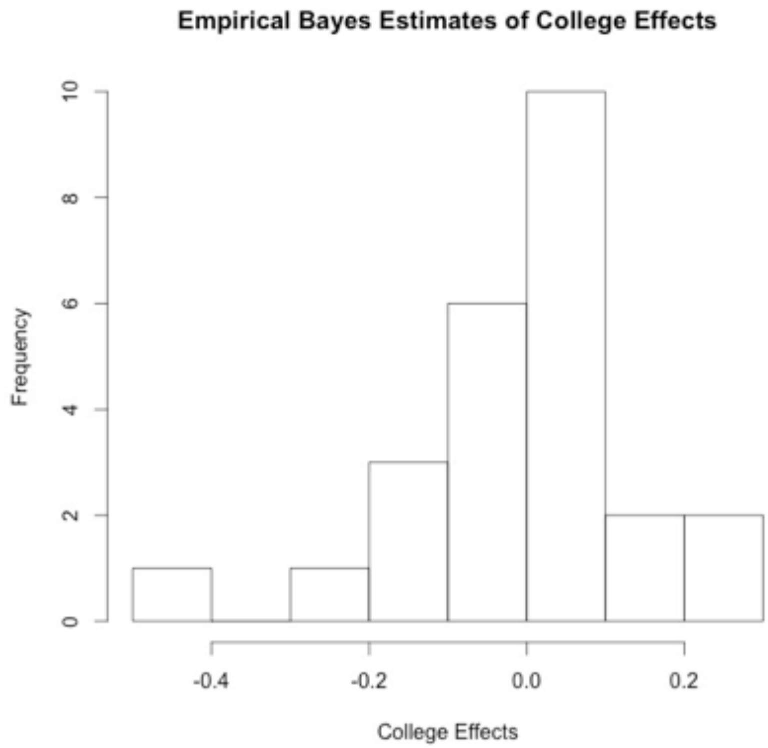

Figure 4.1: EB Estimates of College Effects

Our histogram of the Empirical Bayes estimates of college effects shows that the distribution is skewed a bit to the left. We also see that there are a couple of outlier colleges, primarily negative outliers, which is confirmed in *Table 4.4* below. Here, we assume that colleges, in general, have a difficult time helping "struggling" students excel.

Table 4.4: School Outliers

Positive Outlier Schools			**Negative Outlier Schools**		
School	**Standard Deviation**	**School**	**School**	**Standard Deviation**	**School**
109208	+1	College 4	**190628**	-2	College 15
174376	+1	College 6	**114716**	-1	College 9
236513	+1	College 7	**129367**	-1	College 14

Three colleges are one standard deviation above the mean (zero) in term of empirical bayes estimates: College 4, College 6, and College 7. We can infer that these schools excel the most out of the twenty-five schools in the sample in terms of supporting students who struggle with language and literacy or mathematics. On the other end of the spectrum, College 9 and College 14, are one standard deviation below the mean; and one school, College 15, is two standard deviations below the mean. We can infer that these schools, especially College 15, likely need additional support to help struggling students achieve in the Statway course.

Faculty Effects

While the previous section on college effects helps provide context, this section, which describes individual faculty effects is the core of this chapter. In this section, we discuss the Empirical Bayes estimates of individual faculty effects on student achievement. Given that the focus of this work is understanding positive outliers, our analyses and findings center largely on examining positive outlier results.

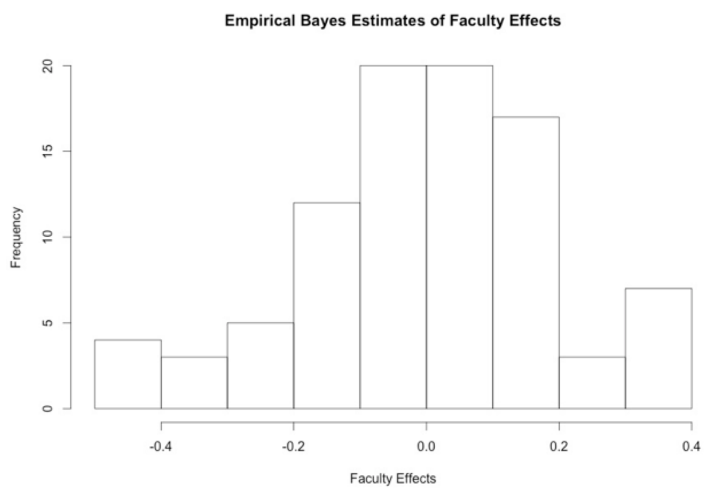

Figure 4.2: EB Estimates of Faculty Effects

Our histogram shows that the Empirical Bayes estimates of faculty effects are a bit more normal than college effects, but again, it seems that it is skewed a bit to the left, indicating that more faculty struggle with helping underprepared students. This distribution is not surprising, as the sample doesn't include the whole population of students, rather it focuses specifically on students who are underprepared in terms of language and literacy and/or mathematics upon entering the Statway course.

Faculty positive outliers.

Table 4.5 below illustrates the findings from our analysis of positive outlier faculty. The analysis described here includes findings from our Empirical Bayes estimates, an examination of possible grade inflation, a brief exploration of the population of students for each instructor, and a probe into student measures around productive persistence by instructor.

Table 4.5: Faculty Positive Outliers

POSITIVE OUTLIERS						
Instr ID	**Stand Dev.**	**Pos Dev. In Prev Analysis?**	**School**	**# of strug. students /# of total students in sample**	**% of struggling students**	**# change productive persistence Ave = .57**
68	+2	x	College 1	30/39	77%	.42
34	+1	x	College 2	16/19	84%	.71
1636	+1	x	College 3	17/21	81%	1.5
1642	+1	x	College 4	13/17	76%	.86
1645	+1	x	College 5	13/16	81%	.4
3620	+1	x	College 6	12/19	63%	1.3
1623	+1	x	College 7	13/16	81%	0
31	+1		College 8	15/15	100%	1.4
1260*	+1		College 9	9/13	70%	1.5
29	+1		College 8	9/18	50%	.7
1706	+1		College 10	11/17	65%	1.25
1734*	+1		College 11	2/3	67%	-.3
3206*	+1		College 12	7/14	50%	0
3609	+1		College 13	6/12	50%	.3

**indicates instructors who may inflate grades*

Our analysis indicates that fourteen faculty are at least one standard deviation above the mean in terms of Empirical Bayes estimates, with one faculty, Instructor 68, two standard deviations above the mean. Six of these fourteen instructors appeared in our previous positive deviance analyses. In previous iterations of this work we used descriptive statistics to identify positive outlier instructors by-hand. The fact that several instructors showed up in both our previous analyses as well as this one, helps confirm, to us, that the analysis presented here is reliable.

While it is not surprising that the three positive outlier schools are reflected among positive outlier faculty, one unexpected positive outlier instructor finding is Instructor 1260, who is an instructor at College 9, a negative outlier school. While this paper does not take up the exploration of the relationship between the positive outlier instructor and his or her academic institution, it would be interesting, in future research, to better understand how instructor-level and organizational-level factors interact in such as case.

It is important to note here that the outcome variable is student final grade in the course, and college or individual instructor grading practices may impact our findings. For example, it is possible that the positive outliers generally give more A's than the negative outlier instructors. We probed this possibility through an examination of the distribution of individual instructor grades compared to the distribution of all students grades in the data set. For this analysis, we used the large data set (n=3008) rather than the smaller sample of "struggling students". The results indicate that that Instructor 1260, Instructor 1734, and Instructor 3206 potentially could be lenient graders, as their distributions were heavily skewed right (these results are indicated with * in *Table 4.5* above). The grade distributions among the other instructors were similar to the grade distribution of all students in the data set.

In this analysis of grade distribution, one instructor, Instructor 1734, only had 3 students in the sample, which is not enough evidence to draw conclusions. We believe he made it to the "positive outlier" group because both of his "struggling" students earned an A, the highest possible grade in the course. This may speak to the grading practices, as discussed in the previous section, therefore we eliminate Instructor 1734 because of limited data.

We also examined the percentage of "struggling" students for each instructor. The percentage of "struggling" students ranged from 50% (Instructor 3206, Instructor 3609, and

Instructor 29) to Instructor 31, who had 100% struggling (15/15) students. One interesting finding is that Instructor 31, who teaches at College 8, had 15 struggling students out of 15 total students, while Instructor 29, who also teaches at College 8, only had 50% (9/18) struggling students. As we continue to explore this problem, we should further explore student placement within colleges, and other institutional factors that impact student attainment. Why, for example, did Instructor 31 have significantly more "struggling" students in his class than Instructor 29?

Finally, we examined individual faculty impact on student attitude toward math learning. Students take a survey in the beginning of the course which measures a student's mindset about math learning. Three weeks later, after students have engaged in growth mindset activities and classroom interventions, students take the survey again. The higher the numeric value, the more growth mindset-oriented the student is (i.e., the student tends to believe that one has the ability to "grow" their brain and acquire new skills/knowledge); conversely, the lower the numeric value, the more fixed mindset-oriented the student is (i.e., the student tends to believe that one either has the ability to learn math or not). The average growth mindset score for the initial survey, among all students in the data set, is 3.03, and the average score for the second survey, taken three weeks later, is 3.6. Thus, the average change in growth mindset, among all students, is .57. The change among the instructors identified as positive outliers ranges from -.3 (indicating that this faculty member's students actually decreased growth mindset) to 1.5, a score 2.6 times higher than the average. Five out of the fourteen instructors showed student change that was more than 2 times the average of .57, 3 instructors showed change slightly higher than average, and five instructors showed change that was less than the average change. See *Table 4.5* for individual faculty averages.

Negative faculty outliers.

In this section, we report the findings of our Empirical Bayes analysis of negative outlier instructors. Given that the aim of the study is to better understand positive deviance, this analysis is much less in depth than the one described of positive outliers in the section above. The findings are illustrated in Table 4.6 below.

Table 4.6: Faculty Negative Outliers

Negative Outliers		
Instructor ID	**Standard Deviations**	**School**
61	-2	College 14
2966	-2	College 8
3208	-2	College 15
3612	-2	College 15
44	-1	College 16
46	-1	College 10
51	-1	College 10
66	-1	College 1
70	-1	College 17
623	-1	College 9
628	-1	College 9
1737	-1	College 18

Twelve faculty members in our study are at least one standard deviation below the mean of zero, with four of these faculty two standard deviations below the mean. We were surprised to find Instructor 61 in this group since we consider him to be heavily involved in the Statway program. We also found the schools identified in the analysis interesting. For example, two positive outlier instructors teach at College 8, and one negative outlier (Instructor 2966). Additionally, both College 15 and College 10 have two negative outlier faculty each, which raises the question: are there institutional factors that contribute to this finding? Again, like our findings from our positive outlier analysis, we posit that an exploration of the relationship between instructor and college effects may produce some interesting insights into the the relationship between individual differences and institutional factors (although, the work presented here does not take up that question).

In summary, we hypothesized that we could, statistically, identify positive outlier instructors using Hierarchical Linear Modeling and Empirical Bayes Estimation. As discussed in this chapter, our findings indicate that this is true, as we found fourteen positive outlier instructors, and twelve negative outlier instructors in our analysis. In the next chapter, we compare positive outlier instructors and non-positive outlier instructors identified in these findings to examine how individual differences account for positive outliers. In particular, we explore how instructors differentially anticipate, see, and attend to student challenges to better understand how differences in instructor knowledge explain positive outliers' successful outcomes.

CHAPTER 5: ACCOUNTING FOR POSITIVE OUTLIERS

This chapter is the heart of this manuscript, illuminating our findings on how individual differences, with a particular focus on differences in instructor knowledge, account for positive outliers. Before we move into a discussion of findings in this chapter, we provide a brief description of participating instructors in the study (see Table 5.1 below). This description provides insight into some background information of positive outliers and non-positive outliers. Our study includes six positive instructors, two average instructors, and three negative instructors. Interviews with instructors ranged from thirty-five to one-hundred and five minutes.

While the aim of this study is not centered on exploring the relationship between expertise and effective teaching, we did collect some data during interviews, including instructor educational background and number of years teaching in general and in Statway, to serve as a proxy for expertise, just to see if such a relationship exists in the data.

Table 5.1: Participating Instructors' Background

Instructor Background

ID	Outliers Status	Interview Date	Interview Duration	Highest Education	Ed vs. Applied	Specialty	Years Teaching Total	Years Teaching Statway
1	Positive	11/13/18	98	PhD	Both	Math; Curric & Instr	15	2
2	Negative	11/14/18	80	Masters	Applied	Applied Math	19	3
3	Negative	11/15/18	105	PhD	Applied	Physics; Math	40	4
4	Positive	11/30/18	47	Masters	Applied	Physics; Math	14	2
5	Average	11/27/18	80	PhD	Applied	Physics; Math	40	5
6	Positive	11/30/18	35	Masters	Both	Math; Math Ed	35	2
7	Positive	12/7/18	51	Masters	Applied	Math	25	2.5
8	Positive	12/7/18	50	Masters	Applied	Math; Computer Science	16	3
10	Positive	1/3/19	44	Masters	Applied	Math; Business Operations	35	3

11	Average	1/16/19	38	PhD	Applied	Physics; Cognitive Science	21	5
12	Negative	1/30/19	53	PhD	Both	Math; Math Education	17	3

Participating instructors taught, in general, between fourteen and forty years, and in Statway between two and five years. Five instructors have PhDs, while six of the instructors' highest level of education is a Master's. While eight of the instructors have applied degrees (e.g. mathematics, computer science, physics), three have a combination of degrees in applied mathematics and education. While some literature may argue that expertise is an important predictor of instructor and student success, there is no suggestion of a relationship between the type of instructor (positive, average, or negative), and number of years teaching, education level (Masters vs. PhD), or and type of education (applied vs. education) in our study. Rather, our findings, as described below, center on instructor knowledge, and how instructor build and deploy that knowledge in practice.

Overview of Findings

Specifically, we explore, in this chapter, the following research question and sub-questions:

- How do differences in instructor knowledge explain for positive outliers' successful outcomes?
    - How do instructor differentially anticipate and see the challenges developmental mathematics students face in succeeding in Statway?
    - How do instructors differentially attend to student challenges in order to effectively teach developmental mathematics?

We hypothesized that positive outlier instructors may anticipate and attend to such trouble spots in lessons differently than their peers, and that positive outliers' expertise in anticipating and planning for trouble spots allows them to plan and prepare more effective instruction to meet diverse student needs.

Generally, we found that instructors *may* be more likely to identify trouble spots than non-positive outliers, and that negative outliers identified half as many trouble spots than positive outlier and average instructors. However, our findings suggest that it is more complex than simple identification of trouble spots. An important, but unanticipated finding in our study, indicates that positive outliers show greater empathy in describing trouble spots than non-positive outliers. Further, while positive outlier instructors generally discuss more pedagogical strategies than non-positive outliers, our data point to deployment of strategies as an important difference in positive outliers. For example, another unanticipated finding from this study suggests that positive outliers have heightened agility in deploying practices in the classroom. Instructor agility includes instances of curricular flexibility (modifying curriculum in-advance or during lesson enactment) pedagogical flexibility (e.g. responding to student needs in flexible ways). Further, we found a relationship between heightened empathy and heightened agility. That is, in most instances instructors with heightened empathy also have heightened agility scores. We also found a positive correlation between empathy and agility. We argue that this suggests, in general, that positive outlier instructors are more likely to notice and empathize with student learning challenges and have the agility to respond to student needs in flexible ways that best meets diverse student needs. In this chapter, we structure and describe our findings following our conceptual framework (see Figure 5.1 below), focusing on how instructors anticipate, and attend to student challenges.

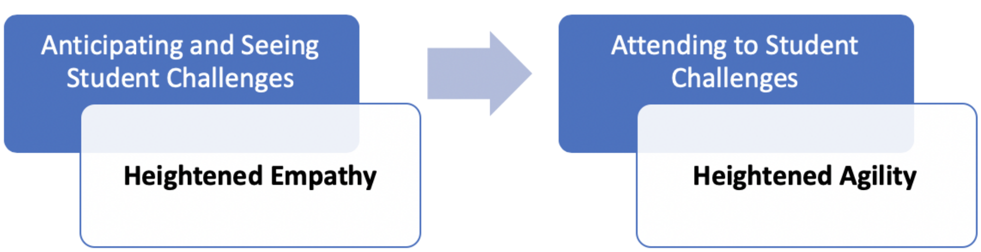

Figure 5.1 Anticipating and Attending to Student Challenges with Empathy and Agility

Part 1: Anticipating and Seeing Student Challenges

Identifying Trouble Spots

In this section of Chapter 5, we describe our findings around instructors' anticipating and seeing student challenges, or trouble spots in Quantway lesson 3.1. We hypothesized that positive outlier instructors would be more likely to anticipate trouble spots than non-positive outlier instructors, and that the kinds of trouble spots identified would look different. In general, our findings did not align with our hypothesis. That is, while negative outliers, specifically, are less likely to identify trouble spots than average and positive outlier instructors, there is not a distinct line differentiating positive outliers and non-positive outliers. Further, our analysis of the focus and locations of trouble spots show that, by and large, instructors across both groups identified similar types of student challenges in the lesson. However, interestingly, unanticipated findings suggest that it may be more complex than simple identification of trouble spots, and that the way in which instructors differentially think about student challenges, especially in regard to empathy, may account for positive outliers. In what follows, we describe these findings in more detail.

Frequency of trouble spots. All instructors identified student trouble spots in our study, with the lowest number of trouble spots being three and the highest ten. Table 5.2 below shows the number of trouble spots, by instructor. Instructors with a (P) are positive outliers, instructors with an (A) are average instructors, and instructors with a (N) are negative outlier instructors.

Table 5.2: Frequency of Trouble Spots

	Positive Outlier Instructors						Non-Positive Outlier Instructors				
	INSTR 1 (P)	INSTR 4 (P)	INSTR 6 (P)	INSTR 7 (P)	INSTR 8 (P)	INSTR 10 (P)	INSTR 5 (A)	INSTR 2 (N)	INSTR 3 (N)	INSTR 11 (A)	INSTR 12 (N)
TOTAL # TROUBLE SPOTS	9	7	10	7	7	8	8	4	3	9	5

Table 5.3 below shows the average number of trouble spots found by positive outliers and non-positive outliers.

Table 5.3: Average Number of Trouble Spots

Average Number of Trouble Spots	
Positive Outlier Instructors	**8**
Non-Positive Outlier Instructors	**5.8**
Average Instructors	8.5
Negative Instructors	4

The average number of trouble spots positive outliers found is 8, while the average number of trouble spots for non-positive outlier instructors is 5.8. However, the mean number of trouble spots for non-positive outlier "average" instructors is 8.5, while negative is only 4. Interestingly, average instructors were *more* likely than positive outliers to identify trouble spots. Together, average instructors and positive outlier instructors are twice as likely than negative instructors to anticipate trouble spots in lessons. As such, while these findings do not suggest a clearly defined line between positive outier and non-positive outlier instructors, it does suggest that the instructors who have the least successful outcomes with students are less likely to anticipate trouble spots than others. It is important to note here that the low sample size of instructors in each category (i.e. there are only two "average" instructors in the study) impacts these findings and warrant future investigations into trouble spots with a larger sample size in the future.

Figure 5.2 below helps us better visualize these results, as it shows the spread, by instructor type, of the number of trouble spots identified.

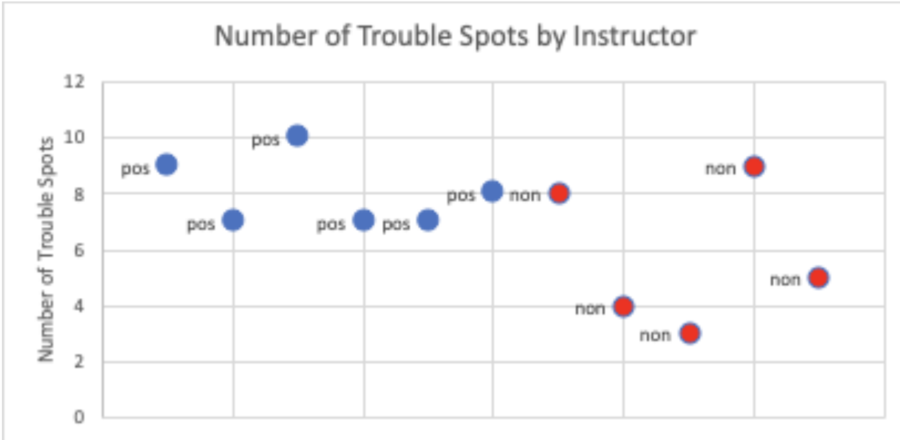

Figure 5.2: Scatterplot of Trouble Spots by Instructor[4]

In what follows, we describe some examples of each of these.

Types of trouble spots. This section is a result of a detailed analysis focused on understanding the types and location of trouble spots identified by instructors. The most common trouble spots across all instructors focus on language and literacy and the complexity of ratios in the lesson to support student learning. One key area of difference between the positive outlier instructors and non-positive outlier instructors is positive outlier instructor identification of student challenges around affective issues, such as confidence, home life, and feeling of belonging in a mathematics classroom. In this section, we discuss, in more detail, instructor descriptions of student challenges around language and literacy, ratios, and affective issues. Other troubles spots identified in the study, but not described in detail here, include formatting, lesson organization and scaffolding, group work, and time.

Language and literacy trouble spots. Both groups identified language and literacy as the most critical area of concern. Nearly every instructor in the study raised the issue of the word *concentration* in the lesson, expressing concern that students would need to support to

[4] Plotting order in all scatterplots is first by instructor type (positive outliers then non-positive outliers), then ordered by chronology of interviews.

understand, conceptually, what *concentration*, before they would be able to engage with the concept mathematically. Instructor 8, a positive outlier instructor, describes this challenge,

> "In Question 2 students will probably ask: what does the word concentration mean? That may take a little bit of an explanation. People, even at the higher levels, have a hard time with the concept of concentration of something". -Instructor 8

Instructor 2, a negative outlier instructor, also describes her anticipation of students' challenge with the word *concentration*.

> Okay, I think students might be a little confused as far as the idea of what is the concentration. What is the concentration of the infant's formula? What is the concentration of the children's formula? Excuse me. Are we gonna make a ratio? I'm confused by it. I don't know what concentration is so I don't know what to do. I can tell you that my students would have gotten very frustrated if I hadn't told them beforehand what concentration means. They wouldn't know. I don't think they would know that. - Instructor 2

Instructor 2, in this example, states the same concern that other instructors have regarding the concept of concentration, taking a step further than Instructor 8, to describe how students might experience this challenge. Other language and literacy trouble spots that were raised by instructors included concerns about student reading level, use of other specific vocabulary words, and numeracy (in this case, students' ability to pull information from one area of the text in the lesson to apply it in another).

Ratio trouble spots. The second largest area of concern, in terms of trouble spots identified across both groups, is ratios. In nearly all instances, instructors expressed concern that students would struggle with how to set up ratios and where to put specific numbers in the setup, rather than the calculations. Instructor 1, a positive outlier instructor, describes this trouble spot well in Question 3, which offers a guide for setting up ratios in dimensional analysis for students.

> “This is a trouble spot. The students can read, but the instructor will have to guide. The instructor really has got to make sure that everybody is understanding why the mL is on the bottom here and on the top here. Why is the mg on the bottom here and on the top here? What is the goal? The goal is to get teaspoons at the end and so everything is revolving around that. It’s like, ‘Hey, where did this come from? Let’s look back at Figure 3. Where did this come from? Let’s look back at Figures 1, 2.’ The instructor will have to help students see that these numbers are coming from somewhere, so that these are all referenced. I think as long as the instructor does a good job of making sure that students understand why the fractions are like this and where they come from, it will be less problematic. But, this is one of those places where I think the instructor really does need to step up and go, this how we do this, because this is a procedure. It’s just a procedure.” - Instructor 1

Most instructors in the study, including Instructor 1, suggested that students would likely not remember how to set up ratios, even if they had been exposed to them in previous units in the course or in previous courses. In this way, they recognized that students would need a reminder of how to set up numerators and denominators in a ratio, and then how to calculate them.

Other trouble spots in the lesson focused on formatting, timing, lack of scaffolding, and group work. While we expected to find wide differences between the positive outliers and non-positive outliers, we were surprised to find that the types and areas of trouble spots are quite similar between both groups. The only area where we found noteworthy variation is positive outliers’ focus on trouble spots related to student affective issues, which were not raised in the non-positive outlier group.

Affective trouble spots. While non-positive outliers did not identify trouble spots focused on student affective struggles, positive outliers did in a variety of different way. Some, like Instructor 7 below, discussed students’ fear of mathematics from the onset of the lesson.

> “If a student actually reads the objectives, they will say ‘Oh, I hate fractions. I don’t know math. I don’t know how to do fractions.’ So, I will have to start by reassuring them that I will go through any questions they have during the lesson.” -Instructor 7

Others, like Instructor 6 below discuss student mindset, and general lack of confidence, and in turn, needing additional instructional support.

> "I find that students at the developmental level are chronically not confident about anything. So me holding their hands for a while, I mean, maybe I do too much of that, but it's something that gives them more confidence." Instructor 6

Rather than focusing just on affective barriers inside the classroom, Instructor 4 discusses affective issues students bring with them from outside of the classroom.

> "What gets in their way, it's outside the classroom with family. Anxiety. Anxiety about academic and motivation. Why am I doing this? It's all of these affective things that may prevent them from being successful." Instructor 4

While Affective Trouble Spots is one area of variation between the positive outlier and non-positive outlier group, and, therefore, is, perhaps, interesting, the number of observations in this category, and others in the analysis of trouble spots, are so small that it is difficult to draw solid conclusions about any true differences between positive and non-positive outlier groups. In other words, for the most part, as described above, our findings across groups in regard to focus and location of trouble spots are surprisingly similar, and do not hold a great deal of explanatory power in regard to the success of positive outliers.

Summary. Findings about the type and location of trouble spots reiterate our findings regarding frequency of trouble spots: while some results, are interesting in that they point to potential group differences, there is not a clearly defined line between positive outliers and non-positive outliers. In this way, we were surprised that our findings did not better align with our initial hypothesis, which anticipated that positive outlier instructors would clearly identify more trouble spots than non-positive outliers.

While our findings suggest that instructor knowledge of "trouble spots", or potential challenges to students may account, in some way for positive outliers, that relationship is not explicitly illustrated by our results. Yet, importantly, as we engaged in this detailed analysis of instructor identification of trouble spots in our study, we found a pattern in the data which suggests that the it may be more complex than simply having the knowledge to identify trouble spots. We saw that the ways in which instructors talked about trouble spots differed quite a bit. While we were not convinced that this would form a pattern across the positive outlier group and non-positive outlier group, we coded the data to explore what this talk looked like across the data. In the next section, we describe these findings, which we believe are very important as we consider how instructor differences account for positive outliers.

Heightened Empathy

An unanticipated, but potentially important finding was *how* positive outliers talk about trouble spots. Positive outliers are more likely to use empathy statements which reflect student point of view (e.g. "students might think"; "here, students might ask"; "students probably will say") than non-positive outliers. During data analysis, I noticed that the way some instructors talked about student challenges differed from others. This prompted coding to inquire into this. The standard instructor talk description of a trouble spot might sound like Instructor 3 discussing scaffolding:

> *Instructor 3: I think students might find 6 a bit difficult. I don't think it's bad or that the lesson should be changed. I think the teacher shouldn't jump in too quickly to offer support.*
>
> *Interviewer: What specifically might students struggle with in questions 6?*
>
> *Instructor 3: The lesson doesn't give them the scaffolding here to go from milliliters to ounces and dollars, all that sort of stuff.*

In contrast, some instructors used language engaging students' point of view. We call this "empathic language", where instructors are sensitive to the thoughts and feelings of the students. In the example below, Instructor 5 uses empathic language to describe student challenges around the vocabulary "unit analysis" in the learning objectives of the lesson. In the statement below, Instructor 5 describes how he believes students will initially experience the language of unit analysis, and how it might come back up later in the lesson.

> *Instructor 5: So, they read that it's called unit analysis. The types of students, they'll be confused between unit analysis and dimensional analysis. They might read unit analysis later in the lesson and think, "well, what's that? We're talking about dimensional analysis."*

The important difference between an empathy statement and a broader acknowledgement of a trouble spot is in instructors' use of language. Do instructors describe how students might feel or think in being confronted with the trouble spots (as Instructors five does above), or does the instructor broadly say that students "might find it difficult" without real insight into why or what students may be thinking or feeling (as in the example from Instructor 3)?

Types of empathic language. Instructors use empathic language to describe students, including simple descriptions of how students might experience the design of the lesson (e.g. formatting), how the instructors' understanding of the student perspective might impact instructional decisions, the external factors that impact student learning, and the variation among students in how students might differentially experience the lesson. In this section, we describe these in more detail.

Lesson Design. Many instances of instructors' use of empathic language in the interviews focused on how students might experience specific elements of the lesson design. For example, Instructor four describes how students might experience question number three in the lesson,

> I think they might be confused about the formatting here. They might look at this and say, "what's the arrow teaspoon?" then get really confused when they look at this part, the teaspoon over milliliters to teaspoon. -Instructor 4

Similarly, other instructors talked about how students might experience the placement of the tables, students having to flip between pages to access information needed to perform calculations, the amount of white space provided in the lesson for student responses, and the sequencing of questions in the lesson, to name a few.

External factors that impact student learning. Some instructors also described external factors that impacted student learning, especially around the topic of the lesson (child acetaminophen overdoses). In the first example, Instructor 7 discusses students' feelings about mathematics, and how that might make the lesson particularly emotional.

> The first thing I thought was that this is kind of an emotionally intense lesson. I try to imagine how some students might take it. I mean, some students are really sensitive, and so that might say, "Oh, since I don't know math, I'm a bad parent", or something like that." - Instructor 7

In the second example, Instructor 1, like Instructor 7, also relates the topic of the lesson to being a parent. In this example, the Instructor says that a parent who doesn't give their child Tylenol, may not have a common reference point for understanding the problem presented in the lesson.

> I think the student was coming from a place of "I don't have any prior knowledge. I don't even give my child Tylenol. I don't have any experience of what you guys [the other students in the classroom] are trying to tell me and so I'm trying to grapple with this mathematical concept without an anchor. I'm trying to grapple with this abstract idea, but I don't have a concrete frame of reference." And so, because she doesn't have prior knowledge, now she's lost. - Instructor 1

Other instructors talk about how student feelings of belonging in a mathematics classroom and confidence might impact how students experience certain parts of the lesson.

Relationship between empathy and instruction. Faculty also connected their understanding of student perspective to their instructional decisions. Instructor 4, in the example below, uses empathic language about students to describe why he is giving direction in a certain area of a lesson.

> I think if I don't give a bit of direction here, they will go into that 'give-up mode' before even tackling it, before getting through any of it"- Instructor 4

In another example, Instructor 2 explains her reasoning for telling students what concentration mean, conceptually, before they get into the mathematics.

> If I didn't start the lesson by telling them was concentration means, my students would be very, very frustrated. They wouldn't know. I don't think they would know. – Instructor 2

This was particularly interesting because while many instructors reasoned similarly as Instructor 2, others suggested that they purposely would not tell students what concentration means to encourage productive persistence. In addition, instructors used empathic language to describe use of direct instruction, specific challenges of relying on group work in certain areas of the lesson, and encouraging productive persistence, among other pedagogical strategies.

Student variation. Several instructors in our study used empathic language when describing how students might experience parts of the lessons differently. In the first example, Instructor 8 describes how some students will need reading support and others will not.

> It will vary here. Students who have decent reading skills will not have a hard time with number four. But those who struggle with reading, will need a little extra help. Sometimes I feel like when there's a long explanation that requires critical reading (in Q3) followed by a question, some students will need additional verbal support on top of the reading, others won't. - Instructor 8

In the next example, Instructor 6 similarly describes how different students will experience the mathematics in the lesson.

I would have students in the room who still don't get it with fractions, who still don't understand what fractions even are, that a fraction isn't two numbers. That's number one. And then, there will be students who might understand the algorithms but don't understand *why* the algorithms work. Many students, even in higher level classes like Calculus, don't get that multiplying one in a clever form doesn't change the value." - Instructor 6

This type of empathic language around different students is, perhaps, the most compelling, as it shows that instructors really know their students, including the varying preparation, knowledge and skills students bring into the classroom. We believe that this may be particularly important as it better situates instructors to respond to students' differing needs.

Frequency of empathetic language. While frequency counts of trouble spots showed little real discrepancies between the positive outlier and non-positive outlier groups, we found distinct differences between instructors' use of emphatic language between groups. Table 5.4 below outlines the number of empathy statements by each instructor.

Table 5.4: Number of Empathy Statements by Instructor

	Positive Outlier Instructors						Non-Positive Outlier Instructors				
	INSTR 1 (P)	INSTR 4 (P)	INSTR 6 (P)	INSTR 7 (P)	INSTR 8 (P)	INSTR 10 (P)	INSTR 5 (A)	INSTR 2 (N)	INSTR 3 (N)	INSTR 11 (A)	INSTR 12 (N)
Total Empathy Statements	**43**	**26**	**26**	**31**	**30**	**25**	**21**	**15**	**3**	**17**	**12**

As illustrated in Table 5.4, in all cases, positive outliers used more "empathy statements" than non-positive outliers, including the average instructors. Further, in all cases the negative instructors used fewer empathy statements than the average instructors. Table 5.5 below shows the mean and median, in regard to the number of empathy statements in the Table 5.4 above, of positive outlier instructors and non-positive outlier instructors.

Table 5.5: Mean and Median of Empathy Statements of Positive Outlier and Non-Positive Outlier Instructors

Empathy Statements	**Mean**	**Median**
Positive Outliers	30	28
Non-Positive Outliers	13.6	15

As evidenced by the Table 5.5 above, our findings indicate that positive outliers are much more likely to use "empathy statements" when describing trouble spots. The box plot below, in Figure 5.3, shows that there is little overlap between the positive outlier and non-positive outlier groups.

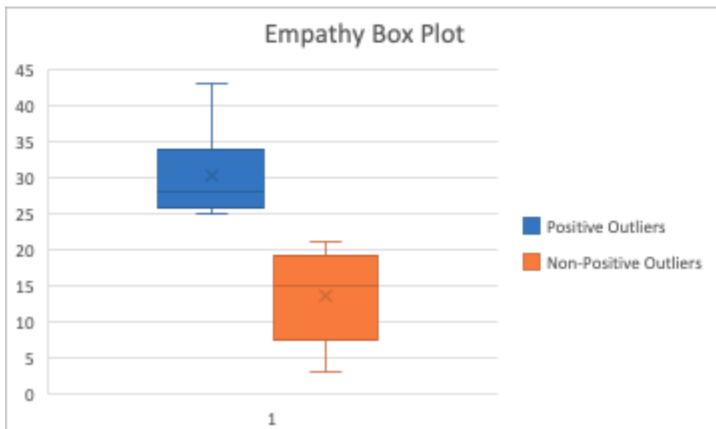

Figure 5.3 Empathy Box Plot

These, coupled with the high number of observations of empathy statements, indicates to us that this is an important finding, and may be a key factor explaining positive outliers. With instances ranging from three to forty-three observations, this is the first category of analysis with substantial numbers of observations. It should be noted here that the instructor with forty-three observations is a bit of an outlier, which may impact the average, however a comparison of medians accounts for this. Thus, we argue that use of empathic language is an important, albeit unanticipated finding, in our inquiry into what accounts for positive deviance. This is surprising because it does not fit into the 'instructor knowledge' lens we expected to find in the study. This suggests, to us, that an empathic approach to deploying instructor knowledge may play an important role in effective teaching.

Summary. Our findings suggest that consistent with our hypothesis, that positive outliers *may* be more likely to identify trouble spots in lessons, but that it may be more complex than simple identification. Generally, our findings around the location and types of trouble spots do not suggest a clearly defined difference between the positive outlier instructors and non-positive outliers. In fact, we were somewhat surprised at how similar the comparisons between the two groups are in regard to this analysis, as we expected the two groups to be distinct from one another in this analysis. However, importantly, our findings suggest that the way in which positive outliers talk about student challenges differs from non-positive outliers. As described above, positive outliers are more likely to describe student challenges by using empathy statements, reflecting on how students may experience these challenges. This suggests that this act of bridging to the student point-of-view may account for some of the success of positive outlier instructors, by allowing instructors to better attend to student needs. When instructors come into a classroom with preconceived ideas about what might be challenging for students and why, they are likely less likely to notice challenges that may differ from their own perspective. As a result, it may be more difficult to attend to students' actual needs, rather than their perceived needs. In what follows, in the next section, we describe the specific ways in which instructors attend to student needs.

Part 2: Attending to Student Challenges

In this section of Chapter 5, we describe our findings related to how instructors attend to student challenges. We hypothesized that positive outliers have a more diverse set of pedagogical strategies on which to draw to attend to student challenges. Surprisingly, our findings suggest that instructors in both the positive outlier and non-positive outlier group discussed similar use unique pedagogical strategies. An unanticipated finding of our study indicates that instructor agility in deploying pedagogical strategies may be a key difference between positive outlier instructors and non-positive outliers. For example, positive outliers are over three times more likely to show agility in pedagogy than non-positive outliers. In what follows, we describe the frequency and types of pedagogical strategies discussed by participating instructors and discuss differences in the ways in which positive outliers and non-positive outliers deploy pedagogical strategies to attend to student challenges, especially in regard to agility.

Pedagogical Strategies

We begin this section with a discussion of the pedagogical strategies instructors in our study described. Strategies fall into seven categories: Direct Instruction, Affective Issues (including Productive Persistence), Building Conceptual Understanding, Language and Literacy, Group Work, Whole Class Discussion, and Adapting Curricular Materials. Importantly, observations of a specific strategy do not include instructors' descriptions of what they see in the video (e.g. "In the video, Eugene is encouraging productive persistence"). Rather, observations only include statements used to describe what the participant instructor would use in their *own* teaching. We take this approach because we our goal in this analysis is to gain purchase on instructors' own practice, rather than their observations of another's.

In Table 5.6 below, we provide examples, from our interview data, of these different pedagogical strategies. The examples in this table are chosen to illustrate different strategies within a category. For example, the Language and Literacy category includes examples both related to language issues and numerical literacy.

Table 5.6: Examples of Pedagogical Strategies

Pedagogical Practice	Examples from Interview
Providing Direct Instruction	I might expect to point out, in question 3, th" this is what you're starting with, this is your goal, and this is walking you through the steps" because I think there would be questions and confusion about the way this is written in question 3. - Instructor 4
Affective Issues (including Productive Persistence)	I think you need some experience with the curriculum to figure out where that tension is between productive persistence and just frustrated and getting ready to shut down. If you give them too much support, they're not persisting, they're not stretching. If you give them too little, they break, so you need a nice sort of balance. I think in question 2A and B, if you go the productive persistence/guided inquiry route, students will struggle. They need some more guidance. - Instructor 1
Building Conceptual Understanding	We, as math teachers, need to think more about how to help the students generalize something before we start talking so much about the abstractions of it. - Instructor 3
	It's important to connect b to c. I think I would have , before getting to C, said, "Ok, in B we've done this, we calculated the ratio of the children's concentration to the infants. Now, you are going to calculate the ratio of the infants to the children's. -Instructor 2
Language and Literacy	Where it says we write it as a rate, I think for my students, I would have to define what rate it. I would have to tell them, a lot of them would not know what rate is. - Instructor 10
	You've got to get them thinking about context early. That's very useful in my opinion. Then, you can get them thinking about what information is missing before they think about the calculations. This is numerical literacy. - Instructor 3
Using Leading Questions	I would have a list of questions to help guide them through it. "What does concentration mean? How are you gonna calculate concentration? How do the concentration compare? - Instructor 2
Group Work	A lot of the time I'm trying to make sure everyone is working productively together in their small groups, to make sure that there aren't people just sitting off by themselves who are getting no attention and not going anywhere. - Instructor 5
Whole-Class Discussion	It might be a trouble spot, but I think if you have a whole class discussion about it before you start answering the questions about what concentration means and why is it different, then I think that it doesn't have to be a trouble spot. - Instructor 2

Adapting Curricular Material	This is good, but I would probably emphasize the idea by maybe doing some other conversions that they're more familiar with. Sort of as an aside, maybe not just volume, but maybe distances, or something like that. Maybe time. Time they're familiar with a lot, so distance, time those kinds of things to really make sure that they have that concept that they're just multiplying by a fancy one. - Instructor 8 (example of non-changing) I would rewrite a lot of the lesson it to support student reading. - Instructor 6

Frequency of pedagogical strategies. To explore differences in how positive outlier instructors and non-positive outlier instructors attend to student challenges, we use frequency counts of the number of times instructors discuss use of a specific strategy during the interview. These results are illustrated in Table 5.7 below.

Table 5.7 Frequency of Pedagogical Strategies

	Positive Outlier Instructors						Non-Positive Outlier Instructors				
	INSTR 1 (P)	INSTR 4 (P)	INSTR 6 (P)	INSTR 7 (P)	INSTR 8 (P)	INSTR 10 (P)	INSTR 5 (A)	INSTR 2 (N)	INSTR 3 (N)	INSTR 11 (A)	INSTR 12 (N)
Providing Direct Instruction	3		3	2	3	2		6	1		2
Attending to Affective Issues (Including Productive Persistence)	16	1	3	8	5	1	6	6	0	0	1
Building Conceptual Understanding	20	6	4	9	9	3	5	7	8	10	4
Supporting Language and Literacy	2	1	3	3	2	5	0	0	3	4	0
Group Work	0	3	3	1	3		0	0	0	5	0
Whole class discussion	0	3	4	1	7	1	1	2	2	1	0
Adapting curricular material	10	8	3	8	2	4	7	1	1	1	3
# of unique pedagogical strategies discussed	**5**	**6**	**7**	**7**	**7**	**6**	**5**	**5**	**5**	**5**	**4**
Total instances of pedagogical strategies discussed	**51**	**22**	**23**	**32**	**31**	**16**	**20**	**22**	**15**	**21**	**10**

We total frequency counts to calculate *unique* pedagogical strategies, and the *total* number of pedagogical strategies discussed by each instructor (as evidenced in the bottom two rows of table

5.7). Using these frequency counts, we compare the means of positive outliers and non-positive outliers to better understand group differences. While we expected to find differences between groups in the use of specific pedagogical strategies, we were surprised to find that, generally, that was not the case.

Our findings show that positive outlier instructors are only slightly more likely than non-positive outliers to have a more diverse toolbox of *unique* pedagogical strategies. For example, positive outliers, on average discussed 6.3 unique pedagogical strategies, while non-positive outliers discussed 4.8. Thus, positive outliers, on average, discuss only 1.3 more unique pedagogical strategies than non-positive outliers.

Our analysis of the means of *total* pedagogical strategies discussed by instructors draws a more distinct, but not very strong, difference between the two groups of instructors. These averages include all instances describing use of a pedagogical strategy. For example, if an instructor discusses using scaffolding for question four in the lesson, and in question six in the lesson, it would count as two observations of "Building Conceptual Knowledge". Our findings show that positive outliers are 1.7 times more likely to discuss different instances of using pedagogical strategies than non-positive outliers. For example, positive outliers, on average, discussed 29 instances of pedagogical strategies, whereas the non-positive outlier only discussed using specific strategies 17 times, on average.

While this may seem potentially significant, when we look at the spread of averages (Figure 5.4 below), we see that positive outliers do not look that much different than non-positive outliers in regard to number of unique pedagogical strategies discussed, given that one outlier instructor is impacting the average of positive outliers. In fact, we can assume that the instructor with 51 observations, as an outlier, has strong impact the positive outlier average.

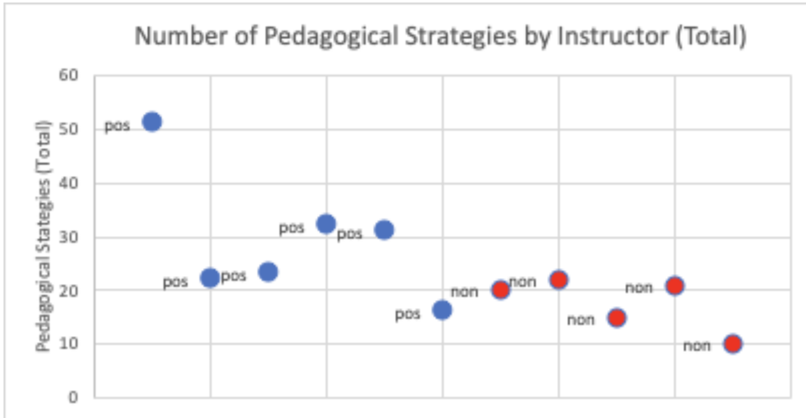

Figure 5.4: Scatterplot Pedagogical Strategies by Instructor

These findings are surprising, as we believed that positive outlier instructors would have a more diverse tool kit of pedagogical strategies in which to utilize, but our study seems to indicate otherwise. That is, we found the number between both groups of pedagogical strategies to be quite similar.

Types of pedagogical strategies. Overall, in the same vein as the frequency counts described above, we were surprised to find that both the positive outlier group and non-positive outlier group discussed very similar types of pedagogical strategies. In both groups, building conceptual knowledge was overwhelmingly the key area of discussion around pedagogical strategies. The only pedagogical strategy that saw a difference between the two groups is *adapting curricular materials*, which positive outlier discussed in more depth than non-positive outliers. In this section, we describe types of pedagogical strategies in more detail.

Building conceptual understanding. Both the positive outlier and non-positive outlier groups indicate that *building conceptual understanding* is an important pedagogical strategy, given the frequency instructors discuss it. Often, instructors discuss different ways they build students' conceptual understanding by describing how they would scaffold instruction to support student learning. In the first example, Instructor 5 describes how he would scaffold students' understanding of the system of measurements.

It says that they are assumed to know a little bit about units of measure, but I think you should start out talking about the difference between volume and weight and concentration and what concentration is. People get confused about the difference between volume and weight because we have a crazy system of measuring. - Instructor 5

In this example, Instructor 5 argues that while the lesson assumes that students will understand the system of measurement, he believes that students will need a bit more support, and explicit conversation around the differences between units of measurement to support student use of measurements in the lesson. Similarly, Instructor 8, also considers where students might have gaps in knowledge, and how to address these gaps through instruction. In this example, Instructor 8 describes how she would remind students of the connections between different pieces of the lesson, including the dosages, information in the reading, and calculations, as a way to prepare students to have the information and understanding to have the know-how to set up the units.

I think, generally, students have a hard time working with units, even if the lesson prerequisites say students should know them. So, I know that that's going to require some intervention. I think that if I were to teach this, I would first, and emphasize, I really like the way this lesson initially emphasizes how important being able to get the dosages right is, so I would emphasize that actually these skills are really, really important, so we really need to pay close attention to how we are reading, and about these things carefully. - Instructor 8

In another example, Instructor 1, describes the importance of feedback in building conceptual understanding. Specifically, he describes how important the *way* an instructor gives feedback can shape understanding.

If you ask a student "Hey, what's two plus two?" and a student goes "four", and you go "Good. Who else has an answer?" Nobody else is going to answer, because you already judge that one to be good right? But if you go, what's two plus two and the student goes, "four", and then without

> any sort of change or tone, you go, "does anybody else have another suggestion?: you elicit more responses and so like, just getting different perspectives is a change in how we should be giving feedback. It's important because hearing different perspectives helps students build new and different understanding of the content and math." - Instructor 1

Adapting curriculum. Another area of particular interest in regard to instructor pedagogical strategies is *adapting curriculum.* Our findings suggest that while all instructors in the study suggest that they would adapt the curriculum in some way, positive outlier instructors are twice as likely to engage in adaptation of materials than non-positive outliers. Instructor 8 below describes the most common way instructors would make modifications to the lesson. In this example, and others like it, Instructor 8 discusses adding content to the lesson without making changes to the printed lesson materials but including additional examples in the lesson to support student learning.

> This is good, but I would probably emphasize the idea by maybe doing some other conversions that they're more familiar with. Sort of as an aside, maybe not just volume, but maybe distances, or something like that. Maybe time. Time they're familiar with a lot, so distance, time those kinds of things to really make sure that they have that concept that they're just multiplying by a fancy one. - Instructor 8

Similarly, Instructor 4 discusses bringing in another example to give students an anchor to understanding ratios.

> I would probably use another example, something like sugar to total content of cookie recipe, or something like that, to get them into the mindset of proportional thinking a little bit at the beginning of the lesson - Instructor 4

We did not anticipate that modifications to the curriculum may account for more effective teaching and learning. This prompted us to explore *adapting curriculum* in more detail to explore how they may account for positive outliers, which we describe in the next section.

Further, during analysis of pedagogical strategies, we noticed that some instructors described use of pedagogical strategies differently than others. While some instructors seemed to have more certainty in their use of specific strategies (e.g. “Students will struggle with this, and I will respond by doing this.”), others showed more flexibility in anticipating and responding to student challenges (e.g. “Depending on students’ responses, I may do this”). This prompted further analysis into pedagogical flexibility. In the next section, we describe our findings related to curricular flexibility and pedagogical flexibility, which, together, we describe as instructor agility.

Instructor Agility

Curricular flexibility. In our more detailed analysis to better understand how instructors talk about *adapting curriculum* we found that observations fall into two categories, including what we call *‘on-the-fly’ modifications*, as well as premeditated modifications to the printed class materials, which we call *printed modifications*. Some examples of ‘on-the-fly’ modifications, like the ones described in the preceding section, include providing additional examples for difficult concepts (e.g. using the example of laundry detergent to explain the idea of concentration), skipping problems in the lesson, altering the process for teaching dimensional analysis from how it is described in problem number three in the lesson, to name a few. Printed modifications include changes to the curricular materials themselves prior to class, including re-arranging question sequencing, replacing some problems with others, adding additional examples, reformatting areas of the lesson, and creating additional worksheets to supplement the lesson, to name a few. These examples are chosen to represent the range of different responses by participants, and build on our understanding of curricular adaptation, described in the previous section, so that we may better understand how curricular flexibility accounts for outliers.

Printed modifications. *Printed modifications* to the lesson are much less common than *on-the-fly* modifications. Our findings indicate that this may be an important area of understanding positive outliers, as all positive outliers in our study indicated that they would make some changes to the printed materials, none of the non-positive outlier instructors indicated printed modifications. To provide some background about what printed modifications look like, we draw on examples from interviews below. Instructor 6, in the first example, describes how he would rewrite the problem context in the lesson to better support student reading at the college level.

> I would rewrite a lot of the lesson it to support student reading. The context is written in short, declarative sentences. My students would feel like this isn't college level, so I would rewrite it to make it more complex. - Instructor 6

In the second example, Instructor 4 says that he would make an additional worksheet to support students who need additional help, or to give to students who finish early.

> I mean, class is always different than what you plan for it to be. You have to go with it. I would want a few more examples and questions in my back pocket. If it wasn't going well, or they needed more examples, I would want to have them written out, so I didn't have to come up with them on the spot, to give students more material. I would have a couple of questions written so that if a group finishes early, maybe I could give them that, or if I felt like they weren't understanding I could give them another one to work on, but I'd want to have 2-4 more of these types of questions ready. But, if it was going well as written, I'd feel fine moving on. - Instructor 4

Extracted from Table 5.9 of Pedagogical Strategies in the preceding section, Table 5.8 illustrates the number of instances of curricular flexibility identified for each instructor. Observations include both on-the-fly alterations as well as alterations to printed material. Instructors with * next to their name indicated that he/she would make printed alterations. This provides important clues into some distinct differences between positive outlier and non-positive outlier instructors.

Table 5.8: Instances of Curricular Flexibility

	Positive Outlier Instructors						Non-Positive Outlier Instructors				
	INSTR 1 (P)	**INSTR 4 (P)**	**INSTR 6 (P)**	**INSTR 7 (P)**	**INSTR 8 (P)**	**INSTR 10 (P)**	**INSTR 5(A)**	**INSTR 2 (N)**	**INSTR 3 (N)**	**INSTR 11 (A)**	**INSTR 12 (N)**
Curricular Flexibility	10*	8*	3*	8*	2*	4*	7	1	1	1	3

First, and perhaps most interestingly, all the positive outlier instructors indicated that they would make printed alterations to the to the curriculum, while none of the non-positive outliers did. Given that Statway is a curriculum that is written with both an instructor's lesson plan and student handout, with great attention to detail in regard to instructor notes, we were surprised that so many instructors would modify printed materials to curriculum. Further, in each of our preceding findings described in this chapter, findings about average instructors (Instructor 5 and 1) were often not too different than the positive outliers. This is the first of our findings related to attending to student challenges which indicates an explicit line between positive outliers and non-positive outliers. Thus, we believe that curricular flexibility, especially in regard to altering printed materials, may offer insight in positive deviance.

Our argument that these findings related to alterations to printed curriculum are important in accounting for positive outliers is compounded by our findings related to instructor averages in regard to curricular flexibility, generally. While every instructor in our study indicated that he/she would make some kind of modification to the curricular materials, either on-the-fly or printed alterations, positive outliers (with a mean of 5.8) are 2.2 times more likely to show curriculum flexibly in regard to number of adaptations than non-positive outliers (with a mean of

2.6), see Table 5.9 below. Given the spread of means, as illustrated in Figure 5.5, we argue that these averages are not impacted by outliers and are a true estimate of group differences.

Table 5.9: Mean and Median of Curricular Flexibility

Total Curricular Flexibility	**Mean**	**Median**
Positive Outliers	5.8	6
Non-Positive Outliers	2.6	1

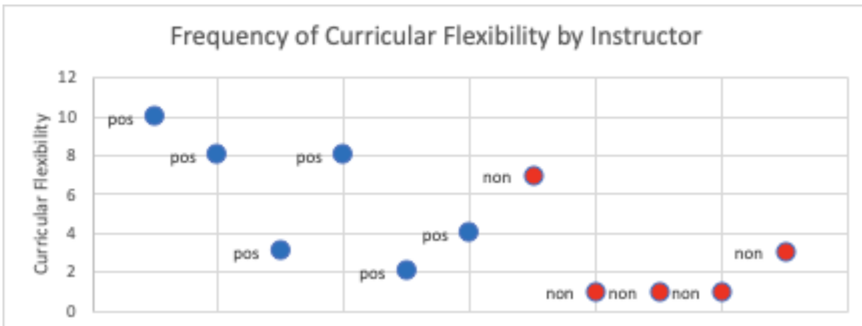

Figure 5.5: Frequency of Curricular Flexibility by Instructor

Pedagogical flexibility. Our exploration of *pedagogical flexibility* focuses on instructor talk around use of pedagogical strategies. We noticed, for example, that while some instructors said things like, "Here, I would write on the board to show students how to set up ratios", other instructors showed less certainty in the pedagogical strategy they would use in the moment, using words like "depend", "if", "may", "probably" to describe student challenges and their responses to such challenges. We call these instances of *pedagogical flexibility.* Observations of pedagogical flexibility include any instance of an instructor showing some amount of uncertainty, or flexibility, in anticipated students challenges and appropriate pedagogical responses. Table 5.10 below highlights some examples of pedagogical flexibility in our data.

Table 5.10: Examples of Pedagogical Flexibility

	Examples from Interview
Pedagogical Flexibility	"**Depending** on how the groups are working, I will…"- INSTR 8 "**If I noticed** that they were having a hard time with the concept, I **may** have…" - INSTR 8 "I would try to explain it my best, **but, if it didn't work, I would probably**…" INSTR 8 "**If** I felt like they weren't grasping it, or if the discussion wasn't as productive, **I would**…" INSTR 4 "I'd expect there to be some questions. I'd expect there to be some confusion. **I might expect** to point out the steps of building the ratios if there were questions about that" INSTR 4 "**Depending** on if the students are getting it....**I might.**."- INSTR 7 Primarily, when I teach, **I really try to listen for what they're having trouble with**, **and so I don't go in with a solid plan of "this is exactly how it will execute"**. I just kind of **adapt to what their needs seem to be**, so **based on sort of what issues come up** as they're going through that, **I would either** work with inidicidual groups, or if a lot of groups are having similar difficulties, I may bring the group together and talk about a concept, and then set them loose again. - INSTR 8 I mean, **class is always different than what you plan for it to be**. **You have to go with it**. I would want a few more examples and questions in my back pocket. **If it wasn't going well**, or they needed more examples, **I would** want to have them written out, so I didn't have to come up with them on the spot, to give students more material. **But, if it was going well as written, I'd feel fine moving on. -** INSTR 4

How does pedagogical flexibility account for positive outliers? To explore this, we show the number of observations of pedagogical flexibility, by instructor in the Table 5.11 below.

Table 5.11: Pedagogical Flexibility

	Positive Outlier Instructors						Non-Positive Outlier Instructors				
	INSTR 1 (P)	INSTR 4 (P)	INSTR 6 (P)	INSTR 7 (P)	INSTR 8 (P)	INSTR 10 (P)	INSTR 5(A)	INSTR 2 (N)	INSTR 3 (N)	INSTR 11 (A)	INSTR 12 (N)
Pedagogical Flexibility	10	11	3	6	10	5	2	0	0	3	1

We use these frequency counts to examine the means between the two groups. As evidenced by the mean and median in the Table 5.12 below, positive outlier Instructors are approximately 6 times more likely to describe their pedagogical strategies in flexible terms than non-positive outliers.

Table 5.12: Mean and Median of Pedagogical Flexibility

Total Pedagogical Flexibility	**Mean**	**Median**
Positive Outliers	7.5	8
Non-Positive Outliers	1.25	1

Figure 5.6 below helps us see the spread of averages.

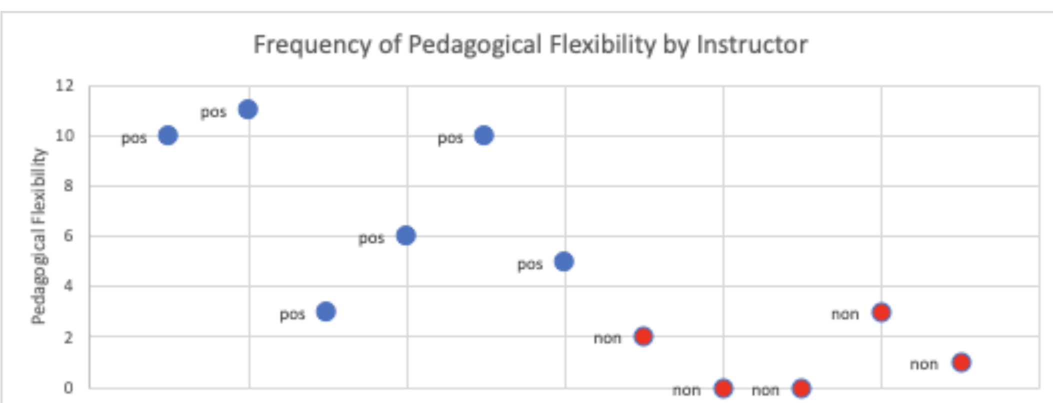

Figure 5.6: Scatterplot of Pedagogical Flexibility

This scatter plot furthers our belief that pedagogical flexibility holds one of the most significant explanatory factors that account for positive outliers in our study.

Although we originally sought to understand how differences in instructor knowledge can explain differential teacher effectiveness, our findings point to instructor differences in the *ways in which they build knowledge* of student challenges, and *the ways in which they deploy* their knowledge in response to challenges, to hold the most significant explanatory power, as evidenced by instructor empathy, and instructor curricular and pedagogical flexibility described in the preceding sections. In the next section, we explore instructor curricular and pedagogical flexibility together, under the umbrella of *instructor agility*, or the ability to notice, and respond flexibly, to varying student challenges. Then, we use explore the relationship between instructor empathy and instructor agility to better understand how these two findings work together to explain positive outlier outcomes.

Part 3: The Relationship Between Empathy and Agility

Agility

As described in Part 2, our findings suggest that in attending to student challenges, positive outliers are more agile than non-positive outliers. We define instructor agility as the ability to notice, and respond flexibility, to varying student challenges. In this study, instructor agility is the sum of instances of curricular flexibility (modifying curriculum in-advance or during lesson enactment) and pedagogical flexibility (e.g. responding to student needs in flexible ways)(see Figure 5.12 below)

Table 5.13: Frequency of Instructor Agility

	Positive Outlier Instructors						Non-Positive Outlier Instructors				
	INSTR 1 (P)	INSTR 4 (P)	INSTR 6 (P)	INSTR 7 (P)	INSTR 8 (P)	INSTR 10 (P)	INSTR 5(A)	INSTR 2 (N)	INSTR 3 (N)	INSTR 11 (A)	INSTR 12 (N)

Curricular Flexibility	10*	8*	3*	8*	2*	4*	7	1	1	1	3
Pedagogical Flexibility	10	11	3	6	10	5	2	0	0	3	1
TOTAL AGILITY	**20**	**19**	**6**	**14**	**12**	**9**	**9**	**1**	**1**	**4**	**4**

Using these frequency counts, we calculate the mean and median of the two groups, so that we can better see differences between the positive outlier and non-positive outlier groups.

Table 5.14: Mean and Median of Agility

Agility	**Mean**	**Median**
Positive Outliers	13.3	13
Non-Positive Outliers	3.8	4

Positive outlier instructors have an average agility count of 13.3, and non-positive outliers of 3.8. Thus, positive outliers are 3.5 times more likely to evidence agility than non-positive outliers.

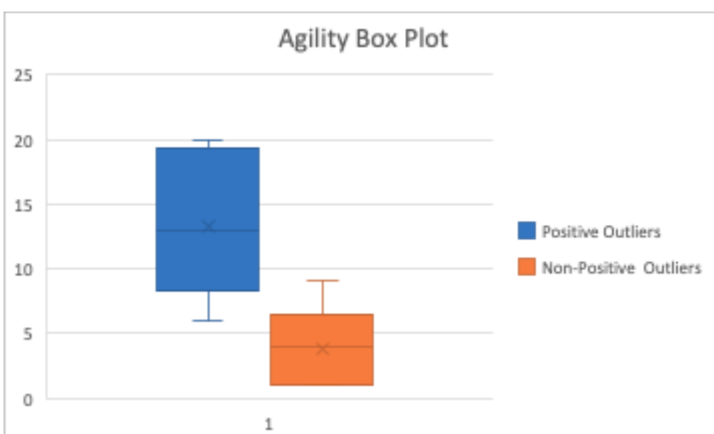

Figure 5.7: Box Plot of Instructor Agility

This, coupled with our box plot of instructor agility above, provides evidence that instructor agility is important in understanding what makes positive outliers different, as there is very little overlap across the two groups. This is not surprising, given our findings from both conceptual flexibility and pedagogical flexibility above.

The Relationship Between Empathy and Agility

Together, our findings suggest that all instructors have the knowledge to anticipate, see and attend to student challenges. While our findings suggest that positive outliers *may* have increased knowledge to support these kinds of instructional activities, it is difficult to draw explicit conclusions, as sample size is small and differences between groups are small. However, our findings suggest that the ways in which instructors build knowledge about students (empathy) and the ways in which instructors deploy knowledge about students and pedagogy (agility) have more explanatory power of outlier success than knowledge alone. This is illustrated in Figure 5.8 below, in the white boxes. In this section, we explore the relationship between heightened empathy and heightened agility.

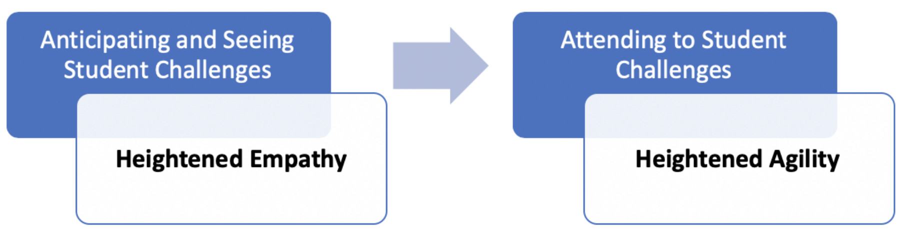

Figure 5.8: Anticipating and Attending to Student Challenges with Empathy and Agility

To do this analysis, we group instructors into three groups within categories of Empathy (left column in Table 5.14 below) and Agility (right column in Table 5.14). Instructors in Group 1 have the highest number of observations in each category; instructors in Group 2 have the second highest number of observations in each category; and instructors in Group 3 have the fewest observations in each category.

Table 5.15: The Relationship Between Empathy and Agility

	EMPATHY	AGILITY
Group 1	**INSTR 1 (43)**	**INSTR 1 (20)**

	INSTR 7 (31)	INSTR 4 (19)
	INSTR 8 (30)	**INSTR 7 (14)**
Group 2	**INSTR 6 (26)**	INSTR 8 (12)
	INSTR 4 (26)	**INSTR 10 (9)**
	INSTR 10 (25)	**INSTR 5 (9)**
	INSTR 5 (21)	**INSTR 6 (6)**
Group 3	**INSTR 11 (17)**	**INSTR 11 (4)**
	INSTR 2 (15)	**INSTR 12 (4)**
	INSTR 12 (12)	**INSTR 2 (1)**
	INSTR 3 (3)	**INSTR 3 (1)**

Note that instructors who are in the same group for "empathy" and "agility" are bolded. Using this table, we can see that there seems to be some relationship between heightened empathy and heightened agility. In most cases, instructors who are in group 1, 2, or 3 in regard to empathy statements are in the respective group (1, 2, or 3) in regards pedagogical agility. Further, all of the instructors in Group 1, and three out of four instructors in Group 2 are positive outliers, while group 3 is made up entirely of non-positive outliers. Instructors who are bolded are in the same group (1, 2, or 3) for both categories (empathy statements and pedagogical agility). Further, empathy and agility share a strong positive correlation (r= .85), further suggesting a relationship between the two. Given this relationship, we are not convinced that empathy and agility are separate things, but perhaps, that they are two parts of the same thing, a proclivity toward continuously seeing students, and shaping practice in response.

Our findings in Chapter 5 show that while instructor knowledge *may* account in some way for differences in instructor success with struggling students, largely, positive and non-positive outliers generally shared similar knowledge in regard to identifying student challenges and pedagogical strategies to attend to them. Our findings, however, point to the deployment of such knowledge in the classroom as, perhaps, the most significant key difference in positive outliers and non-positive outliers. Specifically, we found instructor empathy and agility in deployment of knowledge to hold significant explanatory power of what makes positive outliers different than non-positive outliers.

CHAPTER 6: DISCUSSION

Accounting for Outliers

In this work, we have offered some granular, though preliminary, evidence of how individual differences account for positive outlier developmental mathematics instructors. With the aim of building theoretical understanding of how individual differences in instructor knowledge drive practice, and positive deviance, our work also helps us understand the role of empathy and agility in mathematical practice. Exploring how instructors anticipate, see, and attend to student challenges, we examined the frequency and types of student challenges instructors identified, as well as the pedagogical strategies used to attend to challenges. Table 6.1 below shows a summary of our broad findings.

Table 6.1: Overview of Broad Findings

	Positive Outliers	**Non-Positive Outliers**
	Mean	*Mean*
Trouble Spots	8	6
Empathy	30	14
Unique Ped. Strategies	6	5
Total Ped. Strategies	29	17
Agility	13	4
Curricular Flexibility	6	3
Pedagogical Flexibility	8	1

While positive outlier instructors are somewhat stronger in every category of data analysis (trouble spots, empathy, pedagogical strategies, and agility), our findings indicate that instructor empathy and agility are key differences between the positive outlier group and the non-positive outlier group. In these two categories, positive outliers have double the observations than non-positive outliers. For example, positive outliers use empathy statements approximately twice as many times as non-positive outliers, especially in how they talk about lesson design, external factors that influence student learning, and how their understanding of student perspective drives instruction. Further, positive outliers illustrate agility in attending to student challenges over three times as often as non-positive outliers by having the ability to notice and respond to varying student challenges. Agility in our study focuses on curricular flexibility (e.g. making "on-the-fly" modifications to the lesson or to the printed lesson materials), and pedagogical flexibility, an instructor display of some amount of uncertainty, or flexibility in anticipated student challenges and appropriate pedagogical responses. Only positive outlier instructors in our study indicated that they would make modifications to the printed materials. Further, we are also particularly interested in pedagogical flexibility, as positive outliers are eight times more likely to illustrate pedagogical flexibility than non-positive outliers. Thus, as an unanticipated finding in our study, we argue that future research should examine the nuances of pedagogical flexibility and explore more explicitly the relationship between pedagogical flexibility and instructor deviance in student outcomes.

It is worth pointing out here that the use of total pedagogical strategies is another category of analysis that showed a distinct difference between positive outliers and non-positive outliers. Positive outliers mention specific pedagogical strategies nearly 1.7 times as often as non-positive outliers. Given the findings around agility, we believe that this may be further evidence of instructor's agility in responding to specific student challenges, rather than increased access to pedagogical strategies, given the similarity in numbers of unique pedagogical strategies mentioned across both positive outliers and non-positive outlier instructors.

In what follows, we explore our findings within the context of current literature. First, we take up a discussion of our findings about instructor knowledge, and specifically, mathematical knowledge for teaching, given that is the conceptual framework guiding this student. Then we explore our unanticipated findings, which center on instructor empathy and agility. We discuss how these concepts are taken up in the current literature and reflect on how they might build our understanding of instructor knowledge and effective teaching.

Instructor Knowledge

In the section above, we described the individual differences found in our study that account for positive outliers. We believe that our findings elaborate on teacher knowledge research, and specifically, the work of Ball, Thames, and Phelps (2008) on mathematical knowledge for teaching (MKT). In particular, our findings align with the domains of MKT that are knowledge of content and students (KCS) and knowledge of content and teaching (KCT).

Like the knowledge of content and students (KCS) domain of MKT, our work shows that key areas of teacher knowledge needed to promote student learning include teachers' ability to anticipate students' conceptualizations and mis-conceptualizations of the mathematics concepts. In other words, teachers need to be able to anticipate (and see, in the classroom) what students may struggle with, as well as what they may find interesting, motivating, or confusing (Ball, Thames, and Phelps, 2008). In our study, we found that positive outliers, those instructors with high success rates with struggling students, had increased ability to anticipate student conceptualizations and mis-conceptualizations of the curriculum that non-positive outliers.

Our findings also align with the knowledge of content and teaching (KCT) domain of MKT. Like the domain of KCT, our findings highlight the importance of instructor know-how to attend to differential student conceptions of mathematics. For example, know-how to attend to student differential understanding of materials may include differentiated sequencing of content for instruction, and use specific examples, models, or representations to support student learning, to name a few (Ball, Thames, and Phelps, 2008). We found that positive outliers have greater agility in responding to student challenges than non-positive outliers.

The findings presented in this manuscript provide a granular insight into instructors' KCT and KCS in a developmental mathematics classroom. We argue that our study provides evidence, although an unintended finding, that increased KCT and KCS are key differences to more effective teaching, as illustrated by the positive outlier instructors in our study.

Instructor Empathy and Agility

Our findings suggest that teacher knowledge, as described above, is a key individual difference in accounting for positive outliers. In this section, we explore how our unanticipated findings relate to empathy and agility are taken up in literature. We begin with a discussion of the idea of instructor proclivities for teaching mathematics (Lewis, Fischman, Riggs, 2015). While mathematical knowledge for teaching (MCK), described above, outlines the kinds of knowledge that support mathematics instruction, we argue, following Lewis, Fishman, and Riggs (2015) that proclivities help explain how this knowledge comes into play in the work of teaching. In other words, instructors' likelihood of behaving in certain ways may be explained by their proclivities in teaching mathematics, guided by their their knowledge and beliefs about how to deploy that knowledge. The findings of our work suggest that instructor proclivities toward empathy in seeing, and describing, student conceptualizations and mis-conceptualizations of mathematics, and a proclivity toward responding to the student conceptualizations with agility, significantly accounts for the gains in student achievement by positive outliers in our study. To illustrate what we mean here, we draw on an example from Instructor 8 to illustrate proclivities toward empathy and proclivities toward agility in deploying her knowledge of content, students, and teaching.

Empathy

Throughout Instructor 8's interview, she deploys knowledge of content and students (KCS) with a proclivity toward empathy. In the quote below, Instructor 8 anticipates that students may struggle with mathematics question number four.

> It will vary here. Students who have decent reading skills will not have a hard time with number four. But those who struggle with reading, will need a little extra help. Sometimes I feel like when there's a long explanation that requires critical reading (in Q3) followed by a question, some students will need additional verbal support on top of the reading, others won't. -Instructor 8

Rather than simply saying, "Students will struggle with question number four", she illustrates empathy in her analysis of student struggles, attempting to consider why students will struggle (e.g. critical reading skills, length of text). Instructor 8's proclivity toward empathy is further illustrated as she expects variation in student conceptualizations of question number four, and anticipates how different student may respond (e.g. "some student will need additional verbal support on top of the reading, others won't").

For decades, scholars have indicated instructional proclivity toward empathy as an important instructional quality (Ladson-Billings, 2009; Gordon, 1999; Noddings, 1984). A review of literature indicates that empathy is defined as an increased sensitivity to other cultures (Germain, 1998) and responsiveness to others' perspectives (Goleman, 1998; Oliner & Oliner, 1995). Our findings shows that empathy matters for effective instruction, especially in regards to lesson design, or anticipating how students might experience the design of the lesson and attending to those needs; knowing and considering the external factors that impact student learning inside the classroom as part of understanding how students might experience a lesson, and using an empathic lens to see how students will differentially experience parts of a lesson and using that understanding to tailor instructional decisions.

Researchers have found that instructional empathy, such as that found in our study, can foster motivation, attentiveness, openness, and positive relationships in classrooms, and result in better academic achievement, especially with culturally diverse students (Foster, 1995; Gay, 2000; Irvine, 1990). Yet, interestingly, some researchers caution that while empathy is a desirable trait among instructors, effective instruction is not built on empathy alone but also on sufficient teacher knowledge (Kennedy, 1991). That is, the implementation of empathy in the classroom is an iterative cycle of knowledge-building and using that knowledge to make decisions (Warren, 2014). This aligns with what we found in our study illustrating that both teacher knowledge and empathy, together, are factors accounting for improved student outcomes. Additionally, in line with our study, Delpit (1995) suggests that instructor empathy fosters flexibility in teaching in diverse contexts. Thus, we argue that empathy may be an important building block for instructor agility, described in the next section.

Agility

In another example, we illustrate how Instructor 8 also shows a proclivity toward agility in deployment of knowledge of content and teaching (KCT). Throughout her interview, she discusses many different pedagogical strategies, such as providing direct instruction, guided inquiry, scaffolding, and supporting language and literacy, to name a few. However, what distinguishes Instructor 8, and other positive outliers, from non-positive outliers, is her proclivity toward agility in enacting these strategies. In other words, while all instructors show evidence of knowing how to respond to specific student challenges, positive outliers are more inclined to be agile in response, based on interactions in the classroom. Instructor 8 illustrates this proclivity toward agility in the quote below.

> Primarily, when I teach, **I really try to listen for what they're having trouble with**, **and so I don't go in with a solid plan of "this is exactly how it will execute"**. I just kind of **adapt to what their needs seem to be**, so **based on sort of what issues come up** as they're going through that, **I would either** work with individual groups, or if a lot of groups are having similar difficulties, I may bring the group together and talk about a concept, and then set them loose again. - Instructor 8

Non-positive outliers in our study were much more likely to discuss their pedagogical strategies with certainty (e.g. I will read this passage aloud to ensure all students follow along). Instructor 8's quote above shows an important contrast to this. In her response, she discusses the importance of *not* going in with the definite plan, but being open to what students need, and responding to it in the moment. This is illustrated in her word choice "adapt to their needs", "based on what comes up", and "I would either". This, we argue, is evidence of Instructor 8's proclivity toward agility.

In our study, we use language, as described above, as a proxy for instructor agility in responding to student needs. In other words, one of our foci is understanding *how* instructors talk about instruction as a window into their flexibility. This is supported in literature on instructional flexibility, which argues that teachers must continuously practice reflection and metacognition in order to keep their finger on the pulse about students' changing needs and appropriate instructional responses (Duffy et al, 2009). That is, instructors must always be open to the changing and complex nature of the classroom, rather than stagnant in their perspective of what instruction should look like. Our study also found instructors' flexibility in adapting curriculum to be a key factor explaining positive outliers. Scholars have taken up the work of understanding instructional adaptations for decades (Clark & Peterson, 1986; Hoffman & Duffy, 2016). Given the unpredictable nature of classrooms, where teachers face the challenge of attending to students' differing background, experiences, and academic skills and abilities, it is not surprising that it is widely accepted that curricular adaptations are centerpiece of effective instruction (Wittrock, Clark & Peterson; 1990; Dewey, 1910; Hoffman & Duffy, 2016; Parsons, 2012).

While there is a great deal of work on instructors' adjustments of teaching to the diverse and changing needs of students as a cornerstone of effective instruction (Borko & Livingston, 1989; Pearson & Hoffman, 2011; Vagle, 2016), there is little agreement on terminology. Some terms used to describe what we call agility in this dissertation, include adaptability (Corno, 2008; Darling-Hammond & Bransford, 2005; Hattie, 2009); responsive teaching (Dozier, Garnett & Tabatabai, 2011); improvisation (Sawyer, 2004); reflective teaching (Souto-Manning & Dice, 2007); and dialogic teaching (Boyd, 2012), to name a few. While most of the work on instructor agility is situated in the K-12 setting, we argue that our work shows the applicability of instructor agility in higher education, as well, and especially in the community college context, where student populations are especially diverse.

While we argue that our findings support Ball, Thames, and Phelps (2008) domains of mathematical knowledge for teaching of KCS and KCT, our findings also highlight the importance of instructors' proclivities toward empathy and agility in enacting such knowledge in practice in the classroom. In fact, our findings suggest that these proclivities toward empathy and agility in enacting mathematical knowledge for teaching may account for positive outliers more than teacher knowledge alone. Further research is needed to better understand the relationship between knowledge, proclivities, and student achievement.

Study Significance and Implications

While the field of education has engaged in work on positive outlier practice for decades, few scholars in education to-date have sought to understand outliers in detail to *deeply* explore what outliers do to understand *why* positive outliers deviate from the norm. In cases where practice is not easily observable, a was the case in Gloria Ladson-Billings' Dreamkeepers work, we must seek to understand what underlies, and drives, practice to build theoretical understanding of deviance. Most outlier work in education research tries to understand the external features of outliers' practice, but few studies seek to build detailed, theoretical understanding to explain why deviance occurs in a specific context. In this work, we address this gap, building theoretical understanding of what accounts for positive outliers in Statway, a community college developmental mathematics course. Our findings suggest that individual differences in instructor knowledge and proclivities toward empathy and agility in teaching mathematics explain positive outliers' exceptional success. We argue that our study has several important contributions to the field, especially in regard to mathematical knowledge for teaching, teaching and learning in community college classrooms, and methods for exploring variation in outcomes. We end this section with recommendations for future research.

The Role of Empathy and Agility in Mathematics Teaching and Learning

This study began as an inquiry into instructor knowledge, with a specific focus on mathematical knowledge for teaching. Importantly, our study shows that mathematical knowledge for teaching may be an important element of effective instruction, but that instructor mathematical knowledge, alone, may not account for positive outliers' exceptional outcomes. Our study suggests that instructors' tendency toward empathy and agility in deploying their knowledge may also hold significant explanatory power in exceptional outcomes. Thus, this study sheds light on the need to understand other aspects of teacher characteristics that play a role in classroom experiences. Further, it highlights some ways in which we can broaden our thinking, as a field, about teacher knowledge to include the characteristics that are key to student success.

More specifically, we believe that this study shows the importance of attending to the affective side of mathematics teaching and learning. For students generally, but especially those in developmental mathematics, mathematics is often a scary experience, as students vary greatly in regard to mathematics confidence, knowledge, and skill. Thus, we argue that while it makes sense to continue to investigate the cognitive aspects of teacher knowledge, it is critical to understand the affective factors, such as empathy and agility as well, in order to build more nuance around the idea of teacher knowledge.

In many ways, our study has raised more questions than it has answered: how much of instructor success can be attributed to their empathetic approach and agilely responding to student needs? Or, are these characteristics important because they increase relationship-building between student and teacher? Similarly, what is the relationship between student affect (especially important in developmental mathematics classrooms) and teachers' instructional approaches? In other words, can teachers help students shape their emotions around mathematics learning? Additionally, are there ways that we can capture and study instructors' attention to affective aspects of learning, in addition to empathy and agility, such emotional intelligence?

In sum, we suggest that it is critical to develop research agendas around mathematics instruction, especially in the community college context, that take up work that seeks to explore and understand the socio-emotional aspects of mathematics teaching and learning, both on its own, and in relationship with more cognitive approaches to studying mathematics, such as MKT.

Community College Classrooms

In addition to expanding our scope of mathematical knowledge for teaching, this work contributes to our understanding of community college classrooms and, more specifically, developmental mathematics classrooms. Community college instruction is grossly understudied (Boylan, 2002; Stigler, Givvin & Thompson, 2010), and this study provides rich data qualitative data about developmental mathematics instruction, building our understanding of facilitators and barriers to quality performance in developmental mathematics classrooms (Bryk, Gomez, Grunow and LeMahieu, 2015; Langley et al., 2009; Shewhart, 1931). Second, it provides some insight into what works in community college developmental mathematics classrooms, from a practical perspective, so that we may spread these successful strategies elsewhere. Third, in this same vein, this study illuminates the work of community college developmental mathematics faculty and provides deep understanding of the ways these faculty think about their work as mathematics instructors, and how their knowledge underpins practice.

In particular, our study provides insight into the importance of instructor empathy and agility in community college developmental mathematics classrooms. Community college developmental mathematics classrooms, perhaps, hold some of the most diverse students of any classrooms in the United States. Given that community colleges allow open-enrollment, offer a wide range of professional and academic programs, students required to take developmental mathematics courses have a very wide range of academic and professional goals. Further, students in these classrooms also have diverse life circumstances and experiences, including a range in age among students, students attending school while working part or full-time, students caring for children at home, students that are first-generation college students and non-native English speakers, to name a few (Bailey, Jeong & Chon, 2010; Cohen & Brawer, 2008; Merseth, 2011). For this reason- the extraordinary diversity among students in developmental mathematics classrooms- we argue that an instructor's empathic ability to anticipate how students will experience learning in his or her classroom, and the flexibility to adapt instruction accordingly, is particularly important in this context. Given the dearth of research in community college developmental mathematics classrooms, we believe this is a significant contribution of the study.

Methods for Exploring Variation

We argue that the work presented in this manuscript generates new ways of studying variation and producing more detailed knowledge about outliers in instructional settings. Our conceptual framework draws on anticipating and attending to trouble spots as a lens into differences in instructor knowledge across faculty. We used artifact-prompted analysis to collect the bulk of our data, analyzing both a lesson and instructional videos with instructors during interviews. We found that this conceptual framework and method of collecting data provided granular evidence of instructor knowledge, as well as giving a window into instructor practice. Given the constraints of our study (being unable to collect observational data of instructor practice), and resources, we found these methods to be very effective at producing more detailed knowledge about instructor variation, and what accounts for this variation across the instructors in our study.

In the same vein, this work delves deeper into the more micro nature of variation among individuals. While work that looks at outliers in education often focuses on organizational-level factors (Gallimore, et al., 2009; McDougall et al., 2007; Reeves, 2003; Snow-Gerono, 2005; Thoonen et al., 2011; Yu, et al., 2002), our data pushes us to explore individual instructors as the unit of analysis. In the work reported in this dissertation, we examine the granular nature of positive outliers, focusing on the how and the why of what they do to understand the nature of their deviance. This kind of work, as described in the opening chapters of this dissertation, is not often done in education research. We argue that our findings suggest, that yes, examining individual-level factors can provide explanatory insight into positive deviance. Here, it is important to note that many of our findings were unanticipated. They arose as a result of coding for a different, anticipated, difference. Thus, we we believe, if undertaking work described above, in the importance of being open to what participants bring to light through their responses.

Recommendations for Future Research

Our work provides a foundation for future work seeking to understand what accounts for positive outliers in instructional settings in a detailed way. The work presented here offers significant contributions, primarily highlighting the needs to broaden our research on mathematics teaching and learning to include affective aspects of instruction, including empathy and agility, community college instruction, and methods for examining variation.

First our findings suggest that further exploration of the relationship between the cognitive aspects of teacher knowledge and tendencies toward empathy and agility in deploying that knowledge. The findings in our study suggest that teacher knowledge and affect may be complementary parts of a whole, that should be studied in tandem. One important way to do this would be to include observational classroom data, aimed at highlighting how both knowledge and proclivities play out during enactment of instruction, with an eye toward understanding the two concepts separately and in relationship to each other. We argue that mathematics research should focus on the socio-emotional aspects of teaching and learning as a first-class topic in the community college setting. As discussed earlier, this would include building increased understanding of the nature of the socio-emotional aspects of instruction, including students and teacher affect, relationship-building, emotional intelligence, and empathy, among others. The work reported here underscores we must understand how to better integrate these kinds of teacher characteristics into classroom instructions to improve mathematics teaching and learning.

One limitation of our study is that, given our sample size, we are unable to draw conclusions about differences across positive, average, and negative outlier instructors. Our findings suggest that average instructors will present differences from negative outliers, although for the purposes of our study, they are lumped together as "non-positive outliers". Future research should draw on a larger sample size of instructors, including average and negative outlier instructors, so that distinct differences among the three groups can be explored in more detail.

In sum, it is our hope that the work presented in this manuscript, and the foundation it lays for future work, generates more detailed understanding of mathematical knowledge for teaching, instructor proclivities toward empathy and agility, effective instruction in community college developmental mathematics classrooms, and illuminates a new way to study outliers in educational settings. It is our hope that this work will not only build capacity for studying, and understanding mathematical knowledge for teaching in new ways, but also in new contexts, especially the community college setting. We believe that this work builds toward understanding how to discipline approaches to teaching and learning that get at better at understanding the nuances of variation, so that we may be better equipped to support the spread and take-up of effective instruction across many educational contexts.

APPENDICES

Appendix A

Contextualized Quantway Lesson 3.1

Prerequisite Assumptions

Before beginning this lesson, students should

- be able to multiply two fractions.
- be able to divide two fractions.
- understand that a fraction can be simplified by "canceling" or dividing common factors in the numerator and denominator.
- understand that multiplying by 1 does not change a value.
- be familiar with basic units of measure of length (feet, miles) and time (seconds, hours, minutes).

Specific Objectives

Students will understand that

- the units found in a solution may be used as a guide to the operations required in the problem—that is, factors are positioned so that the appropriate units cancel.
- units provide meaning to the numbers they get in calculations.

Students will be able to

- write a rate as a fraction.
- use a unit factor to simplify a rate.
- use dimensional analysis to help determine the factors in a series of operations to obtain an equivalent measure.

Problem Situation: Acetaminophen Confusion

Andy and Amanda are two new parents with a six-month-old little girl named Isabella. It is 2 a.m. Isabella just woke up crying. She has a fever of 102 degrees Fahrenheit. It is her first high fever. Andy and Amanda are worried. Amanda calls Isabella's doctor to see if they should bring the baby to the emergency room. The doctor tells her to give Isabella acetaminophen (Tylenol®) to try to lower the fever before bringing the baby to the hospital.

The doctor prescribes a teaspoon of acetaminophen. (Acetaminophen is the active ingredient in Tylenol®.) Andy rushes to his local grocery store to buy medicine for Isabella. While at the store, Andy sees different types of acetaminophen. He is confused (see Figure 1).

Figure 1: Different types of acetaminophen for children and infants

(Source:

http://www.fda.gov/ForConsumers/ConsumerUpdates/ucm263989.htm)

Figure 2: Infants' Acetaminophen Drug Facts

Drug Facts

Active Ingredient (in each 1.0 mL)	***Purpose***
Acetaminophen 80 mg........	**Pain reliever/Fever reducer**

(Source: http://www.fda.gov/ForConsumers/ConsumerUpdates/ucm284563.htm)

Figure 3: Children Acetaminophen Drug Facts

Drug Facts

Active Ingredient (in each 5 mL)	***Purpose***
Acetaminophen 160 mg......	**Pain reliever/Fever reducer**

(Source: http://www.fda.gov/ForConsumers/ConsumerUpdates/ucm284563.htm)

Isabella's doctor did not specify the type of acetaminophen to use. Andy assumes the package would give the dose. But, the package only says to "consult a doctor" for children under 2 years. Andy notices two different types of acetaminophen for young children: children or infant acetaminophen. Andy thinks it might be a good idea to buy the infants' type, because Isabella is a six-month-old infant.

Andy looks closely at the formula on the back of each box. The concentration amount of acetaminophen is different in each formula.

The problem is that Andy is not sure what is best to give her. He does not know what a teaspoon is in milliliters (mL). He is worried he might give her too much or too little medicine.

(1) Which type of acetaminophen should Andy buy for Isabella? Is there any information missing that you need to be able to answer the question? Brainstorm possible answers with your group. Write your answer in **1-2 complete sentences.** (It is important to write complete sentences because it helps your instructor better understand your mathematical thinking.)

Acetaminophen Overdoses

Before the lesson, you watched the video "'It Just Goes Silent': Brianna Hutto and Tylenol." The video shows the tragic effects of confusing infants' and children's acetaminophen. Baby Brianna's parents were faced with the same dilemma as Andy and Amanda above. In both cases, doctors were not clear about the type of acetaminophen to give.

In this lesson, you will learn two ways to figure out dosages for patients. The first way is using a chart. The second way is to use the method called dimensional analysis.

Using a Dosage Chart

Let's practice using a dosage chart for acetaminophen.

Figure 4: Acetaminophen Dosage Chart

Child's Weight	Child's Age*	Dose (mg)
6 to 11 lbs	0-3 months	40
12 to 17 lbs	4-11 months	80
18 to 23 lbs	12-23 months	120
24 to 35 lbs	2-3 years old	160
36 to 47 lbs	4-5 years old	240
48 to 59 lbs	6-8 years old	320
60 to 71 lbs	9-10 years old	400
72 to 95 lbs	11 years	480
96+ lbs	12+	640

*Whenever possible, use the child's weight to determine the proper dose. NOTE: This chart was generated for Quantway purposes. Do not use this chart to figure out acetaminophen dosages for your children or patients. Consult the dosage chart for the particular brand of acetaminophen you are using.

(2) Answer the questions below. Show your calculations.

(a) What is the concentration of the infants' formula? What is the concentration of the children's formula?

(b) How many mL of infant acetaminophen should the doctor prescribe for the 5-year old patient?

(c) How many mL of children's acetaminophen should the doctor prescribe for the 5-year old patient?

(d) What would happen if too much acetaminophen is given for a particular concentration?

Using Dimensional Analysis

Dimensional analysis is a method of setting up problems that involves converting between different units of measurement. It is also called *unit analysis* or *unit conversion*. Many healthcare professionals—including pharmacists, dieticians, lab technicians, and nurses—use unit analysis. It is also useful for everyday conversions in cooking, finances, and currency exchanges.

Many people can do simple conversions without dimensional analysis. However, they are more likely to make mistakes on more complex problems. In healthcare situations, like calculating dosages of medicine, mistakes can be very serious, even fatal. Doctors and nurses rely on dimensional analysis to check their calculations.

The advantage of using dimensional analysis is that it is a way to check your calculations. It is always important that you develop your own methods to solve problems. But, this is a time when you are encouraged to learn and use a specific method. Once you have learned dimensional analysis, you can decide when to use it and when to use other methods.

Problem #3 walks you through the dimensional analysis process.

(3) Let's return to Andy and Amanda's dilemma. At the grocery store, Andy calls the doctor but cannot reach him. Instead, Andy speaks to the on-call Advice Nurse.

> Imagine you are this Advice Nurse. You want to know how much medicine should be administered to Isabella. Isabella is a 6-month-old child who weighs 15 pounds (lb). The medicine comes in a liquid form. You will measure in teaspoons (tsp). The children's concentration is 160 mg per 5 mL.

Step 1: Start with what you need to know. You need to calculate how many teaspoons (tsp) should be given to a 15 pound (lb) child. The target unit for this calculation is *tsp*.

$$\rightarrow\ tsp$$

Step 2: We start with a rate that has the target unit in the numerator. Since 1 teaspoon holds contains 5 milliliters (mL) of liquid, we have:

$$\frac{1\ tsp}{5\ ml}\ \rightarrow\ tsp$$

Step 3: We want the mL to cancel out in the denominator, because this is not the unit we are looking for. In children's acetaminophen, every 5 mL of this medicine has 160 mg of the drug. We write it as a rate and multiply by it. Milliliters cancel in this step:

$$\frac{1\ tsp}{5\ \cancel{ml}} * \frac{5\ \cancel{ml}}{160\ mg}\ \rightarrow\ tsp$$

Step 4: Now we need to cancel milligrams (mg). We know Isabelle weighs 15 pounds and recommended dosage for her weight is 80 mg (see the chart presented in figure 4 above). We can use this weight to complete our calculation.

$$\frac{1\ tsp}{5\ \cancel{ml}} * \frac{5\ \cancel{ml}}{160\ \cancel{mg}} * \frac{80\ \cancel{mg}}{1} \rightarrow\ tsp$$

The only unit left is *tsp,* which is our goal. Now we carry out the numerical calculation and obtain $\frac{1}{2}$ teaspoon of children's acetaminophen.

(4) Use dimensional analysis to calculate how many teaspoons (tsp) Andy should give Baby Isabella if he buys *infants' acetaminophen* instead.

(5) In this question you will explore the differences in the concentrations between children's acetaminophen and infants' acetaminophen. We consider little Isabela who is a 6-month-old child and weighs 15 pounds as an example.

(a) How many mg of acetaminophen should be given to Isabella?

(b) Using the dosages calculated for Isabella, compare the portion of a teaspoon dosage of infant's acetaminophen to the portion of a teaspoon dosage of children's acetaminophen. Calculate the ratio of children's acetaminophen concentration to the infant's acetaminophen concentration. Write a sentence that interprets this ratio in the given context.

(c) Recall that children's acetaminophen has a concentration of 160 mg per 5 mL and infants' acetaminophen has a concentration of 80 mg per 1 mL.. Calculate the ratio of infant acetaminophen concentration to the children acetaminophen concentration. Write a sentence that interprets this ratio in the given context.

(d) Write **1-2 complete sentences** to describe and explain the differences between the infants' and children's formula. In your answer, use the Tylenol Problem situation and the calculations you have made in this lesson to help you discuss the differences between the two formulas.

(6) As parents to an infant, Andy and Amanda must consider what to feed Isabela. For newborns, there are two different types of formula: a 'Ready-to-Feed' liquid, and a powder formula. Formula is very expensive. Andy and Amanda must calculate the cost for each formula to determine which one fits their budget. They must feed little Isabela every 3 hours, and each feeding is 140 mL. Remember, 1 ounce= 30 mL.

(a) The ‘Ready-to-Feed’ liquid costs $8 for 32 ounces of formula. What is the cost of using the ‘Ready-to-Feed’ formula for 1 month?

(b) The powdered formula is $32 for 1 container of powder. This makes 169 ounces of formula when mixed with water. What is the cost of using the powdered formula?

Appendix B

Interview Protocol: Lesson and Video Analysis

1. Please take a few minutes to review **Contextualized Quantway Lesson 3.1.** As you are reviewing, please point out, to me, which areas you think may present trouble for students.
   a. Prompts:
      i. Why do you believe this is a trouble spot? In other words, what about this part of the lesson specifically do you think may be challenging for students?
      ii. If you were teaching this lesson, how would you prepare to address the trouble-spot?
   b. Is there anything else that stands out to you about this lesson that you would address in your preparation to teach it?

2. For the remainder of the interview, we'll focus our discussion on two videos of instruction of lesson 3.1. The goal of watching these videos is not to evaluate the instructor in the video, but to connect it to your own practice as a Statway instructor. The first video focuses on question 5c of the lesson, which asks students to calculate ratios. Please take a moment to review question 5c now.
   a. Do you see a trouble spot here?
   b. In what ways, if any, do you think this question may present trouble for students?
   c. Now, I'll show the video. It's about 4 mins. Do you see any places in the video where the students or teacher are struggling?
      i. Would you consider this a trouble spot? Why or why not?
      ii. If so, what signs are there that it's a trouble spot?th

3. Now, I will play the video a second time. As you are watching the video, we ask that you think about your own practice.
   a. What do you notice? How does this instructor use similar or different practices than you may use to address the trouble spot? Please feel free to ask me to stop the video to chat at any time.

b. Follow-Up Questions:
    i. In this clip, the instructor writes information from the problem on the board, and draws on this information to lead students through the problem.
        1. What do you think are his intentions? Why do you think he is doing it this way? What do you think he hopes to accomplish? How is this similar or different than how you may have approached this situation in a Statway course?

4. I am about to start the second video. Remember, the goal of this exercise is not to evaluate the instructor, but to think about your own practice. This video focuses on question two in the lesson. Please take a moment to read question two. Do you see a trouble spot here?
    a. In what ways, if any, do you think this question may present trouble for students?
        i. As you are watching, what do you notice? How does this instructor use similar or different practices than you may use to address the trouble spot? Please feel free to take notes while watching the video, and you may stop the video to chat at any time.

        ii. Follow-Up Questions:
            1. Would you consider this a trouble spot? Why or why not? If so, what signs are there that it's a trouble spot?
            2. In this first clip, Mary is listening as the students debate the concept of concentration, and steps in at the end of the clip with her own explanation.
                a. What do you think are her intentions? Why do you think she is doing it this way? What do you think she hopes to accomplish?
                b. How is this similar or different than how you may have approached this situation in a Statway course?

Appendix C

Instructor Consent

Consent to Participate in Statway Instruction Study

You are asked to participate in a research study for the UCLA Resiliency team conducted by Emily Pressman and Louis Gomez, Ph.D. (lead investigator). You were selected as a possible participant in this study because you currently or previously taught Statway.

Purpose of the Study

You have been invited to this study because the UCLA Design team is very interested in learning about your experiences as an instructor of Statway. In particular, we want to better understand the instructional practices you used in Statway, and your beliefs about developmental mathematics students and instruction. The goal of this study is to better understand developmental mathematics instruction in general, with the aim of improving instruction over time.

Procedures

If you elect to participate in this study, you may be asked to do the following: Participate in a single 60-90 minute one-on-one semi-structured interviews via Skype or Zoom.

Potential Risks and Discomforts to Subjects

Because this is an exploratory study about your experiences as a mathematics instructor, some interview questions may involve issues about experiences with previous mathematics courses. You may feel uneasy about answering some of these interview questions, and may elect not to answer any of the questions with which he or she feels uneasy and still remain as a participant in the study. Further, you also have the right to decide to withdraw from the study at any time, and ask for previously collected interview data to be erased.

Potential Benefits to Subjects

In general, participants may not receive many benefits personally from participation in this study. However, this exploration addresses the need to improving community college developmental mathematics instruction. Thus, findings of this study may contribute to the improvement of services for students on campus. The information gleaned from the study may lead to greater awareness of and support for student needs and instructional practices in developmental math programs. Payment to Subjects for Participation Participants will not be paid for their participation in this study.

Confidentiality

Any information you share with us will be used for research/evaluation purpose only. We (Emily Pressman and Louis Gomez) will be aggregating results from the study and will not be attributing comments to any particular person. You will not be identified by name, course number, instructor, or any other personally identifying information in any report or document. We hope that you will free to share your impressions and insights, whether positive or negative, openly with us. The interview session will be audio- and video-recorded. I (Emily Pressman) will also be taking notes of the conversation. The audio and video recordings will be transcribed for analysis. The video recorded files, transcribed files, and notes will be stored securely in a password-protected laptop of the evaluator until completion of analysis. Only the evaluation staff, I (Emily Pressman) and the partner evaluators (Louis Gomez) and collaborating researchers, who provide the research team with a copy of their IRB approval from their institution to use these data, will have access to the files and notes. The protection of confidentiality does not constitute legal protection. You have the right to know that your information and responses cannot be legally kept confidential if subpoenaed by a court of law.

Informed Consent

Your participation in this study is voluntary. You are not obligated to answer or respond to any question or to discuss anything that you are not inclined to answer or discuss. You can skip any question, or any part of any question, and will not face any penalty for answering, or not answering, any question in any way. You may ask that the audio recording be stopped at any time and/or may leave the study at any time for any reason without consequences of any kind. At this time, I ask you to read, review, and sign the informed consent form below. If you have questions, please ask them now. If you would like to ask a question in private, please let me know. ***Identification and Contact Information of Evaluator***

If you have questions regarding your rights as a research subject, the details of this study, or any other concerns please contact Emily Pressman at eshorton@ucla.edu.

Rights of Research Subjects

You may withdraw consent at any time and discontinue participation without penalty. You can halt your participation in the study at any time. You are not waiving legal claims, rights, or remedies because of your participation in this research study. If you have questions about your rights while taking part in this study, or you have concerns or suggestions and you want to talk to someone other than the researchers about the study, please call the OHRPP at (310) 825-7122 or write to: UCLA Office of the Human Research Protection Program, 11000 Kinross Avenue, Suite 211, Box 951694, Los Angeles, CA 90095-1694."

Informed Consent: Signature of Research Subjects

I have read and understand the procedures described in this “Consent to Participate in Research.” My questions have all been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

____

Name of Subject

____

Signature of Subject **Date**

Signature of Investigator or Designee

In my judgment the research subject is voluntarily and knowingly giving informed consent and possesses the legal capacity to give informed consent to participate in this research study.

____

Name of Investigator or Designee

____

Signature of Investigator or Designee **Date**

Appendix D

IRB Documentation

UCLA OHRPP
Office of the Human Research Protection Program

University of California Los Angeles
10889 Wilshire Blvd, Suite 830
Los Angeles, CA 90095-1406

http://ora.research.ucla.edu/ohrpp
General Campus IRB: (310) 825-7122
Medical IRB: (310) 825-5344

APPROVAL NOTICE
New Study

DATE:	11/9/2018
TO:	LOUIS GOMEZ, Ph.D EDUCATION
FROM:	TODD FRANKE, PhD Chair, NGIRB
RE:	IRB#18-001712 Accounting for Positive Outliers Version: 10.11.2018

The UCLA Institutional Review Board (UCLA IRB) has approved the above-referenced study. UCLA's Federalwide Assurance (FWA) with Department of Health and Human Services is FWA00004642.

Submission and Review Information

Type of Review	Expedited Review
Approval Date	11/9/2018
Expiration Date of the Study	11/8/2021

Specific Conditions for Approval

- **3 Year Extended Approval** - The UCLA IRB has determined that this study meets the criteria for a 3 year extended approval. (For reference, please see the OHRPP guidance document "Extended Approval for Minimal Risk Research Not Subject to Federal Oversight" at http://ora.research.ucla.edu/OHRPP/Documents/Policy/4/Extended_Approval.pdf)

Regulatory Determinations

-- **Expedited Review Categories** - The UCLA IRB determined that the research meets the requirements for expedited review per 45 CFR 46.110 categories 6 and 7.

Documents Reviewed included, but were not limited to:

Document Name	Document Version #
18-001712_Instructor Consent.pdf.pdf	0.01
18-001712_recruitment email v2.pdf.pdf	0.01

Important Note: Approval by the Institutional Review Board does not, in and of itself, constitute approval for the implementation of this research. Other UCLA clearances and approvals or other external agency or collaborating institutional approvals may be required before study activities are initiated. Research undertaken in conjunction with outside entities, such as drug or device companies, are typically contractual in nature and require an agreement between the University and the entity.

General Conditions of Approval
As indicated in the PI Assurances as part of the IRB requirements for approval, the PI has ultimate responsibility for the conduct of the study, the ethical performance of the project, the protection of the rights and welfare of human subjects, and strict adherence to any stipulations imposed by the IRB.

The PI and study team will comply with all UCLA policies and procedures, as well as with all applicable Federal, State, and local laws regarding the protection of human subjects in research, including, but not limited to, the following:

- Ensuring that the personnel performing the project are qualified, appropriately trained, and will adhere to the provisions of the approved protocol,
- Implementing no changes in the approved protocol or consent process or documents without prior IRB approval (except in an emergency, if necessary to safeguard the well-being of human subjects and then notifying the IRB as soon as possible afterwards),
- Obtaining the legally effective informed consent from human subjects of their legally responsible representative, and using only the currently approved consent process and stamped consent documents, as appropriate, with human subjects,
- Reporting serious or unexpected adverse events as well as protocol violations or other incidents related to the protocol to the IRB according to the OHRPP reporting requirements.
- Assuring that adequate resources to protect research participants (i.e., personnel, funding, time, equipment and space) are in place before implementing the research project, and that the research will stop if adequate resources become unavailable.
- Arranging for a co-investigator to assume direct responsibility of the study if the PI will be unavailable to direct this research personally, for example, when on sabbatical leave or vacation or other absences. Either this person is named as co-investigator in this application, or advising IRB via webIRB in advance of such arrangements.

Appendix E

Initial Recruitment Email

Dear [Participant],

I am writing to introduce you to Emily Pressman, a doctoral student at UCLA. Emily has worked with the Carnegie Foundation for a number of years developing curricula and resources for Pathways. She is currently studying Statway instructional practice, focusing on how to better support students who struggle. I am emailing to connect you with Emily (cc'd here), and ask if you would be interested in participating in this work.

We are interested in your insights about Statway even if you no longer teach Statway or developmental mathematics. Participation would involve a single 1-1.5 hour online video conference. Participation is completely voluntary, and answers will be kept anonymous.

Improving community college teaching and learning, especially developmental mathematics, is critical, yet very little research focuses on it to-date. I believe that this is a great opportunity to contribute to, and build, our understanding of how to better support community college students.

If you are interested, please contact Emily Pressman at eshorton@ucla.edu.

My best,

Anthony Bryk

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