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Learning to Teach Physics : Exploring Teacher Knowledge, Practice, and Identity

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LEARNING TO TEACH PHYSICS:

EXPLORING TEACHER KNOWLEDGE, PRACTICE, AND IDENTITY

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ABSTRACT

LEARNING TO TEACH PHYSICS: EXPLORING TEACHER KNOWLEDGE, PRACTICE, AND IDENTITY

by Nellista E. Bess

Urban and rural high schools in the United States often struggle in regard to the staffing of their physics classrooms with qualified teachers. Some states have responded to this challenge with education policy as a means of addressing the critical shortages of physics teachers by permitting inservice teachers to attain physics certification through endorsement programs. Although research on alternative certification typically evaluates and compares diverse models, this study focuses on teachers' own perceptions of their experience in the aforementioned program, as well as their learning and development in and beyond preparation for physics endorsement.

In this qualitative multiple case study, informed by social constructivist and feminist epistemological perspectives, the participants included teachers of various discipline specializations: mathematics, history, biology and Earth science. The study's design included purposeful sampling and three data collection methods: interview, a questionnaire, and classroom observations in regard to the teaching of physics. The teachers underwent a series of semi-structured interviews that focused on the examination of their experiences in context by inviting them to share personal and professional details about themselves, including their physics preparation, and their subsequent professional development and teaching experiences with respect to physics.

The results with respect to the above noted indicate that all four of the teacher participants felt well prepared to teach physics. The curricular materials from the certification program offered teachers support in subject matter content knowledge and pedagogy, particularly during their first two years. In some cases, the participants' physics identity was both stable and enduring over time and context. This study finds that the participants' beliefs about the nature of physics (which encompass sources of knowledge or how physics knowledge is acquired), exerted a far greater influence on teacher practices than even the participants themselves recognized.

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Dedication

This dissertation is dedicated to my beloved husband and our dear son who both provide unending inspiration and encouragement. Thank you for both being so wonderfully patient and understanding as to the time it has taken to finish this dissertation and degree process.

Table of Contents

List of Tables

List of Figures

LEARNING TO TEACH PHYSICS:

EXPLORING TEACHER KNOWLEDGE, PRACTICE, AND IDENTITY

Chapter I: Introduction

In an ideal world, well-prepared teachers would thoroughly understand the nature and substance of the subject matter that they teach, would be well-versed in the latest teaching theories on learners and learning, and would be knowledgeable about subject-specific pedagogy. These teachers would have ready access to well-appointed and equipped classrooms in order to better perform and perfect their pedagogical practices. They would bring their knowledge to bear and make creative modifications to their teaching practices. Unfortunately, not every teacher is adequately prepared to more fully meet the challenges of classroom teaching and a good many teach in a less than ideal school and or classroom setting. Teachers leave teacher education programs and go into teaching environments that vary dramatically: socio-economically, culturally, in the preparation of students and even in terms of classroom support from school leaders, colleagues, and parents. In the classroom setting, teachers must make numerous decisions about how to best teach subject-matter content, to solve problems of practice and, in doing so, they must appropriate conceptual and pedagogical tools that they learned during their preparation for such a position (Grossman, Smagorinksy, & Valencia, 1999).

Purpose of the Study

The purpose of this study is to investigate the experiences by which inservice teachers, whose academic backgrounds are not in the field of physics, expand their teaching specialization to include physics. Therefore, this study is concerned with teachers' own perceptions of their program experience as well as their learning and development in and beyond preparation for a physics endorsement.

Statement of the Research Problem

School districts across the country have been reporting critical shortages with respect to qualified high school physics teachers (American Physics Institute, 2102). In physics classrooms across the U.S., less than half of these classes (47%) are taught by a teacher with a degree in the subject, as compared to 73% of biology classes, and nearly 80% of humanities classes, as can be seen in Figure 1[1] (American Physics Institute, 2012). For reasons that will be gone into later, some school districts face challenges in the recruitment of qualified physics teacher candidates.

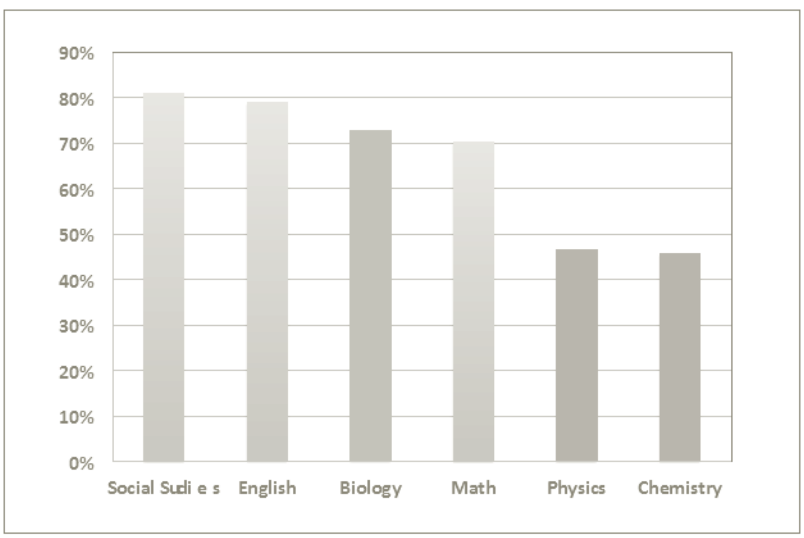

Figure 1. The percentage of high school classes taught by teachers with a degree in the subject (American Physics Institute, 2012).

[1] This data represents the findings of a survey study performed by physics department chairpersons of universities with physics teacher education programs.

According to the American Physical Society (2012), approximately 3,100 new physics teachers that are available to high schools each year 1,700 are experienced high school teachers who are teaching physics for the first time.

One key underlying reason for the shortage of high school physics teachers is the decline in the percentage of undergraduate physics majors, especially those that would like to become teachers (American Institute of Physics, 2012). A recent report by the American Physics Institute (2018) on national trends in regard to the undergraduate degrees earned by STEM majors of all disciplines in Science, Technology, Engineering, and Mathematics indicated that 2.2% of undergraduate science degrees are awarded in physics as compared to 4% of other STEM related programs of study. In addition, when compared across their respective fields of employment, most physics bachelors have not been found to tend to pursue teaching; rather, they generally seek private industry employment. Mulvey and Pold (2017) of the American Institute of Physics found that 65% of physics undergraduate degree holders work in the private market, while just 9% were found to teach high school physics. The majority of those with physics bachelors that do teach the subject in high school are employed within suburban schools. The reasons for this include factors like better wages and working conditions, for example, better access to quality teaching materials and greater administrative support (Hanushek & Rivkin, 2007).

In response to this, states such as New Jersey have generated new educational policy as a means of addressing such critical shortages of physics teachers. This policy grants permission for alternative certification that provides for subject-matter endorsements, i.e., an additional specialization credentials added to an initial teaching certificate (New Jersey Senate and General Assembly, 2014). Such policies are intended to assist in the better distribution of qualified teachers in diverse academic disciplines, including physics, between suburban, urban and rural school districts. The alternative certification programs that offer endorsements in the field of physics vary in their design (Humphrey, Wechsler, & Hough, 2008; Wilson, Floden, & Ferrini-Mundy, 2002).

In New Jersey, for example, the endorsement agreement between provisional teacher education programs or an approved teacher preparation program and the State permits inservice teachers that are already certified to teach in another subject to be able to take on the responsibilities of a physics teacher while still completing the required coursework and other specified certification criteria. Such policy provisions waive the previous requirement to have a degree in physics by substituting a coherent sequence of physics courses in its place. In so doing, this provides more teachers with a pathway to such licensure (New Jersey Senate and General Assembly, 2014).

Although endorsement policies have been helping districts with the most severe shortages to set up staff members in physics classes, it does not address the related problem of the pairing of children in poor rural and urban school districts with either inexperienced teachers or those without a college degree or who even minored in the subject they teach (Lee & Luykx, 2008). Hence, while endorsement policies offer these more vulnerable school districts a solution to such shortages, they further exacerbate the pattern of pairing children in the highest-poverty schools with teachers who are without a major or minor in the subject they teach (Peske & Haycock, 2006, p. 1). In this scenario, a third of all classes assigned to rural and urban high-poverty communities are taught by teachers who do not hold either an undergraduate or graduate degree in the subject that they teach, as compared to about one in five students in low-poverty schools (Peske & Haycock, 2006).

Another significant disconcerting effect of the unequal distribution of well-qualified physics teachers is the disparate impact that it has been having on the educational opportunities of children who attend a school in high-poverty rural and urban districts. Such impact includes, but is not limited to, the underrepresentation of students of color that have been pursuing undergraduate degrees in physics (Peske & Haycock, 2006). Rosa and Mensah (2016) in a study on the underrepresentation of people of color in physics careers, revealed that when children are exposed to school sponsored science programs at an early age, they subsequently develop an interest in the pursuit of science related academic and career paths. Hence, unequal opportunity in physics education with respect to one's social class, in turn, contributes to disparities in the college and career outcomes of such affected students (Cornell University, Physics Teacher Education Coalition, 2011).

When it comes to the recruitment of and retaining of physics teachers, rural and urban high-poverty school districts, which have high numbers of children of color, are less able to compete with low-poverty school districts that can afford to offer better salaries and working-conditions. Moreover, in the same vein, schools in low-poverty districts are known to have more well-resourced classrooms, as well as greater opportunities for staff members to teach advanced placement courses. While examining the effects of socioeconomic status on students' educational experiences, Kozol (1991) chronicled in his book, "Savage Inequalities," how children in poor communities, unlike their peers in wealthy communities, tend to attend schools with less qualified teachers and fewer resources, often including facilities that are in a state of disrepair. Because property taxes and school funding are closely linked in the United States, with most of such tax revenue used for public school education, high-poverty districts with low property tax revenue are dependent on state funding and are more vulnerable to cuts in aid which, in turn, affects their ability to recruit and retain more competitive teaching candidates (Berliner, 2014).

School funding inequities that have demonstrated deleterious effects on a district's ability to improve academic achievement levels and the educational attainment of students from low-income neighborhoods "has mapped so neatly and regularly onto the ethnic realities of our schools" (Ladson-Billings, 2006, p. 6). In fact, a recent report on parents' perceptions with respect to the quality of education that their children receive, found that "black and Latino parents believe that lack of funding for students of color is seen as the biggest cause of racial disparities in education" (The Leadership Conference Education Fund, 2017).

Indeed, parents who live in low-income communities and whose children attend schools affected by inequitable funding, are often caught in the middle of legislation that restricts school funding and that relaxes teaching qualifications for difficult-to-staff school subjects like physics. In the meantime, when high-poverty schools, especially those serving black and Latino students, are challenged in the recruitment and retaining of physics teachers, as they have few staffing solutions, such shortages tend to persist.

Although the trend in research on alternative certification has been to evaluate and compare different models, this study is concerned with teachers' own perceptions of their physics preparation experience. More specifically, the central issue that is investigated herein is that of teacher learning and development in relation to their participation in a physics endorsement program.

Significance of the Study

This study has several implications with respect to future research on such teachers' personal experiences in their participation in endorsement programs, which have value yet offer but a partial solution to the national high school physics teacher shortage. Nevertheless, diverse districts often have limited options in this regard and so must rely on partnerships with endorsement programs to be able to staff their physics classes. Current research being performed in the realm of science teacher education has paid scant attention to the preparation and development of endorsement candidates, and research in this area is scarce. This research contributes to the studies in the current literature concerning the experiences of inservice teachers from various nonphysics backgrounds as they prepare for and develop as physics teachers following their participation in a physics endorsement program. Findings drawn from this study contribute to the knowledge base on this topic in regard to the design and implementation of similar physics endorsement programs, and perhaps toward theory development on how nonphysics majors learn to teach the subject. Hence, it should help to gain a better understanding of the needs of this cohort of developing teachers during their time spent in preparation and across the continuum of their careers. Drawing on Feiman-Nemser's (2001) thoughts on the needs of early career teachers and on the learning-to-teach continuum, the research question guiding this study focuses on the sources of influence in regard to endorsement physics-teachers' learning and development and these teachers' perceptions about such experience. Hence, this question can be stated as follows: How do experiences in and beyond an alternative certification program for the teaching of physics shape teachers' knowledge, practices, and the identity?

Research Epistemology

The research epistemology is inspired by the premises inherent in social constructivist and the feminist perspective, both of which see knowledge as socially constructed within historical and cultural contexts (Brown, Collins, Duguid, 1989; Collins, 1990; Lennon & Whitford, 1994; Peshkin, 1988; Merriam, 2009; Riley, Schouten, & Cahill, 2003; St. Louis & Barton, 2012). Similarly, in feminist epistemology, one of the goals of this study is to represent lived experiences in ways that diverge from the norm and to assert the value of this contribution to the literature. From the feminist perspective:

> All knowledge is the product of a relation between a knower/knowers in certain particular social and political locations, and the 'world' as it appears to her/them, as mediated by the concepts, codes, discourses at her/their disposal. Any knowledge-claims should thus be seen in relation to the context of their production and not in isolation as though made from nowhere (Lennon & Whitford, p. 270).

Feminism epistemology reflects ways of knowing from multiple perspectives, including that of an Afrocentric feminist thought. In this study, black feminist perspective is viewed through the lens of Collins (1990) in order to help others to better understand what it was like to learn to teach physics after having studied in different areas of specialization. Integrating components of the ethics of caring and personal accountability, herein I embrace one's personality as that which adds to an individual's lived experience, thereby underscoring personal biographies, emotions, and expressiveness in the participants' interpretations of events.

From their point of view on the situated nature of cognition, Brown et al. (1989) can be said to argue that one's ability to reason and use knowledge is connected to the activities, context, and culture in which one learned such things. Hence, my interpretation of the study's results, the knowledge co-constructed along with the participants, the research methodology employed, the conceptual and theoretical lenses through which I viewed the participants' lived experiences, and my own personal subjectivities as the researcher here, and how I positioned myself, and was unknowingly positioned by the research participants, which I will explore in the sections below, all are inseparable.

Peshkin (1988), Merriam (2009), and Riley et al. (2003) have asserted that the life experiences of the respective researcher involved therein can influence a study's results. They argued that personal, as well as cultural and social factors, can affect one's data analysis and interpretation, as they inform the assumptions, biases, and theoretical orientations that researchers insert into the research experience. If a researcher does not give thoughtful attention to the role that these contextual factors have on their analyses, they may misinterpret particular events and generate findings that are devoid of these considerations. St. Louis and Barton (2012) offered a similar perspective on their analysis with respect to the role that social positioning has in research based on one's perceived race, gender, and economic class and, I would add, possession of symbolic forms of cultural capital, such as educational attainment, professional credentials, as well as how one communicates through verbal and in written form. St. Louis and Barton noted that, not only do "contextual factors such as the historical, political, social, and cultural forces within a society position people even before they are born," but researchers are wise to consider whether such points mediate the researcher-participant relationship (p.251).

Indeed, in the realm of research, one's attention to how they are positioned based on their perceived race, gender, and economic class, as well as the researcher's symbolic forms of cultural capital, mediate the researcher-participant relationship. Thus, having an awareness of the impact of social positioning by the researcher with respect to the participants, and the converse, is quite important if one is to understand how socially based perceptions sustain the power relations that underlie the researcher-participant relationship. This study, then defines power as "the effect of interactions between unequal positions in a social landscape" (Lynch, 1982, p. 65). Riley et al. (2003) noted that power relations exist in research and that they particularly arise from "imbalances produced through [the] different social positions held by researchers and participants" (p. 3).

Position Statement

The ideals, beliefs, and fears that this researcher has held throughout the research process have informed this study. Therefore, it is important to disclose my background as a researcher in order to help readers better understand the lens through which I interpreted the experiences of my participants. I am an African-American female who grew up in an inner city with concentrated poverty but now resides in a suburb with concentrated wealth.

I am a science educator at the high school level with 17 years of teaching and leadership experience who has an undergraduate degree in biology. Like the participants in this study, I entered the field of teaching through an alternate route program. Moreover, as I held a degree in biology, I was certified to teach this subject. While I do not recall much about that educational experience, I do recall that the program did not provide any subject-specific methods courses.

As a high school Biology teacher, my primary concern was always in regard to getting a clear sense of how the students were understanding the course material. As a result, it seemed best to be quite cued in on body language, facial expressions and to ask the students for their feedback on the lesson, even inviting them to challenge me on a piece of information by asking: "I just explained this and so, as some of you did seem to understand well enough, why didn't anybody ask me about this and that." It was important to me to do so in order to adjust my teaching content and/or practices accordingly if they were facing challenges with the material. This approach seemed, not only to strengthen my knowledge of how to better teach biology, it also developed up a degree of trust with my students built on mutual respect. In fact, I often commended them by saying how much more talented and knowledgeable they were in many areas, including biology, than when I was a student their age. This was effective, as after school many students returned to my class more to hangout than for tutoring.

Memories of the first ten years of my life are scientific in nature. I enjoyed caring for stray animals, including cats and dogs, I wanted to become a veterinarian. Yet in elementary school the only way that I was able to identify with being a good student was through the realm of science. As such, matriculating into a pre-veterinary medicine program led me to major in biology.

While going for my undergraduate degree, I became a substitute teacher and was mentored in regard to this position by a former high school science teacher. After graduation, I started teaching biology at my high school alma mater but, as I also wanted to teach chemistry, and to combine my knowledge of both subjects to create the types of elective courses that I had in college. However, as a biology major, I lacked the number of credits required to officially minor in chemistry. Hence, despite a passing score on the Praxis Chemistry examination, it was all but impossible to acquire the remaining credits needed to meet the State of New Jersey's licensure requirement, as such courses were not offered when I had time off from work in the evenings. Thus, I remained a biology teacher until transitioning to my current leadership position.

As a supervisor of science instruction in a high school, I became personally familiar with the endorsement program under investigation in this study, as my district addressed its physics shortage by recruiting teachers to participate therein. In some cases, once certified, such a physics teacher taught in my department. In the previous 5 years, my district had recruited teachers to participate in the endorsement program while its physics teacher shortage persisted.

My curiosity regarding how nonphysics majors learn to teach the subject lead me to the topic of this research. I also wanted to understand how one develops as a physics teacher despite not being a physics majors in college. Given the amount of resources in regard to both time and money that the district spent on funding such teachers' endorsement, it seemed a worthy endeavor to investigate this phenomenon in order to become informed about how to best support these individuals throughout their career, rather than the converse: that of losing these teachers to other districts or seeing them return to teaching under their initial certifications, thereby increasing the aforementioned shortage.

Hence, positionality also came into play during the research process when I decided not to tell anyone (including the participants) that I was a supervisor, unless they asked me what I did professionally. Furthermore, as one serving in the role of a supervisor can be seen as a person who wields a great deal of power over the livelihood of teachers, I did not want them to view me as a supervisor who was simply there to evaluate their performance with their students. As a result, there are certain lines of inquiry that I avoided altogether, such as investigating the nature of the teachers' subject matter knowledge, or using any data collection methods in my research that assessed their respective knowledge of physics.

Moreover, my subjective experiences in relation to race and gender influenced my relationships with the study's participants. For example, I related to Maya, who is also

African-American, due to what I perceived to be our common experiences as mothers of young men who have persisted despite our having faced a great deal of adversity in order to serve as our sons' role models; we could also be seen as people who both prioritized mentoring relationships with students. I felt a connection to Alex, as we shared a similar upbringing, as well as cultural ties to the Caribbean. I also related to Alex because he reminded of several African-American science teachers I have had in the past who were also male, and who mentored me into the field of teaching. The two of us both value discipline, diligence and share similar views about the importance of education in improving one's quality of life centered on similar family values. I related to Ian and Paul, both white males, as they reminded me of all my previous high school teachers who also shared stories with the class about their own experiences as students. They built relationships with us outside of the classroom by mentoring extracurricular activities like taking part in clubs or coaching sports teams.

I admired the participants' dedication in breaking through and gaining access to the world of teaching high school physics through their work in the endorsement program. Physics is known to be a rather male dominated, white field. I found the participants' attainment levels to be particularly inspiring, especially in terms of the accomplishments of Alex, and especially Maya, as in the field of physics there is an underrepresentation of women in general and women of color in particular. That aside, it has also gained a reputation for being an exclusive club for individuals who are intuitive physicists and mathematicians. Since I had not taken a physics course until college and struggled to earn a "C" in it, I related to the study's participants, who did not view themselves as intuitive physicists, and some of whom had also experienced physics as outsiders with respect to their college majors, or at least that is how they chose to position themselves.

Definition of Terms

This study focuses on the teachers' transition to the teaching of high school physics, including their preparation within the context of an alternative certification endorsement program, their on-the-job learning, and their perceptions of those experiences. I used the terms listed in this section throughout this study in order to describe the respective teachers' learning and development experiences in relation to the: alternate route program, alternative certification program, one's beliefs, classroom teaching practices, coteaching, educative curriculum materials, human agency, inservice teachers, pedagogy, preservice teachers, teachers' beliefs, as well as traditional teacher certification programs. To follow these are broken down in a more detailed manner.

- Alternate Route or Alternative Certification: a non-traditional teacher preparation pathway designed for those individuals who have not completed a formal teacher preparation program at an accredited college or university but wish to obtain the necessary training to become a certified teacher in a state (New Jersey Department of Education, 2018).
- Beliefs: meditating thoughts that function to intervene by influencing human motivation, affect, and action (Bandura, 1989).

- Classroom Teaching Practices: refers to the methods of teaching that are frequently employed in the classroom in relation to planning for, reasoning about, and reflecting on instruction (Windschitl & Barton, 2016).
- Coteaching: the collaborative teaching that occurs when two or more teachers jointly plan, coordinate, and deliver instruction to students in a single physical space (Luckner, 1999).
- Curriculum materials: refers to curriculum materials designed for Grades K - 12 that promote both teacher and student learning (Davis & Krajcik, 2005).
- Inservice teachers: the certified teachers of record who are experienced in a specific subject area of specialization.
- Preservice teachers: the participants of generally traditional teacher preparation programs who are not yet certified teachers of record.
- Pedagogy: deals with the activity of teaching or instructing and the methods used to instruct that distinguishes teachers from other types of professionals.
- Self-Efficacy Beliefs: involves the self-evaluation of one's abilities to complete a certain task or attain a certain level of achievement or performance (Bandura, 1989).
- Teachers' Beliefs: The attitudes and values about teaching students, and the education process such teachers bring into their classrooms. They are the thoughts held by the teacher about the teaching and learning process that go on to influence his/her classroom practices (Parajes, 1992).

- Traditional Teacher Certification Programs: Pathways to teaching certification provided by college or university departments of teacher education offered to preservice teachers that lead to an undergraduate or master's degree in teacher education.

Organization of Dissertation

There are six chapters in this study. In Chapter I, the author introduces the qualitative case study by defining the research question, presenting the purpose for this research, and explaining how it contributes in a significant manner to the research literature on science teacher education and development. Chapter II offers a review of the literature in relation to teacher preparation in alternative certification programs as well as the challenges faced with respect to learning physics. Chapter III goes over the research methods, including the recruiting of participants, collection of data, and the analysis procedures. I also delve into the procedures employed in order to establish the credibility of the study's findings. This chapter also includes a description of the study's limitations. Chapter IV describes the results for all four cases that encompass this study by presenting each case separately. Chapter V offers a cross-case comparison of all four cases. The dissertation concludes in Chapter VI with a discussion of the study's findings and implications, giving recommendations for practices that help support science teachers during their preparation and in their professional development thereafter.

This study begins by framing and giving context to the research topic through a description of the challenges inherent to the shortage of physics teachers now being faced in urban and rural school districts across the United States and goes into its underlying causes as well. The author then goes on to discuss the solution that educational policy has come up with in regard to the staffing needs of districts experiencing such shortages in this area, as well as its impact on teacher quality and student outcomes. This chapter closes by presenting the research question and describing the significance of this study to the field of science teacher preparation and development.

Chapter Summary

This chapter began with a discussion in order to describe the current state of the high school physics teacher shortage and its underlying causes. The author also described the effects that the physics teacher shortage has on the quality of education that districts provide to students in poor rural and urban schools, as well as STEM related opportunities in college and career. I went on to explain this study's contribution to the literature on education and development based on its observations on such teachers' experiences in and beyond their participation in such an endorsement program. I conclude this chapter by stating the epistemological influences on this study, my positionality and go on to define key terms in relation to both teacher learning and development.

Chapter II: Conceptual and Theoretical Framework and A Review of the Literature

The conceptual framework of this dissertation informs its understanding of the preparation of teachers for their practice. The components include: (1) teacher knowledge, (2) conceptions of practice, and (3) practice-based teacher education curricula. Next, I present this study's theoretical framework, which is based on the social constructivist perspective on learning. Finally, I review the research literature related to this study.

Conceptual Framework

Teacher knowledge. Scholars who explore the relationship between teaching and learning agree that both subject matter knowledge and pedagogical content knowledge are crucial to informing effective teaching practice. Like other professionals, such as doctors and lawyers, teachers have a knowledge base on which they can draw. Conceptions of subject matter knowledge, introduced by Schwab (1964) and later expanded by Shulman (1986), emphasized two components, substantive and syntactic knowledge. Respectively, these terms describe what educators should know about the subject they teach and how they should teach it.

Shulman (1986) argued that a well-prepared teacher is one who possesses both types of subject matter knowledge. That is, he or she can recognize various ways of interpreting the concepts of a discipline and can demonstrate sound pedagogical reasoning for selecting one organizational representation over another (Shulman, 1986, p. 9). Moreover, Shulman (1986) explained that it is not enough for a teacher to know the facts or concepts of a domain, but that he or she must also comprehend how these concepts were generated and are related:

> The teacher need not only understand that something is so; the teacher must further understand why it is so, on what grounds its warrant can be asserted, and under what circumstances our belief in its justification can be weakened and even denied (Shulman, 1986, p. 9).

For Shulman (1986), teaching expertise is also characterized by the quality of one's pedagogical content knowledge, or the ability to transform subject matter knowledge into representations that communicate the essential ideas and skills of a discipline to students. According to Shulman, pedagogical content knowledge:

> represents the blending of content and pedagogy into an understanding of how particular topics [big ideas], problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction…. [It] include[s] … the most powerful analogies, illustrations, examples, explanations, and demonstrations … ways of representing and formulating the subject that make it comprehensible to others…. [Pedagogical content knowledge] also includes an understanding of what makes the learning of specific concepts easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning (Shulman, 1986, pp. 8-9).

In addition, Shulman's (1986) notion of this knowledge suggests that it informs planning and teaching.

Other scholars expanded on Shulman's idea of pedagogical content knowledge by including additional components (Grossman, 1990; Magnusson, Krajcik, & Borko, 1999; Park & Oliver, 2008). Grossman (1990), for instance, noted the impact of teachers' beliefs on their classroom practice. She also deems a knowledge of science curricula and curricular resources to be a major component of pedagogical content knowledge. Magnusson et al. (1999), like Grossman (1990), perceived pedagogical content knowledge as consisting of Shulman's two key elements, knowledge of the comprehensible representations of the subject matter and of content-related learning difficulties. Magnusson et al. (1999) built upon the work of Grossman (1990) and Shulman (1986, 1987) by developing a model of pedagogical content knowledge specifically for science teachers. This model contains an extra dimension, topic-specific understandings. Magnusson et al. (1999) described topic-specific pedagogical content knowledge as the representations and instructional strategies useful for teaching a specific topic in science. In concrete terms, this means that teachers can draw on the knowledge of potential learning difficulties and prior experience of the topic, knowledge of the most effective assessment strategies to reveal students' understanding, and knowledge of the science curricula and resources.

Grossman (1990) identified four sources from which pedagogical content knowledge is generated: (a) classroom observation, both as a student and as a student teacher, which often leads to tacit and conservative pedagogy; (b) disciplinary education, which may lead to personal preferences for certain values or topics; (c) specific courses during teacher education, whose impact is normally unknown; and (d) classroom teaching experience. More recently, Park and Oliver (2008) delineated practice-based sources of pedagogical content knowledge. These researchers suggest that it arises from teachers' reflection on knowledge in action and knowledge on action. In addition, an understanding of students' misconceptions shapes planning, teaching, and assessment creation. They also report that a teacher's pedagogical content knowledge may be idiosyncratic in some of its manifestations.

Conceptions of practice. In this study, the term practice is grounded in the sociocultural view of teaching and learning; education researchers have used it to investigate the study of teaching and/or teacher preparation (Cohen & Ball, 1999; Grossman, Compton, Igra, Ronfeldt, Shahan, & Williamson, 2009; Lave & Wenger, 1991). In its simplest form, the description of practice offered by Cohen and Ball (1999), as the "critical activities of [a] profession," applies broadly to medicine, law, and particularly education (p. 13). This definition alludes to the fact that professionals are bound by shared practices that characterize the nature of their work and distinguish members of one profession from another. Highlighting the cultural and historical features of professional practice, Lave and Wegner (1991) conceptualized "practices" as being "property ... created over time by the sustained pursuit of a shared enterprise" (p. 45).

Along these lines, an emphasis on pedagogical practice focuses attention on the integrated work that teachers do in bringing together students, content, and resources (Ball, Sleep, Boerst, & Bass, 2009). Grossman et al. (2009) described practice as "an orchestration of understanding, skill, relationship, and identity to accomplish particular activities with others in specific environments" (p. 2059). More recently, researchers have demonstrated that professional knowledge is embedded in the core practices of teaching. Over the past decade, this idea has emerged as a counter to Shulman's (1986, 1987) concept of pedagogical content knowledge to become a focus in science teacher education and development. In this subfield, Windschitl, Thompson, Braaten, and Stroupe (2012) expanded the notion of practice to encompass the "routine activities teachers engage in devoted to planning, enactment, or reflection that are intended to support student learning" (p. 882). Moreover, Windschitl et al. (2012) proposed that practice is enacted in relation to a professional knowledge base and a specific context, in consideration of what other members of one's professional group are doing and of the audience being served.

Teacher education and practice-based curricula. Teacher education programs have begun to organize preparation curricula and coursework around high-leverage practices, or those that are "most likely to equip beginners with capabilities for the fundamental elements of professional work and that are unlikely to be learned on one's own through experience" (Ball et al., 2009, p. 460). This approach is based on the perspective that teaching consists of practices that can be divided into "teachable elements" (Ball et al., 2009, p. 460), which can be organized and/or run through in a methods course (Lampert & Graziani, 2009). Methods courses provided opportunities for attendees to rehearse how they would facilitate, as classroom teachers, the instructional activities being modelled by the methods instructor (Lampert & Graziani, 2009).

The examination of these key concepts highlights some aspects of the knowledge base underpinning teacher education and development. Overall, these concepts demonstrate that physics endorsement candidates preparing to teach must be competent specialists who demonstrate both a depth and breadth of understanding in the discipline, including subject-specific practices. This involves a familiarity with the nature of physics knowledge and the epistemological modes of inquiry.

Theoretical Framework

Situated learning. This study is grounded in social constructivist theory, which views knowledge creation as a product of social interactions. The theory stems from perspectives on learning and development first articulated by Vygotsky (1978) and expanded upon by Brown et al. (1989) and others (Carlone & Johnson, 2007; Gee, 2000; Holland, Lachicotte, Skinner, & Cain, 1998; Lave & Wenger, 1991; Moore, 2008; Wenger, 1998). Drawing on the work of these researchers, I explore the phenomenon of teachers whose initial certification was not in physics, but who became physics teachers through participating in an endorsement program.

In his social learning theory, Vygotsky (1978) highlights the contribution of interpersonal factors in facilitating thoughts and actions. Brown et al. (1989) add that learning is best understood in light of the context in which it occurs. That is, what individuals in a physics methods course learn about teaching is connected to the activity, context, and culture in which they construct this knowledge. Abstracting knowledge from its authentic context makes it difficult for learners to recognize when to apply it to real-world situations.

In the vein of Vygotsky (1978), Lave and Wegner (1991) and Wegner (1998) emphasize the collaborative nature of knowledge acquisition and the importance of the social and cultural context in guiding thoughts and actions. They conceptualize learning as activities situated in communities of practice—through which shared beliefs, understandings, and behaviors about what it means to be a member are acquired. From the situated perspective, learners enter a community of practitioners first as newcomers, then gradually move toward full participation in its sociocultural practices. Through immersion in the activities of the community, beginners gain access to its knowledge and practices through interactions with veterans and cultural artifacts. Endorsement physics teachers learn to teach through encounters with more experienced instructors and with conceptual tools, such as learning theories and curricula, that "provide organizing frames that guide what they notice, or see, as they grow in their practice" (Nocon & Robinson, 2014, p. 96). Similarly, cultural-historical activity theory states that how teachers respond to problems of practice is determine by the conceptual and physical tools available for use (Saka, Southerland, & Brooks, 2009).

In the communities of practice conceptual framework of learning, learning constructs or reconstructs a social identity. According to Gee (2000), identity is the kind of person one is recognized as being. Identity, however, is not fixed, and, "at a given time and place, can change from moment to moment and … from context to context" (Gee, 2000, p. 99). Therefore, in a community of practice, an individual begins to identify with what it means to be a competent member. For physics endorsement teachers, viewing oneself or being recognized as competent by others will depend on the teaching context.

Science identity. Like Gee (2000), the science education researchers Carlone and Johnson (2007) conceptualize identity as context dependent because it emerges out of the constraints and resources available in a local setting. However, contrary to Gee (2000), they propose that identity can be stable under certain circumstances. They state: “We see identity as fragile and, if habitually accessed, performed, and recognized,” as “potentially enduring over time and context” (p.1192). Carlone and Johnson (2007) also view science identity as responsive to the “influence of social structures like race and gender” (p. 1196). In their research on the participation of women of color in science through academic study and careers, they illustrated the effect of a lack of “recognition by others in cultivating satisfying science identities” among this underrepresented group (p. 1192). This finding points to the role of positioning in the quality of experiences individuals have in science and the meaning they derive from these experiences.

Positional identity. Like Lave and Wenger (1991), Holland et al. (as cited in Bagatell, 2007) located relations of power in the active production of identity. They argue that individuals position themselves or are positioned by others in the context of daily social interactions based on “relations of power, deference and entitlement, social affiliation and distance—with the relational structures of the lived world” (p. 127). In this study, I define positional identity as “a sense of relative social position” within a particular context (Holland et al., 1998, p. 132).

Moore (2008) found that teachers possess multiple positional identities, not only based on race, ethnicity, and gender, but also on economic status, religion, and age, and that these factors influence “how teachers constructed their own identities in relation to the students and communities they served” (p. 700). Moore also suggested that career trajectories of science teachers are closely connected to their positional identities and personal histories in science education (p. 704).

A Review of the Literature

This section surveys the literature on both the challenges of learning physics and teacher preparation in alternative certification programs. First, I investigate why physics is such a difficult subject to learn. Next, I discuss the characteristics of effective alternative certification programs and explore their influence on teacher outcomes.

I performed a search on these topics using two main databases: Google Scholar and Academic Search Complete. As inclusion criteria, I selected peer-reviewed articles from professional journals written in the English language. I used a combination of key terms such as *alternative teacher preparation, alternative certification programs*, and *student difficulties learning physics*. Of the 43 abstracts I initially scanned for relevance to the preparation of science teachers, I used 33. I rejected articles concerning the education of nurses, conference papers, and studies focusing only on linking teacher preparation to student outcomes. The majority of studies evaluated alternative and traditional certification programs by comparing both pathways.

The Challenges in Learning and Teaching Physics

Of the science subjects taught in schools, physics is one of the most difficult. Students possess past experiences, prior knowledge, and preexisting ideas about the way the natural world works, which ultimately influence how well they learn new content (Bransford, Brown, & Cocking, 2000). If learners' informal preconceptions of scientific phenomena are not adequately challenged in ways that facilitate more formal understandings, these ideas will persist unchanged as new ones are encountered (Hewson

& Beeth, 1993). Therefore, even after completing subject-specific coursework, experienced physics teachers still exhibit some of the same kinds of alternative conceptions as do students in an introductory high school physics course (Zavala & Alarcon, 2007).

The challenges for physics learners. Learning science, particularly physics, presents many barriers for students (Bransford et al., 2000; Watson & Konicek, 1990). Research by Redish (1994) and Tuminaro and Redish (2004) suggested several reasons for this. The first is that studying physics requires learners to have a mathematics foundation so they can effectively use or interpret equations that show relationships among quantities (Tuminaro & Redish, 2004). For example, the relationship among acceleration (a), mass (m), and an unbalanced force (F) is given by: F = ma. Aside from algebra- and trigonometry-based physics courses, other approaches include conceptual physics (Hewitt, 1999; McFarling & Neuschatz, 2003).

Second, studying physics requires setting aside everyday definitions of common terms, such as weight, work, and acceleration, and adopting meanings that are unfamiliar to students or do not reflect everyday use (Brookes, 2006). For example, in an everyday context, weight is synonymous with mass. Additionally, Snow (2010) noted that even if students recognize basic terms such as mass in physics word problems, they are still likely to have trouble extracting meaning from a sentence, particularly when they encounter more technical terms like acceleration and tension. Compared with other science subjects like chemistry and biology, physics, with its specialized language and emphasis on abstract conceptual tools, is more difficult to teach and learn (Ornek, Robinson, & Haugan, 2008). The language of physics poses additional challenges for non-native speakers, who must nonetheless learn it in English. For example, although these students may be familiar with a topic, they may struggle to find the English equivalent of first-language words or phrases to communicate their ideas verbally or in writing (Short, Vogt, & Echevarria, 2011).

Third, in physics, communicating ideas requires versatility in the use of many conceptual tools. Students must utilize these tools to represent physical quantities using qualitative mechanisms such as tables or drawings. As Redish (1994) argued:

> Physics as a discipline requires learners to employ a variety of methods of understanding and to translate from one to the other—words, tables of numbers, graphs, equations, diagrams, maps. Physics requires the ability to use algebra and geometry and to go from the specific to the general and back. This makes learning physics particularly difficult for many students (p. 801).

Similarly, McDermott, Rosenquist, and van Zee (1987) found that physics learners have difficulty connecting representations with physical concepts or real-world events, such as constructing a graph for the motion of a ball released from the top of a ramp. Finally, studies reveal that how and what students learn about physics is related to their epistemological beliefs about the nature of physics knowledge (Lising & Elby, 2005) and their goals (Elby, 1999). Lising and Elby (2005) has shown that students concerned only with pursuing good grades spend most of their time focusing on formulas and practice problems instead of learning about concepts and real-life examples.

The challenges for new teacher of physics. As adult physics learners, teachers may experience the same types of obstacles young students encounter. Consequently, these limitations may appear in their teaching in ways that may lead to or reinforce students' conceptual difficulties (Hashweh, 1987). Teachers' misconceptions about physics concepts may prevent them from detecting their students' misconceptions or may make them assess correct student answers as incorrect (Halim & Meerah, 2002; Hashweh, 1987). Moreover, teachers' misconceptions about the ideas that comprise a subject are greater when they teach courses outside their area of specialization (Hashweh, 1987).

Summary of the Challenges in Learning and Teaching Physics.

Learning physics is difficult for adult and younger learners alike. A weak mathematics foundation is an obstacle to knowledge acquisition when the courses focus on quantitative rather than conceptual understanding. The language of physics also challenges students because certain terms are used differently than they are in everyday life. A connection also exists between learning outcomes and students' beliefs about the nature of physics knowledge and how they spend their time while studying for a course. Finally, teachers may have their own informal ideas about physics concepts and principles, which may negatively affect their pedagogical practice.

Characteristics of Alternative Certification Program and Teacher Candidates

Alternative certification programs offer candidates expedited entry into their desired teaching positions. The studies in this section span over thirty years and investigate programs designed to prepare candidates for teaching in public schools. Of these studies, most were conducted via survey and the remainder via interviews. The majority investigated program participants or administrators of college programs.

Characteristics of successful program models. Boser and Wiley (1998), Miller, McKenna, and McKenna (1998), Stoddart (1990), and Tournaki, Lyublinskaya, and Carolan (2009) concluded that pairing high selection criteria with instructional support throughout the first three years of teaching results in alternatively certified teachers who are comparable to their traditionally prepared counterparts. Moreover, the findings indicate that effective alternative certification programs offer additional coursework beyond the initial training (Miller et al., 1998); include mentoring, induction, subject-specific coaching, and other forms of assistance for novice teachers; and develop partnerships with school districts to extend coordinated instructional support (Carter & Keiler, 2009; Foote, Haydar, Gonzalez, Brantlinger, & Smith, 2010). Providing context-appropriate preparation consists of practices like sensitizing candidates to the instructional needs of students from different cultures or orienting them to district-specific curricula and approaches to lesson planning (Stoddart, 1990).

Moreover, some alternative certification programs provide field experiences lasting 12 or more weeks, along with subject-specific methods of teaching courses (Johnson, Birkeland, & Peske, 2005; Kee, 2012). While these factors are generally the most significant, other variables, such as the specific certification program and school context, overlap to influence the growth and development of teachers. Along these lines, Humphrey et al. (2008) revealed that school factors such as strong leadership, a collegial atmosphere, and adequate materials are essential to the effective professional practice of alternative certification teachers. Unfortunately, no studies on alternative certification speaks to the retooling or preparation of practicing teachers for science teaching in general or specifically for physics.

Humphrey et al. (2008) noted that teachers' perceptions of the quality of their certification courses and the value they ascribe to them depend on their readiness to learn. Regarding general or non-subject-specific content and pedagogy, Humphrey et al. (2008) found that participants who could connect their coursework to prior understandings reported greater benefits. For example, the evidence indicates that participants with previous classroom experience are more equipped to learn from their coursework than those without it. The authors concluded that when all program and personal factors are equal, the school context will likely have the "strongest effect" on the learning abilities of alternative certification candidates (p.2).

The Effect of Personal and Professional Characteristics on Teacher Preparation

Several researchers have investigated the experiences of candidates with prior teaching experience and found that it facilitated a successful transition of individuals into their new roles. Scriber and Akiba (2009) found prior teaching experience had a positive impact on the quality of instruction provided to students by mathematics and science teachers. These researchers also noted that prior teaching experience contributed to teachers having a positive disposition toward struggling students when previously gained insights about students' motivation to learn is applied to their new teaching context. These findings support earlier studies that examine the relationship between the personal characteristics of teachers and their practice. Offering the most complex perspective, Stoddart (1990) related teachers' instructional practices to multiple factors, including beliefs about their students' capabilities based on academic or cultural differences. I also showed that in the absence of subject-specific pedagogical knowledge and skills, teachers are likely to develop "highly personalized idiosyncratic approaches to instruction" that are either not appropriate or are inappropriately applied (Stoddart, 1990, p. 15). Moreover, Stoddart (1990, 1993) illustrated how teachers' perceived differences between themselves and their students affect student-teacher relationships and instructional practices. Both studies conducted by Stoddart revealed that when teachers negatively evaluate cultural or academic differences between themselves and a student, they are unlikely to develop or use appropriate and responsive instructional methodologies.

Beliefs about science teaching and learning. Friedrichsen, Van Driel, and Abell (2011) define science-teaching orientation as a teacher's "goals and purposes of science teaching, views of science, and beliefs about science teaching and learning" (p. 359). Brown, Friedrichsen, and Abell (2013) suggested that teachers' science-teaching orientation not only influences their instructional practice, but also how they develop the domain- and topic-specific knowledge and understandings needed to teach science effectively. Similarly, Foote, Smith, and Gillert (2011) examined the instructional practices of novice mathematics educators teaching new content and enacting unfamiliar pedagogy, and related the challenges they encounter to their depth of subject matter content knowledge, the quality of their preparation, and their orientation to teaching mathematics. In particular, Foote et al. (2011) showed that teachers may struggle to enact a new curriculum and its espoused instructional practices when it promotes a teaching orientation that does not reflect their own or does not match the way they learned the same content as children.

Teachers' perceptions of program effectiveness. Studies of how well teachers think their certification program prepared them suggest that a relationship exists between their efficacy beliefs about their teaching abilities and classroom practice. Humphrey et al. (2008), in examining the characteristics of effective alternative certification programs, reported differences in preparation experience and outcomes and concluded that "teacher efficacy was impacted by three input factors: teacher experience, school context, and coursework" (p. 26). These researchers deduced that a supportive school context can be empowering and can make teachers feel they have the skills and knowledge required to succeed in the classroom. On the other hand, a challenging school context can cause alternative certification participants to question their abilities.

Flores, Desjean-Perrotta, and Steinmetz (2004) has shown that high teaching efficacy positively influences instructional experimentation and the use of varied techniques. In addition, the authors note that teachers' confidence in their abilities relates to the amount of instructional experience they possess within an area of expertise. This finding suggests that out-of-field teachers or those teaching subjects not related to their undergraduate or graduate majors will experience challenges with these courses. Experienced teachers who participate in alternative education programs to obtain additional certification to teach a subject outside their area of expertise are like out-of-field teachers and may experience similar barriers.

Teaching Practicum. Like traditional teacher preparation, some alternative program models feature practical components that provide teacher candidates access to opportunities to learning a range of professional skills (Darling-Hammond et al., 2002; Flores et al., 2004; Tournaki et al., 2009. In this regard, several researchers have linked teachers' positive or negative perceptions of their preparedness for teaching to specific programmatic elements. Yet their findings are contradictory. While Flores et al. (2004) and Tournaki et al. (2009) found that teachers who took the alternate and the traditional pathways felt equally prepared for their first teaching assignment, Darling-Hammond et al. (2002) reported that overall teachers from alternative programs generally felt less prepared than their traditionally educated colleagues. Darling-Hammond et al. (2012) noted that alternative program candidates in their study rated their initial preparedness "significantly lower than did graduates of teacher education programs on 25 out of 40 core tasks of teaching such as designing curriculum and instruction, teaching subject matter content, using instructional strategies, and understanding the needs of learners" (p. 290). Kee (2012) found teachers' positive perceptions of preparedness are linked to longer field experience (e.g., 12 or more weeks) and to multiple opportunities to take methods of teaching coursework (at least 3 courses). Similarly, a study was conducted of alternatively certified teachers who prepared to teach physics by practicing with the same curriculum materials and technology they would eventually use with their own students. These candidates reported feeling "very well prepared" to teach their first physics course and "well prepared" to conduct laboratory exercises (Nyre & Talbot, 2012, p. 12). These contradictory findings create a space into which this dissertation seeks to bring more clarity and resolution.

Summary of Program and Teacher Characteristics

The studies discussed here suggest that researchers on teacher preparation in alternative university-based certification programs generally wish to determine their effectiveness compared to traditional programs. Of the studies reviewed, two feature comparisons of only alternative certification programs (Humphrey & Wechsler, 2007; Humphrey et al., 2008). Regarding the participants' level of experience, most researchers investigate preparation programs for new teachers. One study reports on the perceptions of experienced teachers who pursued alternate certification to be able to teach in a new subject area (Nyre & Talbot, 2012).

Of the studies on the factors influencing the instructional practices of alternatively certified teachers, none relate these activities back to subject-specific preparation. Only two studies attribute these practices to the alternative program's coursework or preparation pedagogy (Nyre & Talbot, 2012; Stoddart, 1990). Stoddart (1990;1993) is the sole author to describe subject-specific instructional practices for alternatively certified English and mathematics teachers. Science teachers are not included in the study.

While studies of teachers' beliefs and perceptions contribute to our understanding of how they affect instructional decisions and teaching practice, studies of perceived preparedness do not tell us what teachers actually learn through their coursework experiences or the impact these courses have on their content knowledge of a specific subject or on their practice as a whole (Darling-Hammond et al., 2002; Flores et al., 2004; Kee, 2012; Tournaki et al., 2009). Therefore, this dissertation will investigate the preparation of practicing teachers in physics through their participation in an alternative certification program. It seeks to discover how individuals with non-physics initial certifications learn and develop in their new roles as science teachers following their participation in an endorsement program for physics.

Chapter III: Methodology

Using a multiple case-study approach, this study explores the experiences by which inservice teachers, whose academic backgrounds are not in the field of physics, expand their teaching specialization to include physics. This chapter begins with a discussion of how the research question was crafted. Next, sources of influence on the research design are identified. A description of the physics endorsement program, through which teachers became certified to teach the subject, is provided. After this, the data collection and data analysis procedures used in this lesson are discussed. Finally, a discussion of decisions made to establish trustworthiness of this study is provided.

Research Question

The case study research is guided by the research question: How do experiences in and beyond an alternative certification program for physics teaching shape teacher knowledge, practices, and identity of the program participants? When this research question was created, I was drawing on Feiman-Nemser's (1990) proposed framework concerning the professional learning continuum of teachers along the career path. Therefore, I wanted to not only craft a question that considered participants' preparation experiences, but capture other experiences that participants identified as pertinent to their development as physics teachers.

Research Design

The research design is consistent with the qualitative case study methodology. There is no single definition to describe what case study research is, as this has proven difficult for researchers to define (For example of case study research see: Bogdan &

Biklen, 2014; Merriam, 2009; Stake, 1995; Yin, 2013). According to Harrison, Birks, Franklin, and Mills (2017) the varied definitions among researchers are based on their differing approaches to developing case study methodology, which often reflects the design elements central to their methods. The definition of case study research applied to this current study is drawn from Bogdan and Biklen (2014), who defined case study research as a detailed examination of one setting, single subject, single depository of documents, or one particular event (p. 59).

This study is focused on one particular event as the phenomena of experiences of four teachers of non-physics specializations who switched to physics at various points within their respective teaching careers is being investigated (Merriam, 1998; Merriam 2009). According to Eisenhardt (1991), with multiple cases there is potential for the research to build theory because “different cases offer complimentary aspects of a phenomenon, and by piecing together the individual patterns (of each case) the researcher can draw a more complete theoretical picture” (p. 621). Further, in this particular study, existing research methodology that used a narrative-biographical approach to understanding the personal and professional elements of teachers’ lives and experiences, is drawn upon (Kelchtermans, 1996; Moore, 2008).

Alternative Certification Program Description

The non-degree endorsement program for a secondary physics teacher certification prepares individuals to serve in public school systems at the high school level. Applicants are required to have a position as a full-time teacher and have a standard instructional certificate in any discipline. There was no minimum required number of years of full-time classroom teaching experience. Upon successful completion of the certification program, the teacher must pass the appropriate state test of subject-matter knowledge, which is also known as the Praxis® Subject Assessments. This test measures both general science and physics content knowledge, and is administered through various testing centers (Educational Testing Service, 2018). Passing scores of this assessment are set and determined by the state.

Generally, the participants completed the endorsement program in fourteen months. The program coursework encompassed a series of methods courses designed and centered on knowledge needed for teaching high school physics. The science methods-course curriculum focused on specific practices engaging the participants in learning physics through various high school level curriculum and materials in advance of their eventual use with students. In addition to the coursework offered, the teachers completed a practicum experience. Throughout this study, the endorsement program has been assigned a pseudonym in order to protect the anonymity of the study's participants. For the purpose of this study, the endorsement program has been assigned the acronym ACTS, which represents the fictitious program name: Alternative Certification program for Teaching Science.

Data Collection Methods

Recruiting participants. The participants for this study included teachers of various discipline specializations: mathematics, history, biology, and environmental and earth science. Purposive sampling was used to select participants for this study. In qualitative research, purposive sampling is used when the researcher has knowledge of the population and the purpose of the study (Merriam, 2009). Study's participants were recruited through invitation letters emailed to central district offices. A central office point person in turn forwarded my letter to various school principals. Using purposeful sampling, five potential participants expressed interest in participating in this study. However, one person decided not to participate. In the end, four high school teachers were recruited to participate in this study. In order to protect the anonymity of the teachers in this study, pseudonyms are used in each case to represent these individuals, their colleagues, and the schools were they are employed.

Methods of data collection. In this study, two primary methods were used to gather data. While participant interviews composed the majority of the data, a questionnaire and artifacts of teaching were used as supplementation (Bogdan & Biklen, 2014; Merriam, 2009; Seidman, 2013; Stake, 1995; Yin, 2013). The majority of the data was collected through individual interviews. In addition, when they were available, artifacts of teaching such as assignments used to support student learning in physics were also collected. The interview guide and questionnaire are located in Appendix A. A description of each data collection method is included in this section.

Pilot study. As a way to test the interview guide, two pilot interviews were conducted prior to interviewing the study's participants. Stake (1995) recommended trying the question in a pilot form as a way to determine whether the participants are likely to understand the questions in the same way. The pilot study was conducted with individuals who were not recruited to participate in this study. The first pilot was conducted during the spring of 2016 with a teacher from the school of my employment.

The second pilot was conducted during the fall of 2017, days prior to starting data collection for this study. The willing participants were encouraged to provide honest feedback and the information to retool questions that needed modification, was used.

Table 1

Timeline of Data Collection and Analysis

Year	Research Task	Description
Jun. 2016	Pilot interview guide	
Aug. 2016	Research Log	Began research log. Used the research log to record both descriptive and reflective field notes.
Sept. – Oct. 2016	Recruitment Letter	Drafted recruitment letter and flyer.
Oct. 2016	Pilot interview guide	Began state alternate route program for environmental science teaching license.
Oct. 2016	Recruitment	Emailed invitation letters to school districts.
Oct. 2016	Recruitment	Maya (mathematics), Ian (history), Alex (biology), and Paul (Earth and environmental science) gave their consent to participate in this study. Scheduled interview dates and classroom visits.
Oct. – Dec. 2016	Interview, classroom visit, and questionnaire	Maya and Alex
Nov. 2016 – Jan. 2017	Interview	Paul
Nov. 2016	Classroom visit and questionnaire	Paul
Nov. 2016	Interview and classroom visit	Ian
Jan. 2017	Interview	Ian Ian never returned his questionnaire
Mar. 2017	Interview	Maya
Oct. 2016 – Dec. 2017	Data Analysis	

Participant interviews. To answer the research question, which not only focused on participants' physics preparations and developments within the endorsement program but also beyond that experience, based on Seidman's (2013) recommendation, three semi-structured interviews were used in series. This was designed to place participants' experiences in context by inviting them to share "as much as possible about him or herself in light of the topic up to present time" (Seidman, 2013, p. 21). The interviews were named as follows: Interview one: Focused life history; Interview two: The detail of experience; and Interview three: Reflection on meaning. Using Seidman's interview framework, insights and understandings of the teachers' physics preparations and developments were formed within the context of details they provided about their life experiences. Seidman argued that without context, there is little possibility of exploring the meaning of an experience (p. 20).

For the research design, an interview guide was used, which was composed of questions used to gain access into the participants' lives. The teachers were not questioned following the series of questions listed in the guide because, in some cases, their responses to one question addressed another. All interviews with the teachers were audio recorded. These interviews generally lasted approximately 40 minutes, since they occurred during the school day and between teaching periods. The longer interviews occurred at the end of the school day, and were about 60 minutes.

The first interview allowed participants to reconstruct their early-life experiences at school, in teaching, and of their decision to become physics teachers, including details about preparation for physics teaching. In the second interview, participants provided details of their physics teaching experience and followed-up on their questionnaire responses. The third interview was not used, as Seidman suggested, because in all cases teachers were making emotional connections to their experiences. As a result, the third interview was used to follow-up on previous responses, if any remained, and to clarify the meaning of what teachers were making of their physics teaching experiences. In some cases, if a participant allowed a fourth interview, this was used to follow-up on the responses in the questionnaire, as well as the previous interviews.

Classroom visits. Data was collected from the classroom visits and from observations of physics teaching, through field notes documented in a research log. All classroom visits were scheduled at the teachers' discretions and in advance to ensure that visits did not conflict with other teaching activities at the school, such as a test or a larger school activity. Observation data was gathered from 12 visits. On average, each teacher was visited three times, with the exception of one teacher, who was visited only once. During each classroom visit, there was no interaction with the students or the teacher. Only notes were taken to record the events of each lesson in order to document its features and the teachers' practices, including student-teacher interactions. To rate the teachers' practices related to their use of the physics curriculum developed by the endorsement program, the practices were compared to the teachers' own descriptions of their preparation experiences. Then, teachers' practices were characterized using a rubric first developed by (McNaught, 2009), which was then adapted and appropriated in this study (see Table 6 in Appendix B).

***Teaching artifacts*.** Collecting artifacts for this study was not as significant as anticipated. One reason is that teachers used copyrighted material and did not feel comfortable giving away copies. However, they did show documents used to support their instructional goals, such as homework, classwork, and lab assignments for students. Only one teacher showed copies of assignments he created. He created these assignments by modifying the ACTS content from the curriculum materials. Lesson plans should have also been collected, but were not because teachers were being very guarded, and it was more important that they did not feel threatened by their participation in the study. Also, asking for lesson plans may have suggested an evaluation of the quality of their teaching because, on several occasions, participants asked about their lesson plan quality. This question was surprising and uncomfortable because this was not to be viewed as an evaluation.

Data Analysis Methods

The analytical procedures discussed in this section are adapted from content analysis techniques, which follow the tradition of both the deductive (predetermined categorical framework is used to analyze data) and inductive (multiple readings and interpretations of the data) methods. Generally, inductive approaches are used when the goal of data analysis is to draw meaning from data, and the approach is performed through a process of data reduction strategies, in order to generate a summary of themes describing the phenomenon under investigation (Stake, 1995). According to Patton (2002), qualitative researchers do not need to exclude deductive reasoning when inductive approaches are also being used. Rather, Patton argued that employing deductive methods, such as adoption and application of categories generated in previous studies or drawn from existing theory, is a useful data analysis strategy, especially when utilized at the beginning of the process.

Because there are no simple guidelines for data analysis, Stake (1995) asserts that "there is no particular moment when data analysis begins" (p. 71). In this study, data analysis was begun after crafting the research question. Bearing in mind the goals of the research question, content analysis of the textual data was performed, with a greater portion of the efforts dedicated to participants' interviews. In order to manage the task, the process was divided into three distinct phases: preplanning, organizing, and reporting.

The preplanning phase began after the research questions were crafted. During the preplanning phase, a list of analytical categories was created prior to beginning the field work (Saldana, 2012). In this phase, a short list of phrases was generated to represent categories that would guide analysis and interpretation during data collection. These categories became the foundation of an explanatory coding scheme for describing physics teacher preparation and development. The categories are as follows: influence on teacher knowledge, influence on teacher practice, and influence on teacher identity. The list of coding categories that responded to the research question: teacher knowledge, teacher practice, and teacher identity. Further, after the interview questions were piloted, the list of coding categories was expanded by adding two more new coding categories that emerged through data analysis (e.g. perceptions and beliefs).

Although data analysis began with a predetermined coding scheme generated prior to data collection, while reading through the interview transcripts and other pieces of data remaining open to revising the original “start list” was key in allowing it to expand to reflect the new codes (Saldana, 2012, p. 144).

Saldana (2012) characterized the method of combining predetermined and emergent codes while exploring the data, as eclectic coding. The coding methods used in this study began with “first cycle” approaches, and then proceeded through with the second cycle methods. Saldana (2012) described the “first cycle” coding as “processes taking place during the initial coding of the data” through close reading and creating categories. The “second cycle” represents researchers use of a range of analytical skills that supports continuous revisions and refinement of coding categories. These skills include, but are not limited to, “classifying, prioritizing, integrating, synthesizing, abstracting, conceptualizing, and theory building” (Saldana, 2012, p. 58).

First cycle: initial coding. Through the open coding method, the transcribed interviews were first coded by highlighting the text and making notes of first impressions in the margins of the transcript, using Invivo codes. Saldana (2012) explained that Invivo codes are created based on a key phrase or word used by the participants. Similarly, Bogdan and Biklen (2014) recommended that researchers record possible codes by “jotting them down” as one works with the data (pg. 185). The initial round of open coding resulted in descriptive codes (Merriam, 2009, p.188).

During initial coding, interview transcripts were read in its electronic form. The teachers’ statements were read and coded by labelling segments of information using the participant’s own words and by recording initial ideas in the margins of the documents

(Saldana, 2012). As necessary, these initial or provisional codes were also triangulated with field notes and the teachers' responses in the questionnaire (Saldana, 2012).

Second cycle: reviewing initial coding and impressions. After the initial coding phase, the interview transcripts were reread and then coding continued. During the second round of coding, the teachers' statements were reread to test whether the initial impressions and codes held true. If an initial code seemed no longer appropriate, the code was changed. During this phase, while trying to understand the initial code in relation to the research question, each coding decision was questioned by asking, "What does this mean?" (Stake, 1995, p. 78). The response to this question was used to classify the provisional or initial codes into categories and then themes. For example, based on inferences, the Invivo code '*excellent program'* was recoded and assigned a new code '*perceptions of program experienc*e'. Finally, with each subsequent teacher's case, the codes generated in the proceeding cases were referenced and compared.

Third cycle: classifying participants' responses. At this stage, similar codes were organized into groups. The similarly coded statements formed aggregate groups, generating what Merriam (2009) described as "buckets or baskets" of meaning (p. 182). Take for example, the various provisional codes generated from teachers' statements about learning physics in the ACTS methods course included *learning to solve physics problems* and *perceptions of program experience*, upon review and interpretation of these codes, they were then grouped by assigning them to the same thematic basket. The aggregate groups were assigned a theme consistent with the story that the condensed codes appeared to convey such as *physics preparation*. Condensing the provisional codes resulted in a reduction in the number of overall codes. These baskets were then matched with one or more of the three previously determined categories: sources of influence on teacher knowledge, sources of influence on teacher practice, or sources of influence on teacher identity.

Fourth cycle: examining relationships between codes. As previously described, examining the relationships between codes not only served to organize the data but they revealed patterns of shared experiences among the study's participants After sorting similar codes, it was possible to determine which codes occurred with greater frequency. Out of the approximately 157 codes generated in the proceeding phases, an estimated 25 condensed codes and 11 thematic baskets resulted and they were used to organize each case and then to organize the cross-case analysis.

Fifth cycle: cross-case analysis. In this final phase of data analysis, the sub-categorical themes were compared across all four cases to identity patterns of similarities and differences among them. Rather than ending data analysis with descriptions of the participants' previous teaching experiences within or beyond the methods-course experience, inferences were made about why the teachers shared this information and what it meant in relation to the research question. This line of reasoning led to the findings of this study. Finally, as a result of this process, the data was transformed into abstractions by using concepts to describe the sources of influence on teacher knowledge, practice, and identity in and beyond their participation in a physics endorsement program (Merriam, 2009).

Limitations of the Methodology

Several limitations existed in this study. The first limitation was the sample size. The sample size of four participants was appropriate for the research design; however, the sample size does not represent the actual number of teachers who participated in the ACTS physics endorsement program. When follow-up interviews occurred more than a week after the classroom visits, the teachers had difficulty recalling specific details from the previous lesson. Only three of the participants returned the questionnaire on the influences on physics knowledge and practice, limiting triangulation in that specific case. The same number of classroom visits for each teacher were not performed.

Trustworthiness

Lincoln and Guba (1985) identified four criteria for establishing trustworthiness when conducting qualitative research: credibility, transferability, dependability, and confirmability. Transferability refers to the researcher's ability to provide evidence of the study's trustworthiness by providing "enough detailed description of the study's context" to enable readers to compare the research situation to other situations, including their own (Merriam, 1998, p. 211). Transferability is also known as "fitness," which is the degree of similarity or congruence between two contexts (Lincoln & Guba, 1985; Merriam, 1998, p. 211). Dependability is the degree to which the "findings, interpretations, and recommendations" of a study are supported by the data (Lincoln & Guba, 1985, p. 318). Confirmability is the degree to which the research procedure can be replicated to produce the same results. Lincoln and Guba (1985) recommended that both can be achieved through an "audit trail and process" (pp. 319-27).

Credibility

Triangulation. Triangulation is achieved in this study by using multiple data sources, such as interviews, observations of teaching, a questionnaire, and instructional artifacts. These sources of data overlap and give each other support. For example, classroom observations explored a teacher's self-report of their experience of becoming a physics teacher and of their classroom teaching practice.

Member checks. The study's participants were invited to review their cases, in order to include the clarifying of their responses or to give additional insights about interpretations of their experiences. Each participant was emailed a copy of their individual cases and asked to review the case. Each participant was invited to share their impressions. The participants had two weeks to review their cases.

Dependability and Confirmability

Audit trail. An audit trail is a record of how the study was conducted, and, ultimately, how the findings of the study were reached (Lincoln & Guba, p. 319). As the primary research instrument, a written log of research tasks, field notes, and thoughts about the data or research process were kept. During data analysis, the research log was referenced, as necessary, to support interpretations.

Dependability and confirmability were established in this study using a research log and field notes, writing memos, audio recordings, and transcripts. These strategies provided information about the study's procedures, as well as thoughts and decision-making that lead to the results. For example, in this study, field notes contained descriptive information about classroom observations. The information included descriptions of what was seen, heard, and experienced while observing specific lessons.

In addition, the research log was used as a place to record “logistical information,” such as appointments, “methodological decisions,” and reflections about emotions, questions, insights, and concerns (Lincoln & Guba, 1985, p. 327). Further, the interview transcripts provided evidence of the participants' experiences as they described them.

Transferability

Purposeful sampling. The following strategies helped to support the transferability of this study. The sampling procedures used to identify and recruit the study’s participants, were described. Physics teachers whose experiences matched the selection criteria, were identified and recruited. Teachers recruited for this study participated in the ACTS endorsement program as partial requirement towards physics certification and were teaching physics at the time of the study (Merriam, 2009; Lincoln & Guba, 1985).

Summary of Methodology

In this chapter, the research design of this study was discussed. A discussion of the study’s research question, a description of the physics endorsement program, and participant sampling and recruitment were presented. Next, the data collection and analysis procedures used in this study were described. A discussion of specific decisions used to establish the trustworthiness of this study were presented. The ethical considerations employed over the course of this study were also discussed. The following chapter presents the results and findings from the study.

Chapter IV: Individual Case-Studies

Chapter IV provides a report of the results and findings from semi-structured interviews of each participant. Interviews occurred over the course of five months. Through participant interviews, the following research question was addressed: How do inservice teachers' experiences in and beyond an alternative certification program influence their knowledge of physics, teaching practice, and identity as physics teachers? This chapter presents the results in response to the research question.

Contextualizing the experiences of the study's participants was facilitated through the use of relevant literature around teacher knowledge, alternative certification preparation, and the challenges of learning and teaching physics. In analyzing and interpreting the meaning of the study's results and the supporting themes in teacher learning and development, I am drawing on Bandura (1977), Vygotsky (1978), Lave and Wenger (1991), and Brown et al. (1989). To guide the analysis of physics teacher identity formation, I also draw on models of identity by Gee (2000) and Carlone and Johnson (2007).

In the paragraphs that comprise this section, in-school experiences that participants chose to share are presented, in order to highlight their past experiences as learners and as teachers. The four cases composing this chapter are presented in the following order: Paul, Ian, Alex, and Maya. Each case is organized according to an outline. First, an overview of the participants' teaching experiences spanning their careers up to their switch to physics is provided. Second, the results for the sources of influence on teacher identity are presented. Third, the results for the sources of teacher knowledge are presented. Finally, I present the results for the sources of influences of teacher practice.

Case #1: Paul of Westlake High School

Table 2

Paul's Career and Certification Timeline

Year	Teaching Assignment	Credential program
2009	Earth and environmental science/Westlake High School	began state alternate route program for Earth science teaching license
2010	Earth and environmental science/ Westlake High School	completed state alternate route program for Earth science teaching license
2010	Physics/Westlake High School	began ACTS program for physics teaching license
2010	Physics/Westlake High School	continued ACTS program for physics teaching license
2011	Physics/Westlake High School	completed ACTS program for physics teaching license
2011	Physics/Westlake High School	

Although Paul had a previous science-related career, it was not in education. Teaching is a second career for him. Paul has completed college with a bachelor's degree in Environmental Science, and for fifteen years he was a field scientist conducting research on animal and plant life in rivers and streams. In 2009, Paul secured his first science position as teacher of Earth and environmental science at Westlake High School, and is now lead teacher of the science department. Although Paul still has an interest in teaching Earth and environmental science, he prefers to teach physics.

The Westlake School District is located within a neighborhood where the population is primarily comprised of African Americans, with a small Hispanic population as well. Both groups are socioeconomically designated as poor, and are part of the working-class. Westlake's school district enrolls about 35,000 students per year, and has a faculty of approximately 5,600 teachers. Eighty-six percent of the district students qualify for free or reduced-price lunch.

Overview of Learning to Teach

Paul's preparation for teaching included multiple alternate route programs. First, before enrolling in ACTS, he participated in an alternate route program for licensure in Earth science, and Paul described his initial alternate route preparation as a "good crash course" on teaching (personal communication, November 2, 2016). Paul credited the first alternate route experience with "teaching me about teaching," and noted it was an opportunity to "earn as you learn" (personal communication, November 2, 2016). Following a full day of teaching, Paul attended classes one night a week and "occasional weekends" for a year (personal communication, November 2, 2016).

Paul also mentioned that during his first year of teaching, there were other opportunities for him to learn how to teach, and noted that the district provided professional development workshops on general teaching strategies, for all teachers. While participating in each opportunity, Paul reported that he was open to the experience because he admittedly knew "very little about the actual teaching field, especially at the high school level," and when engaging with the espoused ideas, Paul indicated that he reminded himself to be "completely open" to the experience (personal communication, November 2, 2016). "I told myself that I don't know anything about the specifics of this field, other than my ingrained opinion, and I said that I would just push that aside" (Paul, personal communication, November 2, 2016).

Further, district workshops provided exposure to the pedagogical concepts of multiple intelligences and differentiated instruction, which gave Paul new insights about teaching and renewed his awareness of what it is like to be a student. Paul claimed that as a result of the workshop experiences, he began realizing that being responsive to learner diversity is key to teaching because "everybody doesn't learn the same, and that maybe I should not be looking at someone as if they are skilled or not skilled—and maybe try to figure out other ways that they learn" (personal communication, November 2, 2016).

Paul appears to have differing views about reformed-based practices, such as differentiation and the concept of multiple intelligences. On one hand, Paul is open to the notion all students do not learn in the same way. "When I went to school, we all had to take the same test, do the same rote prepositional phrase, statements—and those students that didn't get it was sort of ridiculed and criticized" (Paul, personal communication, November 2, 2016). On the other hand, he believes that by following through on this practice there is a risk of "coddling" students because "in other opportunities in life it [circumstances] is not always going to cater to what someone is good at" (Paul, personal communication, November 2, 2016).

According to Paul, he learned of the opportunity to switch to physics at the end of his first year of teaching. Paul learned that the district had not renewed his teaching contract because they had decided to replace environmental science, a core course for grade nine students, with physics. And, without a teaching certification in the subject, Paul would have to find a new position at another school. Paul stated, “I could have gone back into the environmental science field and said goodbye to education, but I didn’t want to do that” (personal communication, November 2, 2016). Paul decided he would remain in teaching because it is an occupation that offers him a level of employment stability and security his previous position did not. Paul said, “I fought hard to stay,” and volunteered for a “very uncomfortable situation” because of his “love for the occupation” (personal communication, November 2, 2016).

Sources of Influence on Teacher Identity

Physics identity. Initially, as a physics learner, Paul viewed his physics identity as neither strong nor positive, which made him reluctant to pursue a physics certification through ACTS. Paul had not studied physics until he went to college. According to Paul, his first physics experience in college was “poor,” due in part to a “lousy [physics] professor” who made him feel “dejected” (personal communication, November 2, 2016). Although Paul eventually passed the physics course, he initially perceived physics as his least favorite subject, based on the above experience.

As a student of physics, Paul aligned himself with physicist Albert Einstein, and noted that his primary motivation is to be a life-long learner of physics:

> I have a lot more things I want to learn. Look, one of the smartest men who ever lived, Einstein, he spent his entire life, every single day pretty much, spent hours and hours a day doing physics, and he still didn’t even reach his goals. You know what I mean? So you can put in an infinite amount of time and still keep learning (personal communication, November 2, 2016).

Paul views his continued study of physics as essential for success in teaching the subject.

Teacher as a problem solver. Paul's approach to teaching physics embodies his experience in the ACTS methods course. Paul organized lessons around teaching the concepts and principles of physics through algebra-based problem-solving. Although Paul's physics teaching practice is closely aligned to his preparation experience in ACTS, Paul's beliefs about his teaching practice also appear to reflect his prior experiences as a student of environmental science and as a field scientist. Paul described himself as an analytical thinker, and believes that this quality is an asset in teaching and learning physics. He said, "I still feel that someone who is not analytical or nonscientific will have a harder time in general [learning physics], but it is certainly not an impossibility. They can still learn, and they can still do it" (Paul, personal communication, November 2, 2016).

In further illustrating this point, Paul drew parallels between what he believes is effective physics teaching, and a mechanic who accurately diagnoses a customer's reported engine trouble. According to Paul, a good mechanic knows how all parts of an engine work together, and "can imagine the engine piece by piece" (personal communication, November 2, 2016). Similarly, a good physics teacher knows multiple ways of addressing a physics problem. He commented, "[If] I have a problem that has to be broken down in certain ways, and if I know only one way to solve that problem—how am I going to keep teaching it to my students?" (personal communication, November 2, 2016). For Paul, taking ownership over his own teaching practice is important. To Paul, no one lesson is the same, and he views his capacity to present physics concepts in "different ways" and "using different examples," as aligned with being analytical (personal communication, November 2, 2016. Paul explains:

> So what you see in my classroom is essentially the way that the ACTS program was really run. I just put my own spin on it because I took that time to not only learn what they taught me, but to learn other more in-depth knowledge of physics in some ways. Now, when I teach my students—if they have a question, I can present it in a different way and try to use all of these different examples. I think about how to reteach the same concept, but maybe from a different angle (personal communication, November 2, 2016).

In the statement above, Paul alludes to the fact that he supplements his physics preparation through a further study of physics. Later on in this analysis of Paul's experience learning to teach physics, I will explain how Paul supplemented his preparation.

Teacher as a performer. Paul's beliefs about his physics teaching practice are influenced by traditional models of teaching, combined with his experience as a musician (Trigwell & Prosser, 1996). Paul said, "One of the most important skill sets of a teacher is being comfortable with delivering to a class" (personal communication, November 2, 2016). Paul believes teachers are performers. He said, "You are a performer first and foremost, and what your performance is focused on is delivering, so that students can obtain that knowledge and master the content" (personal communication, November 2, 2016).

Paul also believes there is a place for reformed-based strategies in his teaching practice, such as collaborative learning and Socratic methods. A good friend of Paul, who was also a teacher, introduced him to the Socratic approach. Paul's take on using Socratic methods to engage students during a lesson is that it represents a way to have students take responsibility for their own learning. According to Paul:

> Socratic questioning allows you to deliver the material in a way that is constantly engaging. If you just go ahead and spoon feed someone an answer, really what is the need for them to think deeply—they might just say, [the teacher] is just going to give me the answer anyway, let me just ask (personal communication, November 2, 2016).

Paul associates inquiry-based lab assignments with student-focused teaching. Paul described inquiry-based or "discovery" lab assignments as those that provide students an opportunity to apply learned concepts and principles to performing an investigation. Paul described his favorite lab investigation he assigns to his students. In this investigation, Paul gives his students a general description of the task, which is to design an experiment to launch an object in a desired position using a piece of physics equipment called a marble launcher:

> I will say to them, well, "Now you know a lot of the concepts you need, I want you to design a problem that is a cannon shooting at a wall, and you make that cannon shoot at the wall. You make that cannon shoot at any velocity that you want, at any angle, and put the wall at any distance and at any height that you want" (personal communication, November 2, 2016).

Paul’s approach to physics teaching also includes practices that are aligned to eliciting students’ ideas of physics principles and concepts, which he addressed through Socratic methods he combined with small and whole-group discussions (Trigwell & Prosser, 1996; Larkin, 2012).

While academic development of students is important to Paul, his second priority is that physics learners will attain personal development through their experience in the course. To Paul, learning is “the ability to persevere, to push, to grow mentally, emotionally, and spiritually in the sense that—I can do things. I am a good person. I am a strong person” (personal communication, November 2, 2016). Paul’s position on this matter is based on his own experience learning physics. Paul believed that his own development, while enrolled in ACTS, was both personal and academic, and he wants the same experience for his students. Paul’s thinking is that as a result of learning physics, a subject he disliked and did not think he could learn, he developed confidence in himself. Paul now believes if he can learn physics, so can his students.

Teachers at Westlake High School must demonstrate four core competencies, which include the following: planning and preparation, rigor and diversity, classroom culture, and mastery of content. Paul focuses most on planning and classroom culture. According to Paul, “If you’ve got a good classroom culture and a good plan, really everything goes forward from there” (personal communication, November 2, 2016). Paul added that he continues to experiment with “student-led strategies,” and he explained that in order to support his classroom culture, “I am trying to get more student-led strategies—and I tell them, I boost them up, I say, 'It is your classroom, not mine, I am just part of it'" (personal communication, November 2, 2016).

Summary of the Influences on Teacher Identity

A source of influence on Paul's physics-teacher identity includes his own experience as a physics learner in college, which initially led him to negatively identify with the subject. Other sources of influence include Paul's experiences as a musician and as an environmental scientist. Paul reported feeling competent in each of these identities. He transferred skills he believed were assets from each identity into his teaching practice, such as being analytical and able to effectively communicate. Paul's beliefs about his teaching practice, and specifically how he interacted with his students, are informed by both traditional and reform or student-focused models of teaching and learning.

Sources of Influence on Teacher Knowledge

Physics preparation. Following Paul's experience of engaging with the ACTS algebra-based curriculum as a learner, he was pleased with his methods-course experience, and described that the preparation provided a "great foundation" and a "great way for people to learn physics" (personal communication, November 2, 2016). The curriculum of the ACTS methods courses focused on preparing teachers with the content needed to teach high school physics curriculum (personal communication, November 2, 2016). Paul reported, "I became proficient in algebra and proficient in physics, through the methods course," which was, "essentially through the same exact course that we teach our students" (personal communication, November 2, 2016).

He added, “I had an absolutely great experience, and I can’t say anything negative about the program” (Paul, Personal communication, November 2, 2016). In the methods course, Paul became familiar with the use of specific types of educational technology, as well as the ACTS physics curriculum materials, which included: practice problems, assessments, laboratory experiments, and digital lecture presentations. Overall, Paul attributed the success in his preparation to the ACTS program staff and to his commitment to learning the material. Paul said, “The people of the ACTS program were very supportive, but ultimately I put a lot of time into it—but I really dove into it” (personal communication, November 2, 2016).

Based on Paul’s memories of his methods-course experience, he reported the instructors promoted a sense of community by encouraging the cohort members to support each other; and these interactions often entailed sharing of ideas about teaching and learning physics. Paul mentioned that members of the cohort often discussed topics of mutual interest related to their ongoing experiences in the program, including strategies for solving physics problems. He said the cohort members discussed “our fears of knowing little about physics,” and, similarly, “what our students were experiencing” as first-time physics students (personal communication, November 2, 2016).

As part of Paul’s methods-course experience, he learned from his cohort peers through simulated teaching he called “mock lessons” (personal communication, November 2, 2016). Paul explained that, during the mock lessons, the instructors assigned the class specific content to present. In advance of Paul’s interactions with his own students, the practice lessons were opportunities to teach physics using the provided

ACTS curriculum and materials. Further, the practice lessons allowed Paul to think through the course content and curriculum materials as a physics teacher. Together, Paul and his cohort peers identified strengths and deficiencies in their own physics knowledge. In addition, beyond gaining experience in presenting the course material, Paul received feedback on his teaching, and he gave feedback to his peers.

Working through challenging content. Paul reported that his own struggles, while learning to solve the same problems his students would be expected to solve, helped to prepare him to anticipate what students may find difficult and why. One of the particular challenges Paul faced was solving force problems involving Newton’s Second Law. Paul reported he had underestimated the role of free body diagrams in the process.

In physics, free body diagrams, drawn correctly, show all of the forces acting on an object in a given situation. All the physics is done in drawing the free body diagram, leaving only algebra remaining in the last step. When learning how to draw the free body diagrams, Paul sought support from a peer who was also a physics colleague in the Westlake science department. Paul gave an example of what happened when this colleague tutored him on how to use free body diagrams:

> I had a colleague, one of my fellow teachers, who was taking the ACTS courses at the same time as me. I was struggling a little bit with the dynamics chapter, but she really pointed out to me how the free body diagram is essentially the key to solving so many problems in physics, once it comes to the mechanics of physics. And she pointed out to me—just how to draw the diagram, and she put it in a simpler form. When she did, the light bulb went off, and I had the "aha" moment.

> I said, "Oh!" And I just saw it from a completely different perspective. The light bulb went off, and I said, "Oh, this isn't just a hokey pokey thing" (Paul, personal communication, November 2, 2016).

Paul's experience learning how to use free body diagrams led him to appreciate the model's importance in solving problems involving forces. He concluded, "And I have been hooked ever since, and it is one of my favorite topics to teach now" (Paul, personal communication, November 2, 2016). Through Paul's own difficulties learning to use free body diagrams, he also learned that, if students experienced difficulty identifying all of the appropriate forces in the diagram to solve problems, they are more likely to get the problem wrong. Paul also said the following about teaching free body diagrams and other concepts he found challenging to learn, "It got easy in some cases to teach the concepts because I struggled with it myself" (personal communication, November 2, 2016).

Physics practicum. During Paul's practicum experience, he was assigned to teach a physics class. Paul regarded his practicum teaching experience as significant to his preparation because here he began to develop confidence in his knowledge of the subject. He reported that practice teaching offered him opportunities to test his knowledge of physics. Paul explained, "So teaching it [physics] allowed me to see what I wasn't getting, and what I was getting. It helped with my education, but it also helped my delivery of it" (personal communication, November 2, 2016). Despite preparing before a lesson, Paul recalled receiving unanticipated student questions during lessons:

> The first couple years of teaching [physics], I spent a lot of time outside of school working on my craft because I tried not to give my students a problem that I

> couldn't solve. There would be [unanticipated] questions that would come up inevitably, but I tried to avoid the fact that I would be giving them something that I don't know how to do (personal communication, January 19, 2017).

Paul reported that when his students asked him a question for which he did not have an answer, he responded by being "transparent with my students," and told them, "I am not 100% sure" (personal communication, January 18, 2017). According to Paul, he would either offer to research the answer after class or suggest to the student, "If you want to do a little research and find that for me and discuss it with me—I will give you extra credit" (personal communication, November 2, 2016).

For Paul, the practicum combined with the methods courses were experiences that helped him to feel competent in his new role. Owing to his practicum experience, Paul described a very positive transfer to physics teaching, although he acknowledged he had to invest additional time to learning physics well enough to teach the subject to students. He noted, "I do believe that teachers have the responsibility to go above and beyond what the program has to offer" (Paul, personal communication, November 2, 2016).

Continued study of physics. After completing his certification coursework, Paul supplemented his ACTS preparation by building on the problem-solving approaches learned in the methods course. In doing so, Paul practiced solving physics problems from sources other than the ACTS curriculum materials. According to Paul, "I put time in above and beyond what ACTS was teaching" (personal communication, November 2, 2016). Paul reported that supplementation served two purposes: to prepare for the Physics Praxis, the subject matter test, and to strengthen his knowledge of physics content for teaching. Paul described his use of the Internet resources on physics:

> As I prepared for my Praxis, I really ramped up my studies. I found a fair amount of supplemental material on my own. I found websites that helped me further, and I still do that. I go to Khan Academy sometimes when I have questions about certain things, and I want to see how they are addressing it, so on and so forth. Physicsclassroom.com, I think is another website that is excellent. I reference these because I still want to learn more (personal communication, November 2, 2016).

Paul reported his main supplementation strategies were reviewing tutorial videos and reading “mostly high school level [physics] textbooks because the college level was calculus based” (personal communication, November 2, 2016).

Other supplemental resources Paul used included online tutorials such as “Khan Academy” and physics teaching websites that featured practice problems. Paul explained that all of the supplemental resources presented the “same general topics [as the ACTS physics curriculum], and they presented all of the same formulas and laws” he learned while participating in ACTS, but the information “was presented differently through the wording of questions. They provided different ways of looking at things,” which he found “very valuable” (Paul, personal communication, November 2, 2016).

Summary of the Influences on Teacher Knowledge

Although Paul’s ACTS preparation experience in the methods course appeared as a primary source of his knowledge for physics teaching, other influences included engaging with the ACTS high school physics curriculum as a learner. While learning to teach physics, Paul encountered challenging concepts he was able to work through independently and with the help of an experienced physics colleague. Paul viewed his practicum experience as an opportunity to test his knowledge of physics in relation to students' questions of specific concepts or problem solving. As a result, Paul supplemented his preparation, primarily on physics problem solving, in order to address gaps in his own knowledge. Paul's focus on developing his fluency in solving physics problems is attributed to the importance he places on having alternative methods already prepared to present to struggling students.

Sources of Influence on Teacher Practice

Knowledge of physics content and curriculum. Paul summarized aligning his teaching practice to the ACTS curriculum by commenting, "Once you start teaching it, that's really when you start getting better" (personal communication, November 2, 2016). Paul's confidence in his knowledge of the ACTS curriculum led him to begin adapting assignments for his students (personal communication, November 2, 2016). Paul admitted that before he began modifying the curriculum for his students, he made these changes for himself. For example, Paul revealed that during his first year of teaching physics, he omitted problems from the lessons he did not know how to solve. Paul reasoned that, rather than risk confusing his students, he would exclude specific questions:

> So my first modifications came from omitting questions or making them easier. I wanted to give the right answers, rather than winging it. So it doesn't mean that I omitted a lot, but there are some highly rigorous questions, even at the freshmen

> level, and until you understand the concepts strongly it is hard for you to be able to solve it on your own and be able to answer when someone asks you a question (personal communication, November 2, 2016).

When Paul adapted the ACTS curriculum materials for his students, he did so with the intent of addressing perceived gaps in their pre-algebra skills. Some of Paul's adaptations included rearranging the order of lesson topics or introducing mathematical skills one at a time, rather than all at once. Paul noted, "So when your students are deficient in an area or need more practice, you need to create things that have more questions" (personal communication, November 2, 2016). For example, Paul showed me an introductory graphing assignment he created for his grade 9 students who had difficulty describing an object's motion when graphed:

> So this [worksheet] is something that ACTS has [developed]. I just modified it creating problems for supplemental work. I wanted them to recognize the Cartesian coordinate system of x and y graphs. Because ultimately, not only do I want them to be able to create a graph, which is important, but most importantly, reading the graphs, and even further than that, analyzing the slope of a graph (personal communication, November 2, 2016).

Having developed confidence in his knowledge of the curriculum goals, Paul adapted assignments to support his students in achieving the goals.

On the day of my visit to Paul's Advanced Placement physics class, he taught a review lesson on Newton's Laws of Motion. Paul enacted the lesson using each piece of technology equipment he had learned to use during preparation with ACTS. For example, he used the electronic whiteboard to display the ACTS prepared electronic (PowerPoint) presentations for students to use as a reference during the lesson. During the lecture, students responded to formative assessment questions embedded within the presentation, using the classroom response system (clickers). As part of the lesson, Paul facilitated both small group and whole group discussions. When asked why he dedicated a significant part of the lesson to re-teaching the concept of inverse proportionality, Paul indicated he wanted to address existing student misconceptions on the concept. Experience has taught him that, “Even the honors don’t understand inverse proportionality” (personal communication, November 2, 2016). Therefore, Paul believed it was worthwhile to revisit the concept in the review lesson “because a lot of students get it right away and some students do not, so I need to give them a lot of it” (personal communication, January, 19, 2017).

Confidence in knowledge of Socratic methods. Aside from problem solving, Socratic teaching methods were prominent elements of Paul’s teaching practice. Paul was drawn to using the Socratic methods, and, as previously mentioned, he believes that Socratic questioning is a “more engaging” teaching method (personal communication, November 2, 2016). For Paul, it represented a shift from his previous teacher-centered learning experiences as a child.

Relating to physics colleagues. Besides Paul’s interactions with the physics colleague who tutored him while he was enrolled in ACTS, he did not discuss details of relationships with other physics colleagues. Paul appears to prefer his relationships with students over the ones he has with other teachers:

> I hear teachers say sometimes that they are on an island, and they feel very isolated when you close the classroom door and you don't have adult interaction, sometimes for the rest of the day. I never feel like that. The interactions that I have with my students are so fulfilling that I never feel isolated or feel like I cannot wait to have adult communication, I never feel that way light laughter] (personal communication, November 2, 2016).

This result relating to Paul is also supported by his questionnaire response about whether he had visited the classroom of his physics peers to observe them teaching. On this questionnaire item, Paul selected, "Never" from among the Likert choices (personal communication, November 24, 2016).

Relating to physics learners. On the questionnaire, Paul rated *Reviewing Students' Work* highly for having had an influence on his knowledge of physics (personal communication, November 24, 2016). This response was consistent with Paul's recollection of enhancing his knowledge of physics by reviewing students' work. Paul recollected, "There are things now that I breeze through quickly, and I remember struggling with this five or six years ago and they will get better too" (personal communication, November 2, 2016). In fact, it is worth mentioning again that Paul shared that, by in large, his approach to teaching a difficult concept or problem to students developed out of having found it challenging. And, as a result, "It got easy in some cases to teach the concepts—because I struggled with it myself" (personal communication, November 2, 2016).

Summary of the Influences on Teacher Practice

The ACTS methods course and physics curriculum materials were not only key influences on Paul's physics content knowledge, but they also shaped his practice. Also, for Paul, experiences such as struggling to learn concepts he found difficult, informed how he taught physics. In Paul's day-to-day thinking of physics teaching and learning, he combines Socratic techniques with both small and whole-group discussions, and he reported using lab assignments as an opportunity for students to apply their knowledge of physics.

Paul's knowledge of physics teaching includes: algebra and trigonometry in learning physics, content representations, curriculum resources inclusive of—and—beyond those learned during his ACTS preparation, topic-specific knowledge of students' difficulties in learning physics, and educational technologies for use in supporting and assessing student learning.

As Paul looks toward his future as a physics teacher, he plans to remain at Westlake High School, despite having received offers of employment from other districts.

Summary of Paul's Case

Paul would seem an unlikely candidate for physics teacher because he suffered a negative experience learning physics in college, which caused him to dislike the subject. Today, Paul is enthusiastic about physics education. While enrolled in ACTS, Paul's interactions with his cohort peers and the support of the instructors, assisted him in renegotiating a positive physics learner identity. This was a key transformation that translated into increased confidence and persistence in completing the physics certification requirements. With Paul being able to perceive himself as a competent physics learner, he, in turn, began perceiving himself as a competent physics teacher. In the end, Paul's own challenges as a physics learner influenced his physics knowledge and his current teaching practice to the extent that he is empathetic towards struggling learners, focused on developing relationships with students, and has expressed an overall willingness and a flexible response ability to student's needs.

Case Study #2: Ian of Ridge Regional High School

Table 3

Ian's Career and Certification Timeline

Year	Teaching Assignment	Credential program
2002	History/previous high school	began state alternate route program for history teaching license
2003	History/previous high school	completed state alternate route program for history teaching license
2012	History/previous high school	began ACTS program for physics teaching license
2013	History/previous high school	continued ACTS program for physics teaching license
2014	History/previous high school	completed ACTS program for physics teaching license
2015	Physics/Ridge Regional High School	

Following several careers, at the time of the study Ian had thirteen years of experience in education. Prior to teaching, Ian served in the military, worked in real estate development, and the technology sector. In college, Ian majored in history and political science, while also finding time to pursue his childhood interest in astronomy. Ian was first hired to teach history at his previous school district in 2002.

Ridge Regional High School is comprised of students from a nearby low-poverty, economically-diverse suburban neighborhood. Only six percent of the 1,100 students are designated as economically disadvantaged. The racial and ethnic representation of the students is 89 percent white and 11 percent non-white students, including: 4 percent Asian, 4 percent Hispanic, 2 percent African American, and 1 percent Native American. Over the past 2 years, Ian has only taught physics at Ridge Regional High School. Ian joined the staff of Ridge Regional the year it started teaching physics, which is a full-year algebra-based physics course offered to students in the ninth grade.

Overview of Learning to Teach

Ian, a new history teacher at his previous district, reportedly worked in a "chaotic school," which led him to focus primarily on classroom management (personal communication, January 22, 2017). Therefore, his first objective was to "have rules and procedures, and for the kids to follow them" (personal communication, January 22, 2017). At that time, Ian was an alternate route teacher, and his largest concern was, "I needed to know how do you get those guys into their seats and going into the direction that I need them to go in" (personal communication, January 22, 2017). For Ian, the first alternate route experience fell short of providing him with "practical" information that he appeared to feel is basic to teaching; he "needed to know how to write a lesson plan, do a gradebook, and how to group students" (personal communication, January 22, 2017). He described the content of the program as "useless nonstop nonsense" (personal communication, January 22, 2017). Out of this experience, Ian did find the conversations with fellow first-year teachers more beneficial than the course lectures on "recognizing the signs of teen depression" and "education law" (personal communication, January 22, 2017). Ian compared his first year of teaching, while undergoing alternate route preparation, to being a novice swimmer asked to do "synchronized swimming" when "I'm just trying to get to the other side of the pool right now" (personal communication, January 22, 2017).

Ian mentioned he did not receive any enjoyment out of being a disciplinarian, or what he called a "hardcore" teacher who ran a "regimented" class (personal communication, January 22, 2017). According to Ian, "I was highly effective in a difficult school" where during a typical lesson "it was difficult to get students into their seats" (personal communication, January 22, 2017). Ian reported that he began taking a different approach with his students after noticing that students were already having a tough enough time with other adults disciplining them throughout the school day. Ian reasoned, "Why do I have to do it too? These guys have so many people yelling at them already, I don't have to do that" (personal communication, January 22, 2017).

Ian also acknowledged, although his students were compliant, he was not satisfied with his teaching practice:

> I had everybody in their seats and taking notes, it [teaching] was very regimented. And the school was rather chaotic, and so getting them in their seats with no chaos was a huge accomplishment. I was really happy, at first, when everybody was writing and taking notes. And I am walking around feeling like it is working, but then it was like feeling that I was kind of dragging them through a lesson (personal communication, January 22, 2017).

Ian revealed he began sharing control of the classroom after teaching a lesson during the 2004 election primary season. He experienced “a great combination of everybody on task—it was not just me lecturing and giving notes, but it became that great conversation that you want to be having with kids” (personal communication, January 22, 2017). Ian added:

> That’s where I saw success with them first, and then, when I became a stronger teacher, I started building a better rapport with them once I was able to make the material interesting. And found that I had a really good rapport with them, that started building like a reputation. Like, you’ve got to take Mr. Ian’s class. And then they start asking you to do in-services, and then I was made master teacher, unofficially (personal communication, January 22, 2017).

After becoming physics certified, Ian was hired to teach physics at Ridge High School, a “very accomplished school,” where he currently works (personal communication, January 22, 2017). Within recent years, the high school has been awarded the academic “Blue Ribbon” based on the achievement of its students. Ian views his transfer to physics as a “great personal accomplishment” because it meant that he “mastered” a difficult subject that was “so unfamiliar” (personal communication, January 22, 2017). Ian adds, “So for them [Ridge leadership] to take a look at me and say that I am doing a good job; it’s nice to feel effective and professionally accomplished” (personal communication, January 22, 2017).

Sources of Influence on Teacher Identity

Physics identity. Ian developed a positive physics identity as a child. At that time, Ian aspired to be an astronaut, which led him to develop an interest in astronomy. Ian's alignment with physics strengthened during his junior year in high school, and here his identity was affirmed again. Ian reported he performed well in physics, without having to put forth much effort. Ian said:

> I had physics in school. I had it junior year. I did okay. I was usually one of the more-smarter kids in the room, so I could coast without really applying myself. I wasn't a bad student, but I got by on raw intelligence (personal communication, January 22, 2017).

Ian commented on how easy it was for him to pass the physics tests:

> The teacher would ask multiple choice questions. He was really bad at asking multiple choice questions because his answers were too similar. So it was really easy without even knowing all of the physics. I would read the problem and know—alright, he is looking for acceleration—alright, that is gravity, that is velocity—I would know just by the units. I already know the answer just cause your answers stink [laughing lightly]. I pulled stunts like that, and it got me through with a "B", when I should have been an "A" student (personal communication, January 22, 2017).

History identity. Ian had a positive history identity, which developed when he was a child. Outside of Ian's studies at school, he had an interest in history and surrounded himself with friends who shared his same interest. Together, they took up studying military science becoming "junior military historians" (personal communication, January 22, 2017). Ian's interest in the science of military history led him to have a greater understanding of global and social events, which resulted in him being ahead in all history classes. Ian prefers to see himself as an independent thinker, self-disciplined, and resourceful. For Ian, the strategy was easy, "I just read all the books, that's all I did" (personal communication, January 22, 2017).

Ian is skilled at debating, a talent he developed by the time he went to college. Ian was confident in his ability to command a room, based on his knowledge of history. Ian explains:

> So history was effortless, absolutely effortless. Without even trying, I was like a straight "A" student. And at the university level, you can take over a room. I would play devil's advocate in certain situations and start pulling out historical events to back up an issue, and you look like a genius (personal communication, January 22, 2017).

In college, Ian was less concerned about learning history. Confident in his foundation in the subject, he preferred courses where the professors encouraged debates and engaged their students through argumentation. Ian said of his college courses, "I was there for the argument. I was like, I already know the history, man. I can pass your final now. I'm here for the debate" (personal communication, January 22, 2017). Associating with a competent history identity appears to have lead Ian to pursue a history degree in college, and to become a history teacher. Before his experience in ACTS, confidence was part of Ian's physics identity.

Master teacher identity. Ian's master teacher identity is a product of how he has viewed himself as a history teacher, and how others have viewed him in this role. In either case, Ian was a leader. This identity centered around exercising authority inside and outside of the classroom. Ian appears to view teaching synonymously with having order, routines, and structure. Prior to teaching physics, Ian developed a positive reputation among staff and students of the high school where he previously worked. Ian reported, "When I spoke in a staff meeting, people listened," and, "Unofficially, I ran the [history] department" (personal communication, January 22, 2017). He was also involved in "running [school] assemblies" and "organizing events" (personal communication, January 22, 2017). In the following quote, he described the nature of his influence, and how he feels it changed once he transferred to Ridge High School:

> I was highly effective in a difficult school. I was a positive leader outside of the classroom with my colleagues. So I had a strong reputation, and I think I was respected there. When I spoke in a meeting, people listened. That was nice, but now [in a new position] I am quiet at the back of the room (personal communication, January 22, 2017).

Furthermore, as previously mentioned, according to Ian, his teaching earned him a positive reputation among students.

Ian was so confident in his ability to relate to students that when he considered pursuing physics, he felt it gave him an advantage over teachers with physics degrees. Ian felt strongly that majoring in physics does not guarantee an individual would be a good physics teacher. He commented that most physics majors who became teachers "can't teach or they teach way over the heads of students" (personal communication, January 22, 2017).

Besides relating to students, Ian's master teacher identity is associated with being creative, resourceful, and collaborative. As the master teacher, Ian was known for creating his own teaching resources, including PowerPoint lecture presentations he eagerly shared with the history department. As the master teacher of the history department, Ian's colleagues used his teaching materials, including the lecture presentations, which he pointed out were still in circulation and being shared among teachers of the history department. "My friends at my previous job are telling me that everybody, the whole history department, is still using all of my PowerPoints" (personal communication, January 22, 2017). Identifying with being a successful teacher of history influenced Ian's decision to pursue physics, because he viewed the transfer to science as adding physics knowledge to his teaching repertoire.

Teacher as a subject-matter expert. After Ian transferred to Ridge High School, he began viewing himself as a "rookie" (personal communication, January 22, 2017). He was new to physics, and was teaching at a different school. Like Ian's history identity, his identity as a physics teacher is closely linked to mastery of content knowledge and having ownership over that knowledge. Ian explains it this way:

> When I first started teaching, I knew all of the history and didn't know how to teach. And when I came here, I knew how to teach, but didn't know the physics. So it was that crazy switch. And then, this is such a different environment. It is night and day. So adapting to this and the professionalism here, aw, I felt like a

> rookie trying to catch up for a while (personal communication, November, 15 2016).

For Ian, making the transition from history to physics weighed on his confidence. Throughout Ian's interviews, he often joked and made light about some of the events that occurred during his transitional first-year experience by describing situations that left him feeling like a "fraud" or an "imposter" (personal communication, January 22, 2017).

Ian described several emotional experiences arising from a lack of confidence in his physics content knowledge. The one that captures Ian's first-year experience occurred when he was assigned to teach an honors physics class. Ian was somewhat intimidated by this assignment, mostly because the students were well-prepared to take the course and selected based on having a strong foundation in mathematics. Ian colorfully captured the emotional component of that course experience, in the following way:

> Oh, God! That class was like running down a hill at full speed—just petrified that you were going to trip and just crash [laughing lightly]. Everybody is looking at you with their pens in their hands—and I'm thinking that I better start saying something and not mess up. Alright, here we go! (personal communication, January 22, 2017).

As a result, Ian constantly worried about failing in front of his students, and, for the same reason, he was afraid to seek out help from colleagues—Grace an experienced teacher who teaches chemistry and physics—and particularly from John and Smith who each have a PhD in applied physics.

In the following quote, Ian narrates when he had to teach a lesson on projectile motion, which was a topic he struggled with in ACTS:

> For the honors guys [students], you are actually introducing trigonometry because they have to use the angles of the launch to calculate distance and the rest. And I was at a total loss for how to teach this. I think I barely got through that section in the training, and I went into full panic mode because I have to come into the honors class tomorrow and teach them a section of the material that I'm really weak on (personal communication, November 15, 2016).

On the day of the lesson, Ian's thoughts were:

> I remember standing up at the board in front of the class saying to myself, all right man, here we go. I hope that I do not mess this up—and you did not want the kids going, "You're a fraud," or "I'm telling my mom you don't know what you are doing." I felt I could not go to Smith and John because they might say, "Dude, you should know how to do this." So I muscled through it [preparing and teaching the lesson], and actually came up with a good system (personal communication, November 15, 2016).

In as much as Ian appeared to struggle with his confidence, he found ways of experiencing success during his transition.

Ian, new to science, held beliefs about the practice of teaching and the learning of physics, which was influenced by his ACTS preparation, as well as his experience in teaching history. In Ian's view of teaching, he likes the idea of continually experimenting with different pedagogical approaches. As he puts it, "I'm always open to, and I don't want to get set in one particular teaching style. I think that I have seen too many teachers get way too rigid—it's conform, conform, conform" (personal communication, January 22, 1017).

Informed by his experience as a history teacher, he talked about his preference for "conversations" and "debates," and helping the student develop their own knowledge (personal communication, January 22, 1017). In physics, Ian remains hopeful about having the same types of interactions, and stressed he valued lessons that are "fun," and learning where students are "actively participating" (personal communication, January 22, 1017).

Unlike Ian's role as a teacher of history, whereby he felt his purpose was to help his students become citizens informed of their civil and constitutional rights, Ian views his role as a physics teacher differently. Ian feels his role as a physics teacher is to inspire students to study science, and he believes one of the best ways to inspire students is by making lessons fun. In Ian's own words:

> Science, it feels like you are trying to light a fire, and you are taking a room full of kids who might be bored of science or intimidated by it. And for me, it [teaching science] is just kindling that flame—and you have to say to students, come on this is going to be fun, don't be intimidated, don't be afraid of it—come on, come with me—you'll have a good time (personal communication, January 22, 1017).

Ian's physics teaching practice is closely aligned to his preparation. He uses lectures as a way to present course material, and labs to reinforce student learning by providing an opportunity to apply previously learned concepts and principles (Trigwell & Prosser, 1996).

Summary of the Influences on Teacher Identity

Ian continued to identify with the subject of history by drawing on personal and professional experiences. For Ian, drawing on these experiences informed his views on the types of student-teacher relationships he desired to also have in physics. As a result, Ian developed a desire to have fluid roles between himself and students of the course. Ian was not satisfied with leading lessons and he wanted students' curiosities to shape the lesson focus. Ian identified positively with physics until he began preparing to teach the subject. Yet while Ian held a positive physics identity going into his preparation, his views about himself as a physics learner were negatively impacted by this experience. Encountering challenges as a physics learner and while teaching the subject caused Ian to feel as if he was faking his way through—due in large part to his desire to have expert knowledge of physics. Ian's initial positive physics identity was further challenged when he compared himself to science peers in the methods course. In addition, while Ian's comparisons of himself to physics colleagues at Ridge High School also made him feel like a "fraud," at least one of his colleagues, Grace, served as role model and whose professionalism he wanted to emulate.

Sources of Influence on Teacher Knowledge

Physics preparation. Following Ian's method course experience, he learned that algebra and trigonometry were the mathematics needed for high school physics. Ian viewed himself as an experienced teacher. Therefore, while participating in the methods course, Ian was not interested in learning about general teaching strategies. Rather, he was focused on learning subject-specific content knowledge. Ian commented, “I think the strength of the program is giving me the content [physics], but since I was already a veteran teacher, I didn’t need them to teach me how to teach. I know how to do that” (personal communication, January 22, 1017). While Ian was enrolled in the methods course, he reportedly began thinking about how he would present the content to his future students. Ian commented, “As I was going through the material, I would have thoughts. I don’t think that I would teach it that way, because it’s too confusing the way they did it” (personal communication, November 15, 2016).

Working through challenging content. Overall, Ian found his methods-course experience challenging, and, in some ways, he viewed that his switch from history had placed him at a disadvantage to his cohort peers, who he felt were “used to solving these types of problems, but for me I was like how do I—I don’t even know where to start” (personal communication, November 15, 2016). He commented, “I was unique because not only was I learning the science, but I was really learning all of the mathematics at the same time” (personal communication, November 15, 2016).

Ian’s strategy for learning how to solve physics problems was to adapt the approach modeled by his instructor. Ian streamlined procedures by reducing the problem-solving method into 4-steps. This adaptation proved so successful for Ian that he credited it with getting him through his coursework, and he eventually modeled it for his own students. Ian described his thinking at the time as, “I just changed to this solution style for myself, out of desperation. I had to learn how to do math again, and maybe that really helped with the kids. I was like them" (personal communication, November 15, 2016).

After Ian overcame challenges with learning algebra, he was not convinced he could learn trigonometry too. Ian described how he almost quit the program when he first encountered trigonometry. He said, "I was just numb. I am going to tell my wife that I quit. Never mind the algebra that I learned last year. I can't do this [trigonometry]" (personal communication, January 22, 2017).

For Ian, learning trigonometry in the methods course that addressed teaching Advanced Placement physics was another challenge, but not one he was prepared to accomplish on his own. As a result, Ian sought assistance from a mathematics teacher who taught at his high school. "I said to her, 'You have to teach me trigonometry really fast,' and she did," (personal communication, January 22, 2017). According to Ian, with the help of his colleague, he "learned the fundamentals" of trigonometry needed for solving projectile problems (personal communication, January 22, 2017). Ian said his colleague taught him the basics of trigonometry through the mnemonic SOH-CAH-TOA (2017).

In the study of trigonometry, the mnemonic is used for evaluating how the lengths of the sides of the right triangle (opposite, adjacent, and hypotenuse) are related. Ian said, "She starts talking to me about SOH-CAH-TOA. I said, what the heck is SOH-CAH-TOA? Then she explains, sine, cosine, tangent, hypotenuse . . . and after she was finished, I thought to myself, I might be able to do this" (personal communication, January 22, 2017).

Ian had a lighthearted way of talking about some of the challenges he experienced while in ACTS. He struggled with the feeling that his classmates and instructors would judge him because of his non-science background. "I thought everyone was going to find out that I was a faker," or think, "What does this guy think that he is doing studying physics?" (personal communication, January 22, 2017). Over time, Ian's experience in the methods course for teaching Advanced Placement Physics course became less difficult. Ian said the "class got a lot better once his panic over the first couple of chapters went away" (personal communication, January 22, 2017).

Ian reported that once he had a firm grasp of the mathematics, his concerns about learning the course content and passing the course were replaced with excitement and renewed optimism:

> I remember being really excited when I got an "A" back on one of the tests—then I got motivated by that success—then I wanted to get everything right. I didn't want to just coast by with getting most of the problems right. I became a bit like a perfectionist (personal communication, January 22, 2017).

Compared to Ian's physics identity in high school, when he did not have to put forth much effort in passing a physics course, Ian's ACTS experience challenged him, and he seemed to have appreciated the challenge. Ian's experience in the ACTS methods course lead him to renegotiate his physics identity from a student who got through the course by "coasting" to one who is a "perfectionist" (personal communication, January 22, 2017).

On the whole, Ian credited his persistence and self-direction with getting him through the methods course experience. Ian said, "So it was a lot of late nights in the library and problems and repetition and just getting up in the middle of the night and going and doing problems. And you know, little by little things started making sense, and they started clicking" (personal communication, January 22, 2017).

As a result of Ian's own challenges in the methods course, he felt positioned to relate to struggling students. Ian said, "I was that kid in that seat over there. This was me in ACTS saying, what the hell is going on" (personal communication, November 15, 2016).

Physics practicum. As mentioned previously, participants enrolled in ACTS must teach at least one physics course while they go through the program. However, this requirement was modified for Ian because the district did not assign him a class. Instead, Ian co-taught physics two days a week with a cohort peer who was also a fellow history teacher in Ian's department. Yet the arrangement offered Ian few opportunities to teach because his colleague had a difficult time with classroom management, leaving Ian to act as a disciplinarian. Ian described the arrangement as, "I assisted in a class, but I was only able to do it two days a week. And that was more class management than teaching physics" (personal communication, 2016).

Ian was not equally involved in the planning, assessment, and other related instructional activities. He felt that the arrangement may have been a more positive experience had he been paired with another teacher, and one who was equipped to succeed in a challenging classroom setting. When I asked Ian about how this experience factored into his perceptions of preparedness, his response revealed that, despite the classroom trouble, the co-teaching arrangement was not an ideal paring. According to

Ian, “I didn’t gain much from that experience. I feel like I didn’t start doing this until last year, until I started here [Ridge]” (personal communication, January 22, 2017). He characterized his role in the co-teaching arrangement as acting more like an assistant than a teacher.

Although Ian would have liked more opportunities to teach physics during the co-teaching arrangement, he was also not certain whether teaching a physics course fulltime, while still learning the material, would have been beneficial for him, given the rapid pace of the ACTS coursework. Ian stated he often considered the benefits of teaching physics part-time, compared to teaching physics full-time. He concluded that it would have most likely been a “stressful experience teaching physics full-time” (personal communication, January 22, 2017). Ian added, “I remember staying up until four in the morning studying for a test that I had the next day. So, when I think about which path would have worked better, I really don’t know” (personal communication, January 22, 2017). While Ian’s practicum experience was not ideal, it still offered opportunities to take risks in his developing practice.

Teaching the 4-step technique. Co-teaching afforded Ian opportunities to observe his co-teacher enacting the practices modeled by the ACTS instructors. Ian also observed how students interacted with the content and reacted to the specific teaching practices. Ian reported, “I moved around, providing support to students who needed additional help” (personal communication, January 22, 2017). During this time, Ian noticed that the students were having a difficult time organizing their work according to the problem-solving procedure his co-teacher had modeled for them.

As a result, Ian had an opportunity to see how his 4-step method to problem solving would work with struggling students. For example, Ian reported that while working with individual students, he noticed most had difficulty following the problem-solving techniques being taught. Watching the students struggle during the lesson, he thought back to his own experience learning how to solve physics problems, and the idea came to him that he should introduce them to the “4-step technique” he developed in the process of his own struggles with physics problems (personal communication, January 22, 2017). At the end of class that day, Ian asked his co-teacher for permission to teach the next class.

> I told him that I have this idea, and I think that this might help. I said, “I’ll take class tomorrow, and I will show them [the technique] and I will try it out [with the students] and see if it works.” And it started working really well. And so I said, “We have to keep doing this!” (personal communication, January 22, 2017).

Ian’s experience introducing the 4-step technique to the physics learners during his practicum was an affirming start to his physics teaching career. Ian reflected on how well the 4-step method worked for the physics learners:

> Now with this [4-step] process, I feel like I should sell it at this point. I can walk by and see that students have the 4-steps and everything looks right, he or she is good and I am off. And then, I can see and point out to the student, “Hey, you forgot the units, when everything is laid out.” It is very easy to see who is struggling, and who is on task (personal communication, November 15, 2016).

Ian's confidence in his 4-step method led him to take ownership for the success of the students whom he assisted during the practicum, and he had confidence that it would help his future physics learners as well.

Summary of the Influences on Teacher Knowledge

For Ian, changing from teaching history to teaching physics was a significant adjustment. Ian's concern was learning physics and mathematics, which included algebra and trigonometry. Mathematics was one of Ian's greatest challenges, and he turned to a mathematics colleague for help. Although Ian had considered leaving the program, he changed his mind as soon as he began making gains in the coursework. Ian's practicum experience provided a boost to his confidence. This experience allowed Ian to test out his own method of problem-solving in advance of teaching it to his own students.

Sources of Influence on Teacher Practice

Knowledge of physics content and curriculum. Ian, focused on learning physics and the related mathematics, was less concerned with taking up specific teaching strategies modeled in the methods course. Despite Ian's belief that his teaching practice did not have to closely align with his preparation, teaching physics problem solving was a core component of his practice. The ACTS physics curriculum materials were also central to Ian's practice.

During my visits to Ian's classroom to observe his physics teaching, I noticed he used ACTS physics curriculum materials that he modified for use with his students. The lessons also included electronic presentations for lectures, assessments, homework, and classwork assignments. Ian did not use the clickers to assess learners. Instead, he used whiteboards and had students go to the board to write out their problem-solving procedure and solutions by applying the 4-step method, which they called “grandma’s recipe” (personal communication, January 22, 2017).

Ian appeared to encourage student collaboration. When visiting with Ian and his students, I noticed they worked in groups while solving practice problems and during the free-fall lab activity. When Ian signaled it was time for students to work in groups, he would announce “Let’s get in your groups” (personal communication, January 22, 2017). It was not long before all groups were formed with students who were seemingly accustomed to working with one another. The students also worked in small groups when performing the free-fall lab. This lab activity was designed for students to investigate objects’ acceleration due to gravity, which took place days after they learned to solve free-fall type problems. Each student performed their assigned role, such as timing the ball drop, retrieving the dropped balls, and recording the data. Outside of their small groups, Ian’s voice was central to the lesson, and the students generally directed their questions to him and not to each other.

When Ian used the electronic (PowerPoint) presentation, including the embedded formative assessment questions, he did not use the classroom polling devices or clicker to collect student data. Ian felt that using the clickers was not “useful” or “as effective as they [ACTS] think” (Personal, communication, November 15, 2016).

Ian based this opinion on his practicum, where he gained experience using clickers to assess students. Using clickers was new for Ian, and he explained that he did not use them often. “I would forget that they were there, and I would have them out on everybody's desk, and a couple of minutes later, oh yeah, the clickers. Alright everybody, do this problem with the clickers" (personal communication, November 15, 2016). Ian described his experience with formatively assessing his students using the clickers as:

> So the clickers—it works for a little while, and then you get those button mashers. For the first week or two, students are into it. There is a lot of peer pressure, and they compare answers. At first, they don't want to be that one in the small percentage of the names [who got a question wrong], and that works for about two weeks. And after two weeks, nobody cared. They were just mashing the buttons (personal communication, November 15, 2016).

When Ian transferred to Ridge High School, his classroom was not equipped with clickers, but he did have access to student-sized whiteboards. According to Ian, "I found the whiteboard is a more hands-on approach, especially when it comes to them learning and showing the math. And collaboratively, I feel that it is more effective than the clickers" (personal communication, November 15, 2016).

Confidence in appropriating physics curriculum materials. Ian reported he modified most of the ACTS curriculum resources because he believed doing so made teaching the material "easier" (personal communication, January 22, 2017). He commented, "I find myself doing that a lot with the [ACTS] program material, taking it apart and putting it back together in my own way. And it's a lot easier to teach. Because then you really own it, and then it looks effortless" (personal communication, January 22, 2017).

When teaching a lesson, Ian combined problem solving with modified ACTS resources. Ian reported that although he initially used the digital presentations, he did so without making modifications to the content, but soon became dissatisfied with this practice. He referred to the ACTS electronic presentations as a “good script,” but he needed to “make it his own” by “tinkering with it” (personal communication, November 15, 2016). Ian made modifications to the digital presentations, sometimes informed by his methods-course experience, through revisions that included omitting material he thought would be “too confusing” for students (personal communication, November 15, 2016).

Ian also modified classwork and homework assignments for students by omitting specific questions. Highlighting the role of reflection in his practice, Ian explained how he made decisions about what to modify:

> So you will always go back and always reflect, and say I really like the way that they presented this problem in this part of the packet. And I really hate the way that they do this over here, it is too confusing. So, I am going to cut that out. I’m going to use this and change that. And you just start finding out that you are making things your own (personal communication, November 15, 2016).

Ian also stated he was not pleased using the presentations without modifying them because it was a practice with which he was not accustomed (personal communication, November, 15, 2016). As previously mentioned, in Ian’s role as a history teacher, he had grown accustomed to creating his own digital presentations. Ian commented, “Some people are like that, they do what the book is telling them to do. I know people who teach like that. I can't. No, this has to be mine and my thing" (personal communication, November 15, 2016).

Ian also adapted and used content he found while searching the Internet for supplemental teaching materials:

> Now I borrow things from other colleagues in the department in my school and stuff that I find online. It starts with, "Hey, I like the way that this guy did this lesson or these problems or this activity." And so you just steal stuff and tweak it and make it your own. The problem that I have now is that I have too much, and I have to start sifting through it. And now I have a physics program pile. So what I have to do now is mash it altogether into something that I like. This is what I plan to do over a period of time. Hopefully, I will refine it and make it better (personal communication, January 22, 2017).

Overall, Ian's goal to transform the physics courses assigned to him and make it "his own," has led him to even modify the teaching materials he received from Grace, the experienced colleague who informally mentored Ian (personal communication, January 22, 2017).

Experimentation and taking risks. Ian reported he has a "trial and error teaching style" which motivates him to "steal [ideas for lessons] from colleagues" and try them (personal communication, January 22, 2017). However, Ian added, "If it [the lesson] didn't work, I'd either get rid of it or modify it, which I still do to this day" (personal communication, January 22, 2017). According to Ian, he began experimenting with the STEM challenge kits and looks forward to making them a part of his teaching practice for the foreseeable future. “If I can find a way to do that every day of the year, I’ll be a happy man” (personal communication, January 22, 2017).

In another example, Ian described how a lesson on Newton’s First Law, designed to teach the principle of inertia, evolved from being a small part of a lesson into a lab activity for students to perform. Ian offers a description of how he thinks through components of a lesson. He starts off with:

> So, you are like, okay, I am going to get Solo cups, notecards, and pennies. Then, break them [students] up into groups. Then, you are like, now what else can I do while they are in their groups—with the notecard, pennies, and Solo cups? Maybe—they can stack it [the cups], they can try to pull the cards out, and everything will collapse onto each other, if they do it right. How about if I make a worksheet where they have to explain to me what happened and why it happened? And it [lesson] just builds and keeps getting bigger. So you’re never really quite happy with—saying—oh, I am just going to show them how it happens (personal communication, January 22, 2017).

As Ian puts it, “I’m still tweaking lessons right up to the minute, the last minute before class. And sometimes, it [planning and enactment] just spirals in really good ways, and sometimes, it just doesn’t work. Like the table cloth trick that just turned into a big old mess” (personal communication, January 22, 2017).

Ian, on the role of reflection in his practice, said, “You have to honestly reflect on what works and what doesn’t. Why it worked, and why it didn’t. And then, you just try something else. Keep throwing stuff at the wall until it sticks, and then find something else and start messing with that" (personal communication, January 22, 2017).

Relating to physics colleagues. Ian, as a new teacher at Ridge High School, visited the classroom of his physics colleagues. These classroom visits helped reduce Ian's isolation. He noted that observing his colleagues teach informed his own teaching practice. After each visit, Ian reportedly compared the approach he observed his colleagues perform to the way he had planned on teaching a topic or has taught a topic. This practice led Ian to make changes in his own teaching, even if it did not always happen instantaneously. For example, during the summer following Ian's first year at Ridge High School while preparing for the 2016-2017 school year, Ian reflected on a lesson Grace taught during one of his visits to her class. This lesson featured the second kinematics equation.

Ian mentioned how, after watching Grace take a different approach to the kinematics lesson, he decided he would adopt her way in the upcoming school year. Ian explained that Grace had modified the second kinematics equation ($x = x_o + v_o t + 1/2at^2$) for her students, by shortening it. According to Ian, he was initially reluctant to depart from his preparation by modifying the equation. However, Ian revealed that after teaching the equation the way he learned it, he felt Grace's approach was better. Ian found that teaching the equation his way took him twice as long to get through the lesson. Ian said:

> I never used to do this [shorten the second kinematics equation while teaching it], but one of my colleagues [Grace] did it, and I thought it was kind of silly at first when I started, but I was younger and arrogant. I was like, oh yeah, I can

definitely do without this (personal communication, November 15, 2016).

He explained:

> Over the summer, when I sat and reflected on how I did—I decided that I would teach it like Grace, with taking off the first half of the equation, initial position (x_o), and initial velocity times time ($v_o t$). I am just going to use the one-half "a" "t" squared ($1/2at^2$) (personal communication, November 15, 2016).

Ian reasoned that his decision was twofold, saying, "Initial position (x_o) and initial velocity times time ($v_o t$) are always zero in 90% of the example problems that are given in all of the books" (personal communication, November 15, 2016). In teaching honors last year, this change may not have made sense, because Ian's students had strong algebra backgrounds. However, Ian found that the adaptation was appropriate for his current physics students who were "deficient in the prerequisite pre-algebra skills" (personal communication, November 15, 2016).

Upon reflecting on Grace's approach, Ian realized it was useful in helping students without a strong pre-algebra foundation work through physics problems. For instance, according to Ian, shortening the equation assists these learners in understanding the significance of specific mathematical operations, like squaring numbers or performing its inverse of the operation, or finding the number's square root (personal communication, November 15, 2016). On the day of my visit to Ian's classroom, he was teaching a lesson that featured the second kinematics equation. After the lesson, Ian explained how and why he adapted the lesson to depart from the way he learned to teach the equation in ACTS:

> So what's going to happen over the next few days, I am going to get them comfortable using the square in the formula. That's the first time they are going to see that. So, I am going to show them a couple of ways to solve that, then we are going to solve for time. When they solve for time, that means that they are going to use a formula where the square is going to become the square root. They haven't done that before. I found out that it was better for them to concentrate on using the squared in the formula first and then the square root (personal communication, November 15, 2016).

Once Ian had decided to act more responsively to Grace's ideas, he found it to be a valuable learning experience. For example, after Ian observed Grace conduct a lab with her physics students, he asked her for a copy of the activity. In response, Grace not only gave Ian a copy of the lab, but she also gave him electronic copies of all her teaching materials, including lesson plans and even copies of her teaching notes, which he reportedly "reads extensively" (personal communication, January 22, 2017). According to Ian, "One day she said to me, 'Oh! By the way, you may need this' [handing Ian the lab activity]. She also sent it to me by email, along with other materials that turned out to be her entire years' worth of stuff, which was great" (personal communication, January 22, 2017).

Ian's response to Grace's support illustrated how his master teacher identity was changing, as a result of her support. In other words, Ian did not find Grace's support threatening to his (physics) teacher identity. In fact, Ian began aspiring to be more like Grace. He said:

> Grace is incredible! She basically has every day of the year already planned; every ditto, every lesson, every guided note, and homework assignments already done for the entire year. She also has it online with everything laid out. And I want that! I don't want to stay up at night re-doing stuff [modifying and gathering curriculum materials from ACTS or other resources]. I want that! (personal communication, January 22, 2017)

Ian's reaction to Grace was unlike his response to his other two physics colleagues, John and Smith, who both had a PhD in applied physics and whom he limited contact and communication to only brief encounters, because of their status and credentials. Meaning, outside of visiting their classrooms to observe them teach physics, he did not ask them for assistance.

One of the reasons being, Ian reported that, after observing Smith and John teach, he did not find some of their practices useful for students:

> Looking at what they were doing in their rooms, I can say that I did not like everything. Mr. Smith makes it [physics] too complicated than it needs to be. He appeared to like increasing the degree of difficulty, just for the sake of increasing the degree of difficulty. As for my other colleague, John, he just talked over his students' [heads] (personal communication, January 22, 2017).

Therefore, when Ian needed help with preparing for a lesson on a concept he had no prior experience teaching, he did not seek their guidance. Ian also joked about how he interacted with John and Smith by saying that, "As the 'rookie' I am still a bit quiet about things. I usually give a little nod, oh yeah, yeah, and get out of the room before anybody asked me a real question [about physics]" (personal communication, January 22, 2017). Ian admitted that isolating himself was not a helpful strategy, but at the time it made sense. He added, "I probably could have saved myself a lot of long nights working, if I had gone to them sooner. But I didn't want them to know that I didn't know anything about physics" (personal communication, January 22, 2017).

Overall, Ian's goal to transform the physics courses assigned to him and make it "his own" has led him to even modify the teaching materials he received from Grace.

Relating to physics learners. One of the reasons Ian gave for adapting the ACTS curriculum resources, including the presentation slides, is he was concerned about how students would perceive him. "You can see the kids, they are just like, he is just reading off the board" (personal communication, November 15, 2016). In addition, Ian reported he had begun to make changes in his teaching practice by decreasing the problem-solving focus. According to Ian, "The year before when I started teaching, it [physics] was just the math. You'll catch yourself in the middle of a lecture, and, especially in the kinematics chapter, it starts feeling like a math class where the focus of the lesson is on formulas and solving problems" (personal communication, January 22, 2017). As part of Ian's shift, he hoped the students' voices would have a larger role in the lesson through discussions, debates, and the "types of conversations that he wanted to have with students" (personal communication, January 22, 2017). However, Ian explained he was still figuring out how to have debates and discussions in physics. Ian explained:

> In science, it is hard to have that debate when they don't have that knowledge of—for example—if you are talking energy policy and the difference between

> fusion and fission and things like that, you can't have those debates in conversations [if they don't know the difference between the processes] (personal communication, January 22, 2017).

Compared to physics, Ian felt debates were easier to have in a history class:

> In history, you didn't need tools or knowledge to have a debate about politics or to have a discussion about the fourth amendment or voting. For example, should we lower the voting age? Automatically, once you pose the question, you started getting students saying, "this stinks" or "this law is bad." Then you go, why? And you can go from there (personal communication, January 22, 2017).

In place of having debates and discussions, Ian reported his strategy has been to focus on engaging students with engineering-based activities called "STEM challenges," using science kits he discovered in the storage closet of the physics department (personal communication, January 22, 2017). Ian outlined his plan as:

> To get my students to that point, I am starting to find tasks—they call them STEM challenges, where basically you task the students with accomplishing something like a robot build or something like that. You give them a bunch of materials and a task, and then see if they can accomplish that task; like, here are some manila folders and rubber bands, make me a car that is going to make it across the room (personal communication, January 22, 2017).

Ian also views his shift as a way of sharing control of the lesson with the learners:

> And so as I am starting to incorporate these lessons, it is more giving them the reigns. So, it is not just step-by-step instruction and then you can sit back and

> watch them get creative with things and tinker. I am starting to find that path with them, and I would like to do some more of that (personal communication, January 22, 2017).

Ian proudly added, “We are going to start messing with stuff like collision cars, and have them [students] start explaining what they saw and what happened. If I can find a way to do that every day of the year, I’ll be a happy man” (personal communication, January 22, 2017). Ian’s most recent interest in the STEM challenge took place following my visits to observe him teach in November 2016.

Summary of the Influences on Teacher Practice

Given Ian’s nonphysics academic background, the preparation experience provided by ACTS had a significant impact on his teaching practice. However, although Ian viewed that experience as preparation for the Praxis content-examination, he still took up and enacted the practices espoused in the ACTS physics curriculum and preparation. Specifically, Ian mainly taught physics through problem-solving. Whenever Ian diverged from his physics preparation he did so because he believed strongly that he knew a better approach. Further, the culture of Ian’s science department at Ridge Regional High School and Ian’s relationship with Grace gave him access to models of physics teaching practices and materials that he adapted for his own use. As Ian now begins to consider alternate ways of teaching physics, he draws from his previous experience teaching history and it is influencing his desire to have students engage in debates and discussions around physics.

Summary of Ian's Case

Given Ian's history teaching background, learning to teach physics was both a personal and professional accomplishment. After 12 years of teaching history at his previous district, he left history to teach physics in a new school. In a new teaching setting, Ian was often worried about being perceived by his colleagues and students as a "fraud." As a result, Ian worried about rebuilding his reputation as a teacher of physics, while he gained confidence in his new role. Although Ian was initially reluctant to open up to his new colleagues, he found interacting with them valuable. Motivated to make the course material his own, Ian applied his growing subject matter knowledge to modifying the ACTS curriculum materials. Ian had also hoped to promote physics discourse, like the types of interactions he experienced with his history students. In the meantime, Ian has incorporated STEM challenges into his teaching, in order to shift the focus away from problem solving and to make the course more aligned with his beliefs about his own practice.

Ian's knowledge of physics teaching includes the following: algebra and trigonometry in learning physics, content representations, curriculum resources inclusive of—and—beyond those learned during his ACTS preparation, topic-specific knowledge of students' difficulties in learning physics, and educational technologies for use in supporting and assessing student learning.

As Ian thinks ahead and continues teaching physics, his own professional learning goals include deepening his own understanding of mathematics by pursuing a degree in the subject, given his experience with struggling algebra students. Ian also desires to pursue a bachelor's degree in mathematics to prepare for teaching Advanced Placement Physics courses.

Case Study #3: Alex of Liberty High School

Table 4

Alex's Career and Certification Timeline

Year	Teaching Assignment	Credential program
2000	Biology/Alternative High School	began state alternate route program for biology teaching license
2001	Biology/Alternative High School	completed state alternate route program for biology teaching license
2003	Biology/Liberty High School	
2009	Physics/Liberty High School	began ACTS program for physics teaching license
2010	Physics/Liberty High School	continued ACTS program for physics teaching license
2010	Physics/Liberty High School	completed ACTS program for physics teaching license
2010	Physics/Liberty High School	

Alex has 16 years of teaching experience in the sciences. With an undergraduate major in biology, Alex was first hired by an alternative education high school for students at risk of dropping out. Here, he taught biology. Since becoming physics-certified, Alex primarily teaches physics, but also teaches biology and environmental science. Of all the courses Alex is certified to teach, he prefers teaching physics.

The Liberty School District is comprised of an ethnically diverse group of families who are socioeconomically designated poor and part of the working-class. Of the approximately 25,000 students, ninety-one percent are eligible for free and reduced-price lunch. Liberty High School is comprised of 1,600 students, of which 51 percent are

Hispanic, 21 percent African American, 19 percent Asian, and 7 percent white. The district reformed its science instructional program because there was a lack of previous academic opportunities.

Overview of Learning to Teach

Prior to teaching physics, Alex primarily taught biology. From 2000, Alex taught biology at an alternative education high school for three years, until the program lost its funding and closed. Alex reported he enjoyed his time at the alternative school. Alex, focusing on the relationships between staff and students, reported, “It was a small community that turned into a small family” (personal communication, October 6, 2016). Next, Alex joined the teaching staff of the Liberty School District, where he taught biology and environmental science until 2010 when he became physics-certified.

Compared to teaching physics, Alex mentioned that overall he found the biology curriculum challenging to teach because they generally emphasized learning “concepts” and “memorization” (personal communication, October 6, 2016). Based on this experience, Alex concluded biology was difficult for students to learn because it lacked a focus on mathematical sense making, which he believed created many opportunities where “students can get lost” during a lesson (personal communication, October 6, 2016). He said, “When I was teaching biology, it was mostly concepts and laboratory exercises” (personal communication, October 6, 2016). Having had less success with the biology students, Alex was often disappointed when it appeared they were not motivated to take responsibility for their learning, and this issue remained a significant area of concern for him, even now with physics learners.

Sources of Influence on Teacher Identity

Physics identity. As a physics learner, Alex imagined himself as competent and capable of success at any level, which he credits to his mathematical foundation and ability to "reason abstractly" (personal communication, October 6, 2016). Although Alex did not study physics in high school, he successfully completed one year of physics in college, as an undergraduate student who was pursuing a pre-medicine matriculation. While in college, Alex developed a positive physics identity, and his physics learner identity translated into his experience in ACTS, allowing him to persevere through the challenges encountered.

Mathematics identity. Alex has a positive mathematics identity, and being competent in mathematics is how he also defines his physics identity. Alex's mathematics identity developed through successful participation in various mathematics courses throughout his academic experiences. During interviews with Alex, he continuously brought his mathematics experiences into our discussions. In commenting on his high school and college experiences, Alex highlighted his foundation in mathematics, and he explained, "When I was in high school, I could handle the math and I thought it was too easy" (personal communication, October 6, 2016). With regards to Alex's undergraduate experience, he highlighted that, "I had to take remedial courses in English, but not the math, okay. Because in English, I had to learn how to write, punctuation—and you know, it wasn't my favorite" (personal communication, October 6, 2016).

Alex identified that being disciplined is one of his core values, which influenced not only how he related to mathematics, but also influenced how he related to all of his students. Regarding Alex's relationship with his own students, in an effort to understand their disinterest in doing homework or studying, he often compared himself to these physics learners. For example, when talking about students who were not performing well in physics, he often related his students' performances to his own as a mathematics learner. Alex commented:

> Back when I was in elementary school in my country and the teacher gave homework, I didn't question why I had to spend two hours studying. I was disciplined. I had that discipline. Whereas, now, students—don't do homework. They ask me, "What homework are you talking about?" (personal communication, October 6, 2016).

Identifying with mathematics influenced why Alex prefers to teach physics. Alex commented, "I felt more comfortable as a physics teacher" (personal communication, October 6, 2016). When I pressed Alex to tell me more about his comfort in teaching physics, his response highlighted that he relates to physics through mathematics. Alex responded:

> Yes, well—physics teaching, of course, you have to be prepared in advance. In preparing and teaching my lessons, I like the mathematical aspects of that whatever happens you have to use some kind of mathematical equation. For instance, in physics we focus a lot on, you know, objects in motion. So, how do

> you prove that? You prove it through mathematics (personal communication, October 6, 2016).

For Alex, identifying with mathematics influenced his decision to pursue physics in college and to pursue a physics certification.

Teacher as a subject matter expert. Alex's beliefs about teaching and learning are influenced mostly by traditional models. Some of Alex's student-focused views include his ideas about the importance of welcoming classroom environments. He said, "My role as a physics teacher is to create an environment in my classroom where the students are comfortable, and where they know that the information that they will be receiving is about physics and it's going to be fun" (personal communication, October 6, 2016). In Alex's view, the role of the teacher is to pass on knowledge of the subjects to students (Trigwell & Prosser, 1996). He reasoned that, "Students can't decide for themselves what they are going to learn" (personal communication, October 6, 2016). According to Alex, "I am the teacher. I am the experienced one. I know the easy route. This is basically what we [teachers] are doing—is to show them the easy route. Meaning, when teachers connect A and B for the student, it will make sense" (personal communication, October 6, 2016). Alex added, "Otherwise, they [students] would open the book and go to this page and that page and not absorb anything. So you have to know how to structure it [content] so that it is meaningful, and that the students understand it, and they get it" (personal communication, October 6, 2016). Alex's perspective on teaching and learning appears to reflect his own academic experience as a young learner, of which he characterized as a "traditional route" involving "a lot of memorization" and "teachers—teach you in a way that you understand" (personal communication, October 6, 2016).

Other descriptions Alex used to describe influences on his beliefs of teaching were, "I'm from the school of direct instruction. You know, from what I can recall, everything was about the teacher" (personal communication, October 6, 2016). Alex disagrees with the more current notion of teacher as facilitator, which is a view of teaching he has reportedly encountered attending district-sponsored workshops. Alex said, "I understand you have to make changes, but in my experience the students don't know what he or she should learn, right? So you have to package that information for them, right, so of course you have to be creative" (personal communication, October 6, 2016).

In addition, Alex's conception of teaching is in line with what he believes is his purpose as a physics teacher. For Alex, this purpose is to prepare students to study the subject at the college level (personal communication, October 6, 2016). Also, within Alex's view of teaching, reflection is used to inquire into his own teaching practice by thinking about ways of planning or improving a lesson in relation to specific student characteristics or responses (Buehl & Fives, 2009).

Teacher as a role model. Outside of teaching, Alex has a successful small business in home remodeling and general contracting. To Alex, there are many similarities between being a contractor and being a physics teacher. Alex pointed out that contractors draw from a similar knowledge-base as physics teachers, because the technical side of construction is based on the fundamentals of physics, which is applied to the process of designing and building structures. Likewise, Alex views teaching physics as a process similar to apprenticing students into ways of thinking about the subject. Alex said:

> For example, I do construction. In construction, I have to teach you how to frame. I have to teach you the right way. Otherwise, if you are measuring a door or window frame, it won't [get it] leveled. Okay, I have to give you my technique. I teach you how to read this, how to read that, then you, yourself will become an expert (personal communication, October 6, 2016).

Alex's above statement demonstrates how he views the role of teacher and expert as one in the same. Therefore, Alex believes the two professional identities are in harmony with each other. In both cases, being a subject matter expert is a key professional identity characteristic.

Alex uses his own experience as a physics learner to motivate students. He gives them advice by saying, "I want this to be practice because if you guys are going to be in the engineering or computer science fields, you need the patience to persevere through solving problems. Even it means that on Saturdays and Sundays you are home studying all day long" (Alex, 2016). Alex aligned his efforts and preparation for physics with professionals that have status in society, such as "doctors" and physicists like "Albert Einstein," who he referenced as "our best minds" (personal communication, December 11, 2016).

Physics has brought Alex a renewed sense of purpose in his teaching career. Alex views high school physics as a foundation needed for student success in college physics or for being applied to a related career. For this reason, Alex is proud to be in the position to prepare students, whose academic and personal life experiences he finds relatable. Alex, as a black man, has had similar life experiences as the students he serves, including family life and socioeconomic backgrounds. He views himself as a role model of students. When Alex was 16, he immigrated to the United States from a country that is economically poor, but rich in culture, national pride, and natural resources. Since Alex moved to the United States and transitioned to adulthood, he has moved upwards, not only when it comes to socioeconomic status, but also his social status within his community, all of which he attributes to hard work in all facets of his life, especially in education. As a result, Alex values having positive relationships with students, based on mutual respect.

Alex reported that he sometimes feels discouraged about his ability to motivate students, and that there are factors beyond his control. Alex commented, “I can only deal with them while they are in the classroom. I can pray and can say please, please, you are going to have a test tomorrow…study, study, study—but I can’t force them” (personal communication, October 6, 2016).

Summary of Influence on Teacher Identity

A source of influence on Alex’s physics teacher identity includes his own experiences as both a mathematics and physics learner. Alex believes he is competent in physics because of his mathematics foundation. Another source of influence on Alex’s teacher identity is his traditional beliefs about the role of the teacher and students, which he combines with concerns like providing students with a welcoming classroom culture that helps to foster "enjoyable" learning experiences. Although Alex views himself as a role model, he is sometimes less optimistic about his ability to motivate his students.

Sources of Influence on Teacher Knowledge

Physics preparation. Alex was completely satisfied with his preparation experience. He reported that the methods course "exceeded his expectations," and he highlighted the benefit of engaging with the high school physics curriculum as a learner (personal communication, October 6, 2016). He added, "I think that this program well prepared me to teach physics" (personal communication, October 6, 2016). Despite having successfully completed a year of undergraduate physics, a requirement for matriculated pre-medicine students, Alex not only found the pace of the ACTS coursework demanding, but he was surprised by how much more he learned about physics. He added that instructors "taught more concepts than typical of a college semester" (personal communication, October 6, 2016). According to Alex, the methods course units of study included those encountered by first and second year physics students, which are: kinematics, dynamics, electricity and magnetism, optics, and nuclear physics. Alex commented that the course activities included the following: performing experiments, doing problem solving, having discussions generally performed in groups, and completing homework assignments, which provided additional practice in problem-solving and were completed independently by each student (personal communication, October 6, 2016).

Alex kept up with the demands of the methods course by devoting time beyond the scheduled class sessions to practice solving physics problems or to research content presented in class that remained unclear to him. Alex said, "I have invested a lot of time [learning physics], my routine was, after class, I went home and studied from 8pm to 11pm, and on the weekends for upwards of 10 hours because I wanted to be successful. It was tough, and I felt like I was in college again" (personal communication, October 6, 2016). Partly because of the competitive ACTS culture and partly to protect his positive physics identity, Alex avoided asking for help or clarification on specific course material, even when he might have felt it warranted greater attention from the instructor. In order to maintain a competitive position, Alex supplemented his own learning. He explained that the "internet was my resource" (personal communication, October 6, 2016). Seemingly pleased with the way he managed to keep up with the demands of the course, Alex emphasized, "If you were confused about something—you didn't want to look like you didn't understand," he chuckled, "So you go home and you spend extra time to go through the example problems trying to understand" (personal communication, October 6, 2016).

Working through challenging content. While Alex avoided seeking help during class, outside of the methods course he sought support from an experienced physics teacher in his department. Alex's physics colleague was already certified in the subject, but he had been participating in ACTS to learn the algebra-based approach to physics teaching. Alex reflected on an experience that he "found challenging," which involved solving multistep problems and using multiple equations (personal communication, October 6, 2016). Alex explained that to solve this type of problem, one had to first "find velocity" using one equation before solving for acceleration, which required him to use another equation (personal communication, October 6, 2016). Alex's challenge did not involve mathematical skills—his challenge was conceptual. Alex summarized his difficulty by saying, "I did not see the connection between the two different equations" (personal communication, October 6, 2016). Alex stated that his colleague was "generous with his time," and he even allowed Alex to call "anytime" for tutoring, which sometimes took place over the phone or in-person (personal communication, October 6, 2016). Furthermore, in the absence of Alex receiving support from his trusted colleague, he studied on his own, or, as he called it, "doing research" (personal communication, October 6, 2016). Alex explained why he often did his own "research." He commented, "If you are not familiar with a topic, you get the textbook. You have to read on your own" (personal communication, October 6, 2016).

Physics practicum. During Alex's practicum, he was assigned to teach one class of physics fulltime. Alex reported he had relied almost exclusively on his physics preparation and, specifically, the ACTS curriculum resources to guide him through the lessons. From this experience, Alex became much more familiar with the content of the ACTS curriculum. Alex, viewing his practice as a performance, described his use of ACTS curriculum materials as being "scripted" (personal communication, October 6, 2016). Alex reasoned that closely following the curriculum was necessary. He explained, "In the beginning, I stayed on script. I was acting. It wasn't me, okay? I didn't feel comfortable enough to take risks [going off-script]" (personal communication, October 6, 2016). Alex justified his decision by suggesting that it is common for new teachers to rely on curriculum resources, such as using a teacher's edition for guidance when teaching a lesson. Alex reflected, "At the beginning, my first year [teaching physics], it had to be scripted the first year because you want to make sure that you taught the information they way that it was taught to you" (personal communication, October 6, 2016).

Continued study of physics. While Alex generally remained scripted, he diverged from closely following the ACTS curriculum whenever he identified gaps in his own knowledge of physics or mathematics concepts. Alex addressed these perceived gaps by supplementing his preparation through additional research, which sometimes yielded lab activities and ideas on how to teach mathematics concepts. For example, when Alex began planning for a lesson on uniform circular motion, it forced him to acknowledge he still had gaps in his understanding about the concept of a circle. Specifically, Alex realized he did not understand what the number 3.14 (pi π) really meant. Thus, he wanted to prepare to respond to students' questions regarding why the circumference of a circle is 3.14 (pi π). According to Alex, he not only researched the answer, but he also searched for ideas on how to teach the concept of 3.14 (pi π) in a "meaningful way" so as to leave his students with a firm understanding of the concept and without gaps in their own understanding (personal communication, October 6, 2016). Alex explained how he thought through that experience:

> When I was teaching circular motion to my students, I said to myself that I needed to do some research. I needed to know why the circumference of a circle is 3.14 (pi π). When I took math previously, I don't remember my teacher ever explaining [it] to me (personal communication, October 6, 2016).

In preparation to expand his own knowledge of the pi concept, Alex explained that his strategy was:

> I had to go to different sources, so I read different mathematics books because I wanted to see the information presented in different ways. Finally, then I found out the circumference is three times the diameter, plus there is a little left over. That little bit left over is the .14—and I also learned how I would teach it. I would use a rope to show them the relationship—why pi is 3.14 (personal communication, October 6, 2016).

Alex gave another example of the time he added a mini lesson in order to show his students how to use the coordinate system to find the signs of the trigonometric functions.

Summary of the Influences on Teacher Knowledge

Alex indicated that the methods courses, which provided opportunities to learn the material encompassing the high school physics curriculum, had a significant influence on his knowledge for teaching. When Alex perceived gaps in his understanding of the course material, he addressed the issue by seeking out additional physics resources. Alex reasoned that if he found a concept difficult, his students might too. As Alex conducted his own research on physics or mathematics concepts, he gathered materials that were helpful in presenting mathematics and physics ideas to students.

Sources of Influence on Teacher Practice

Knowledge of physics content and curriculum. When I visited Alex's classroom to observe him teach a physics lesson, in my experience there, I noted that his approach to teaching the subject was consistent with the descriptions of practice he provided during previous interviews. During the lessons, Alex taught his students how to reason about physics concepts through various algebra-based physics problems, which he or his students modeled at the board. The lessons also included “direct instruction” supported by components of the ACTS curriculum, such as the classwork and homework problems assigned to students, and the Atwood Machine lab investigation (personal communication, October 6, 2016). In Alex’s own words:

> I use direct instruction for at least the first ten to fifteen minutes of class to present them with the information. I probably asked them a few questions to see where they are, to see where I am going with it. And, after that, I allow them to collaborate to work together on questions. Within that small group, they have to be able to answer those questions based on the information that I provided to them. Then, of course, I monitor them as I walk around (personal communication, October 6, 2016).

Again, these practices that Alex described were illustrated during my observations of his lessons on Newton’s Laws of motion, except the lectures were longer and he included demonstrations to expound on inertia. Also, regarding student collaboration, when they were encouraged to discuss the concepts presented, I observed students talking with a peer or in small groups. I also observed students working together during the Atwood machine lab. In Alex’s physics class, he assigned the Atwood experiment because it was an application of Newton’s Laws.

In the Atwood experiment, there is a hanging mass attached to a string that passes around a pulley attached to a cart on a level track. When the cart is allowed to move, the weight of the hanging mass will pull the cart along the track. Alex reasoned that he assigned the Atwood experiment because, “Doing a lab is really to reinforce the concepts, it makes learning hands-on. It is a fun way to learn because it helps the students to make connections” (personal communication, October 27, 2016). Despite Alex’s enthusiasm for integrating labs into his teaching, he did not have access to a traditional lab facility with a separate space for investigations and a separate space for lectures.

Alex also formatively assessed his students, a practice he took up during his ACTS preparation. However, Alex noted that aside from both the electronic whiteboard and projector in his classroom being broken, he was not using the classroom response system to poll his students because he did not have a classroom response system. In place of the clickers, Alex assigned students specific problems to solve or conceptual questions to answer. After students had selected an answer from among the multiple choice problems, Alex selected a volunteer to give their answer. Sometimes, the volunteer would work their problem out on the board for the rest of the class to see. Alex would summarize the main idea or elaborate on the concept or principle featured in the questions before moving on to the next part of the lesson.

Confidence in appropriating physics curriculum materials. In responding to the study’s questionnaire, Alex attributed “physics-teaching experience” to his confidence in presenting the course content (personal communication, October 6, 2016). Alex explained that, “It has been a couple years now. I don’t need the book [ACTS content]. Why? Because I [have] accumulated so much knowledge doing it [teaching physics], and in many different ways, because this is where the experience counts” (personal communication, October 6, 2016). With confidence, Alex began relying less on the content in the ACTS electronic presentations to guide him during lessons, and he began to make modifications to the scope and sequence of the curriculum topics. Alex reported that once he fully understood the relationship between concepts in the ACTS curriculum, he no longer felt pressured to teach the topics in the order suggested. As a consequence of being less scripted, Alex commented, “There is more time to take questions because I can skip information and fill that void with something else from another chapter” (personal communication, October 27, 2016).

Alex related his confidence with an increased willingness to have unscripted interactions with his students during lessons, such as posing and responding to students’ questions more freely. Alex commented, “I guess, now, it’s we have more contact. I have more interactions with the students. I can walk around the room, I can ask questions” (personal communication, October 6, 2016). Alex described his current teaching practice as, “I will present the topic—opening it up for discussion to get the students involved” (personal communication, October 6, 2016). During my observations of Alex’s practice around classroom discussions, I found that his voice was central to the conversations, and he closely monitored the content of the discussions by redirecting students whose contribution appeared to divert from the focus of the discussion.

Alex added that because of experience and confidence, he can now adjust the “rigor” of a lesson by including or excluding advanced mathematics, such as trigonometry (personal communication, October 6, 2016). Alex commented:

> I can easily adjust a lesson for different students. For example, the freshmen, I am teaching them kinematics in one-dimensional motion. If they haven’t had

> trigonometry, I don't go into 2-dimensional where they have to use basic trig-functions such as sine and cosine, which they do not have yet. If I am teaching seniors in a class that is non-honors, the students may have more skills, in terms of algebra 2 and trigonometry. Then, I will add 2-dimensional motion in the lesson (personal communication, October 6, 2016).

Alex mentioned the academic levels of the students in his physics classes often varied, so knowing how to adapt the lesson to address the needs of individual students was essential.

Alex explained he also related confidence with feeling like he had ownership of the course content, by understanding it at a deeper level. According to Alex:

> Over time, you will develop content knowledge. At first, you will solve problems just to solve problems. Okay, but over the years I experienced those "aha" moments—when what I am teaching makes sense in a new way, and then it [physics knowledge] becomes mine. I'll never forget it, and no one can ever take that away from me (personal communication, October 6, 2016).

The other changes to Alex's teaching practice were influenced by suggestions from the department leader who recommended he shift his instructional focus from mathematically-based to conceptual.

In terms of how Alex viewed changes to his teaching practice, he compared his current practice to his first year of physics teaching:

> In the beginning, my first year, I was like teaching slide after slide, and I went through each problem one by one. Then, they [students] responded, and I assessed

> them at the end, right? So, I was really the focus of the lesson. I was the person in front of the room, and everybody [learners] was sitting. Now, I am able to cut that [the repetition] down, a lot, because the knowledge is here now (personal communication, October 6, 2016).

Alex noted how interactions with students changed once he became comfortable with his knowledge of physics.

Relating to physics colleagues. Besides the physics colleague who tutored Alex, he talked about another colleague with whom he shared a classroom. This second colleague was a former mathematics teacher that became physics certified through ACTS. Because Alex and she taught in the same classroom, their schedules allowed them time to observe each other's physics lessons. Alex recalled the time when he learned a useful tip from this fellow physics teacher. One day, while observing her teach an introductory physics lesson on the topic of speed, he noticed she helped students struggling with algebra solve a problem by showing them how to isolate one variable at a time using a proportional model called a magic triangle.[2]

Outside of Alex's two physics colleagues, he did not develop relationships with any other physics teachers. Overall, he expressed disappointment by the isolation in the science department. He expressed regrets about missed opportunities for himself and other physics colleagues to collaborate and to learn from each other. Alex felt strongly

[2] When using the magic triangle to isolate each of the three variables, D (the distance) goes in the top part of the triangle, S (speed) goes in the bottom left of the triangle, and T (time) goes in the bottom right of the triangle. If you want to calculate the speed, cover up S in the triangle, and you get S = D/T. If you want to calculate the time, cover up T in the triangle, and you get T = D/S. If you want to calculate the distance, cover up D in the triangle, and you get D = S×T.

that the isolation was unproductive for teachers and, ultimately, for students as well:

> We should have some consistency as a science department. Most people around here work in isolation. Working in isolation does not help the teachers nor does it help the students, you know. It is a big community. Why should I or any other teacher start from scratch? When I first started teaching physics, I was spending so much time researching looking for what laboratory activity that I could do. What are some video clips I can incorporate into my lessons? (personal communication, December 11, 2016).

Alex described the science department at his school as having limited collegial opportunities, and he placed the onus on the department leadership.

Relating to physics learners. Alex explained that when planning for lessons, in addition to identifying what students will learn and be able to do at the conclusion of a lesson, he drew from his experience in ACTS. Alex commented, “I try to remember where I had the most difficulty, and I apply it to my teaching” (personal communication, December 11, 2016). Specifically, he felt informed about what his students might find difficult, based on his own experience. In planning, Alex said that when he thought about “what was difficult for me to understand, I figure there has to be a way for me to explain it to them” (personal communication, October 6, 2016). For example, Alex said the following about finally learning how to determine the sides of a right triangle, and how he explains it to his own students:

> If only someone had said to me, “Alex, this one is obvious (pointing to the long side). The long side is going to be the hypotenuse, and it is always opposite the

right angle. Then, it is very easy to identify the other two sides of the triangle. The shorter of the two remaining sides is the given opposite side, and the side next to that is the adjacent side" (personal communication, October 6, 2016).

During one of my visits to Alex's classroom, I observed him while he taught a lesson that included a review of principles related to projectile motion in which he focused on concepts like vertical and horizontal velocity. In the interview following this lesson, I asked Alex to what did he attribute the difficulties of some students, and he related it to gaps in their mathematical foundation. Alex was puzzled by his student's lack of mathematical knowledge because, although some of his students had taken pre-calculus, he found that they often struggled with "simple" mathematic concepts. Alex assessed the situation by saying, "If they understand functions and limits and things that are very abstract, then the simple math that we are doing should come easy" (personal communication, October 6, 2016).

Reflection. According to Alex, students were generally the focus of his reflections. Alex reported that, "I learned from my experiences—when I think about the way that I taught a topic the last time, I think about the number of students [who] did not get it. Then, I think about ways that I can do things differently in the lesson to make sure that all the students get it now" (personal communication, October 6, 2016). In planning for a lesson, Alex indicated he reflected on his own experiences as a physics learner in ACTS. Alex previously commented, "I try to remember where I had the most difficulty, and I apply it to my teaching" (personal communication, December 11, 2016).

Relating to department leadership. Alex explained he had "shifted" his instructional approach, following the feedback he received from the department chairperson regarding his practice (personal communication, October 6, 2016). Alex reported he had shifted the focus of his practice from problem-solving to a conceptual approach. Alex commented, "They told me teach more conceptual, saying, too much algebra-based problems. We don't want you to teach so much of the math" (personal communication, October 6, 2016). It is important to note Alex did not report receiving any additional support from his supervisors following their request.

Therefore, Alex was left to interpret conceptual physics teaching in his own way, which appeared to involve assigning his students fewer problems to solve. For example, when Alex taught universal gravitation, he reportedly left out the calculations altogether. According to Alex, "I have shifted a little bit" (personal communication, October 6, 2016). For example, when teaching universal gravitation, he reportedly "filtered out much of the mathematics," and he claimed that, "In the end, they still understood the lesson in terms of the concept—what universal gravitation means" (personal communication, October 6, 2016). Alex added he only showed the students the equations, but he did not assign problems for them to solve. "I showed them this is the equation that we use. It doesn't matter if there is less mathematics. It matters that they were still exposed to the idea of universal gravitation" (personal communication, October 6, 2016). Alex commented that he reinforced this concept in a subsequent lesson on simple harmonics, as well as electricity and magnetism. "When we did electricity, electric force, I showed them the connection to—it is the same thing as universal gravitation" (personal communication, October 6, 2016). Alex highlighted that focusing less on the mathematics was not a difficult adjustment because he knows how to make connections between different concepts. He said, “I know what to filter now. In other words, it [the lesson] is not scripted anymore. Now, I can skip a chapter just so we have a chance to explore one idea over another” (personal communication, October 6, 2016).

Lack of support. Of particular concern to Alex was the lack of support he perceived from the department chairperson. Alex explained that teaching resources within the department were scarce, and it negatively affected the quality of his lessons. Alex commented that, “We didn’t get a lot of support,” and he felt strongly that being supported would have helped him experience greater success with his students (personal communication, December 11, 2016). Alex reported that his students missed out on lab activities when he did not have the resources. He explained he replaced those lab assignments with simulations. Exasperated, Alex commented, “I mean, how many PHET simulations are you going to do” (personal communication, December 11, 2016). Alex explained that without the labs, students grew tired of the simulations and practice problems. He reported, “Had we gotten the support, then the students would buy into the program too” (personal communication, December 11, 2016). Alex commented, “If the superiors do not buy-in either, then it is difficult for the teachers to be successful, because it does not matter what you do” (personal communication, December 11, 2016). Therefore, in as much as Alex felt strongly about the importance of lab activities in learning science, having to find his own resources was discouraging to Alex:

> When you are the one that has to go out to get it, it is easy to procrastinate

> because you have so many other things to do. Sometimes, I put it off and say, "I will do it next week." And the next thing you know, the marking period has ended, and I didn't even get to it [buying materials for a lesson]. Students need hands-on. They tend to remember the concepts more (personal communication, December 11, 2016).

Alex viewed the lack of support unfair to his students.

Summary of the Influences on Teacher Practice

As a former biology teacher, Alex much preferred to teach physics because of its strong alignment with mathematics. Moreover, given Alex's solid foundation in mathematics teaching physics through problem-solving was an approach that he found consistent with his skillset. Since becoming physics certified, his physics teaching practices remains closely aligned to his preparation experience—which appears largely due to both his personal and professional experiences with traditional teaching methods, which were reinforced during his ACTS preparation and through his current use of the ACTS physics curriculum. Hence, Alex views the role of the teacher as the knowledge expert and he generally takes the led during lesson. While Alex is open to evolving his teaching practice, his experience in the science department at Liberty High School has been isolating and he also experiences a lack of support from department leadership.

Summary of Alex's Case

Compared to teaching biology, Alex much prefers to teach physics. While it seems physics helped Alex find new meaning in his work with students, teaching the subject had not altered Alex's views about the roles of teachers and students. Alex also views himself as a role model for students, although he is sometimes discouraged. Alex's knowledge of physics content and pedagogy are strongly aligned to his preparation, and he also views his mathematics background as an asset in his physics teaching. When Alex was not leaning on his experienced physics colleague for help, he supplemented his ACTS preparation through online tutorials on physics problem solving. Alex searched websites designated for teaching physics and mathematics for ideas on how to present specific topics. Although Alex was open to collaborating with physics colleagues, there were few opportunities for him to do so. His department chairperson, who was not supportive of the ACTS curriculum and pedagogy, recommended he focus less on problem-solving and more on a conceptual-based teaching, but offered him no support.

Alex's knowledge of physics teaching includes the following: algebra and trigonometry in learning physics, content representations, curriculum resources inclusive of—and—beyond those learned during his ACTS preparation, topic-specific knowledge of students' difficulties in learning physics, and educational technologies for use in supporting and assessing student learning.

As for Alex's future in physics teaching, one of his goals is teaching some of the topics he rarely could in the first year physics course, such as optics, astronomy, and nuclear physics. In preparation for these opportunities, Alex plans on enrolling in college courses for these subjects.

Case Study #4: Maya of Willow High School

Maya, a new physics teacher of less than one year, had 5 years of previous teaching experience, primarily in mathematics. With an undergraduate major in mathematics, Maya was first hired by an alternative education middle school in 2012. While there, she taught pre-algebra for one year before transferring to Willow High School in 2013, where she taught algebra. Since 2016, Maya has only taught physics. Prior to teaching, Maya held a position as a government contractor who inspected chemical plants.

Willow High School is part of the Willow District, a large urban district which enrolls about 12,000 students and has a faculty of approximately 1,200 teachers. Willow High School enrolls 700 students with a 39 percent Hispanic, 59 percent African American, 1 percent Asian, and 1 percent white student population. Eighty-six percent of the students are eligible for free and reduced-price lunch.

Table 5

Maya's Career and Certification Timeline

Year	Teaching Assignment	Credential program
2011	Mathematics/Willow Alternative Middle School	began state alternate route program for mathematics teaching license
2012	Mathematics/Willow Alternative Middle School	completed state alternate route program for mathematics teaching license
2013	Mathematics/Willow High School	
2013	Mathematics/Willow High School	began ACTS program for physics teaching license
2014	Mathematics/Willow High School	continued ACTS program for physics teaching license
2015	Mathematics/Willow High School	completed ACTS program for physics teaching license
2016	Physics/Willow High School	

Overview of Learning to Teach

Maya's participation with ACTS was her second alternate route experience. When Maya was hired for the mathematics position at an alternative middle school, which was her first teaching assignment, she did not have a standard teaching certificate. She completed licensure requirements through an alternate route program. Maya completed the year-long program by attending class twice a week. She said, "We met on Fridays from four to nine o'clock and on Saturdays" (Maya, personal communication, October 25, 2016). Maya described her initial alternate route experiences as "valuable" and mentioned that course instructors "were so forthcoming with their information and truly trying to make sure that we were successful teachers, and I truly appreciated that" (personal communication, October 25, 2016). Maya described what she learned from the instructor of alternate route program:

> I mean, he gave us some really good tips. The instructor said things like, "Your first year teaching is going to be your toughest year," and, "This is what to say to parents, and don't say that to parents." And, how not to put yourself in xyz position because you'll be vulnerable to this and that (personal communication, October 25, 2016).

Maya reported the other topics addressed ranged from general teaching strategies, including classroom management and record keeping to how to build relationships with parents. She described a supportive culture in the alternate route program. According to Maya, "We shared hands-on activities then the teachers implemented those ideas discussed in class. And, in the next class meeting, they reported back on their experiences" (personal communication, October 25, 2016). Maya provided more detail of her alternate route program experience:

> We would discuss pedagogy in our different disciplines because there were teachers from other subjects. It wasn't just math folk in this program. There were people from language arts, art, and all that. And we would talk about pedagogy, classroom management, some teaching skills, and techniques. We would share some ideas and talk about what's working in your classroom, what's not working in your classroom, and different ideas. And, we would implement them. If we met on Friday, we would implement that following week and report that following Friday. How did it work with your class? Did it work well? (personal communication, October 25, 2016)

Maya reported she was pleased with her alternate route experience, where she learned general teaching ideas that she incorporated into her classroom teaching. As part of Maya's alternate route experience, Maya was assigned a mentor teacher, and she reportedly benefited from her guidance because most of what they discussed was applicable to her teaching. Maya recalled:

> I had a mentor because the district assigned you a mentor. And she was like the best of the best in the district. I would ask her specific questions, and ask her open-ended questions to see what she was going to say. And when I went to her, I would soak up everything (personal communication, October 25, 2016).

Maya described a unique first-year teaching experience in which she reportedly taught little mathematics. Instead, she and her middle school colleagues, most of whom were also new teachers, were told by the principal of the school to focus on building rapport with students and addressing behavior before they could begin teaching content. Maya on her principal's directive:

> Our principal, his motto was we had to modify the behavior before we could teach them. So his thing was behavior first and academics second. So that is what we did. I learned how to build a rapport with my students. So, I spent that year pretty much building a rapport with my students. When I was finally comfortable with it, then I started teaching them, truly teaching them. It was a very different environment, very different (personal communication, October 25, 2016).

Initially, whether Maya agreed with her principal or not, she did what she was asked to do, and she found a strategy that worked, which was listening to her students:

> The first year was truly emotionally draining because these kids came with baggage and needed someone to listen. It was difficult sometimes to actually listen to their stories because, for me as an adult, I don't think that *I* would have been able to handle what they were dealing with (personal communication, October 25, 2016).

Maya recalled her first breakthrough with a mathematics learner:

> I had one student my first year who earned a "C", and he said, "Ms. Maya, I have never gotten a 'C' ever before in math." I thought, wow, I am teaching them something. I said to the student, "Listen, you should really be proud of yourself because every single thing that you are doing here, you have earned. I only report what you do. I don't give you anything, and you did that and you could do so

much more" (personal communication, October 25, 2016).

Maya commented, "I was teaching in a brand new program where they were building the program from the ground up" (personal communication, October 25, 2016). Meaning, she and her colleagues received little guidance from the school's leadership, with the exception of the workshops from an outside organization, that specialized in behavioral management, brought in by the principal. Maya said of her relationship with her fellow novice teachers, "Since we were all new teachers, we all supported each other" (personal communication, October 25, 2016). Maya explained that although she and her colleagues would share ideas, most of the time "we winged it," and if the strategy worked in one class, "we would share it amongst each other" (personal communication, October 25, 2016). And then someone reported back to the vice principal "who told the principal what we were doing and whether he supported us. And if the principal liked the idea, it became law" (personal communication, October 25, 2016).

Overall, Maya described a first year experience that included support from her colleagues at the middle school. Besides the support of her colleagues, Maya reported that participating in the alternate route program was an experience that also helped her adapt to the classroom environment, the students, and overall, the demands of the position.

Sources of Influence on Teacher Identity

Physics identity. Identifying with a positive physics identity influenced how Maya experienced her physics preparation. Maya was persistent when she experienced a difficult time with ACTS peers that questioned her engagement with physics and whether she belonged in the program. Maya, on her ACTS peers' reactions to her contributions in the class, said, "When I get the answer and nobody else gets the answer, they are like, how did she get it?" (personal communication, October 25, 2016). Maya highlighted her confidence in her physics abilities by saying, "I will surprise you all the time. So, go ahead and underestimate me" (personal communication, October 25, 2016).

Mathematics identity. Maya has a strong mathematics identity. According to Maya, "I always enjoyed math" (personal communication, October 25, 2016). This led her to pursue engineering as a major in college, and then ultimately earn a bachelor's degree in mathematics. What Maya likes about teaching and learning mathematics is there are multiple path ways to correctly solving a problem. Maya views her abilities in mathematics as an asset to her studies in physics. Maya's mathematics identity has also been a source of conflict, based on how others perceived her ability to engage in the subject. Maya explained that in math spaces, she was often negatively positioned in relation to mathematics. Meaning, as an African American woman, Maya reported that in classroom settings her abilities as a mathematics learner were often questioned by her peers.

Maya said her peers would say, "She [Maya] doesn't know anything about this" (personal communication, October 25, 2016). For Maya, identifying with a positive mathematics identity influenced her decision to pursue physics.

Teacher as a mentor. Although teaching is a second career for Maya, she has always sensed a calling to the profession and has always wanted to be a teacher. Maya's image of herself as physics teacher is related to her knowledge of physics, as well as her ability to translate her knowledge to meet the needs of individual students, which was a consistent theme in her interview narrative. Maya's concern with meeting individual student needs is also aligned to her image of herself as problem solver, and closely linked to her reflective practice. Maya describes this connection:

> So I teach to their [students] learning style, that's how I deliver instruction. I am consistently doing a self-assessment. I am always looking at it as like, what could I have done differently? Why aren't they getting it? Is there another way that I could teach it differently? Is there another way that I could teach it to make it easier for them, simpler, or make it make more sense? So, I think about those things all the time (personal communication, October 25, 2016).

For Maya, having a mentoring and collaborative relationship with her students is also a characteristic of her physics teacher identity. One of the ways Maya mentored her students is by displaying inspirational quotes in the classroom to encourage them to persevere through challenges in their learning. As she puts it, "I say to them, just because it is physics doesn't mean that you can't do it. You can do it. You just have to take your time. You can learn it. You give them that confidence—I tell them you just have to trust yourself" (personal communication, November 7, 2016). When Maya was not speaking to her students directly, she encouraged them with inspirational quotes. During my visit to Maya's classroom, the following quote was handwritten on a mini whiteboard and displayed on her desk: "Your present choices dictate your future options" (personal communication, March 29, 2017).

In line with Maya's focus on mentoring her physics students, beyond helping them to achieve academically, she hoped they would also achieve personal growth, such as increased "confidence" (personal communication, October 25, 2016). She also hoped they would become independent thinkers, and, as an outcome of her students' experiences in physics, would learn to trust their own judgment and to make informed decisions. Maya explained, "Students need to know that the lack of knowledge will not get them very far, and the more you know, the less likely people are going to be able to tell you what to do" (personal communication, March 29, 2017).

Teacher as a problem solver. Maya's beliefs about teaching physics are similar to her beliefs about teaching mathematics. Although Maya used traditional strategies, the needs of students remained at the core of her teaching practice (Trigwell & Prosser, 1996). In her own words, "Every student learns differently. I want to touch on each learning style, and that's how I deliver instruction" (personal communication, November 25, 2016). Maya explains what she means by teaching to students' learning styles:

> Every child is different. I can't just say, "Here, two plus two is four." I have to show them why. And some of the kids have to touch the two and put the four together. Some have to hear it. I try to hit every learning style. So, that was my goal for myself. You know, for me it is figuring out how many different ways can I deliver this so that a hundred percent can get it (personal communication, November 25, 2016).

Maya believes students should have an active role in the classroom. She felt strongly that when a student "takes ownership of their learning, their education will be more valuable to them" (personal communication, October 25, 2016).

Maya also held traditional views about the core components of science lessons, such as lab assignments. She viewed these tasks as a way to reinforce student learning in vocabulary development. Maya also viewed lab assignments as an opportunity for students to apply physics principles and concepts.

Summary of the Influences on Teacher Identity

Prior to physics teaching, Maya has positively identified with science and mathematics. Despite how Maya identifies with these subjects, she has always valued relationships with her students. Maya's views on teaching and learning reflect both traditional and student-focused perspectives. Her beliefs about teaching are traditional, in the sense that she views teachers as being responsible for preparing and providing instruction. However, Maya strongly believes a successful lesson is one in which the teacher meets the needs of each learner, a goal she has for herself. Beyond her goals for the academic achievement of students, Maya hopes her students will experience personal development through physics. Maya also views herself as a collaborator and values opportunities to share and learn from colleagues.

Sources of Influence on Teacher Knowledge

Physics preparation. Maya reported she was satisfied with her preparation, and she stated that, "Overall, it was a good experience" (personal communication, November 25, 2016). The methods course met Maya's expectations in terms of "gaining more knowledge and understanding about physics, and learning the pedagogy to teach it at this [high school] level" (personal communication, November 25, 2016). Aside from physics content, Maya reported becoming familiar with the ACTS curriculum resources, and particularly the lab activities. Maya learned about the various equipment and materials needed for the labs, what the tasks entailed, and the key concepts explored in each lab. Maya explained that she experienced the labs first-hand by observing the instructor "run the labs" while the class engaged with the activity as learners (personal communication, October 25, 2016).

Regarding how to use the other curriculum resources, Maya mentioned that the instructors offered the class recommendations. According to Maya, the instructors would share their own experiences with the class, informing them of "what type of information to give the students and what type of information not to give the students" (personal communication, October 25, 2016).

During class, Maya began drawing from her algebra teaching experience, and applied what she knew about teaching the subject to the material presented. According to Maya, while in class she started "thinking about what makes the concepts easier for them to process and understand," and she reportedly began developing her own physics teaching notes (personal communication, October 25, 2016). Maya explained that she focused her efforts on combining what she knows about students' difficulties performing specific algebraic operations with her physics knowledge. For example, Maya describes her thinking at the time as:

> Already having taught algebra for a few years and knowing the challenges that students may have just doing algebraic equations, and knowing that they will have to do the same processes in physics, I already knew that they would have challenges (personal communication, November 7, 2016)

She added:

> So, I started planning where I would introduce new questions during the lesson, in order to mitigate their confusion. I thought about what type of additional or background information I would give them. (personal communication, November 7, 2016)

Physics practicum. Maya underwent a modified practicum experience involving a co-teaching arrangement with an experienced physics colleague, Phillip, for one class period a day. Maya taught class, except when Phillip took over. And on those days, she assisted students where she could and recorded insights into her teaching notes. Maya, on her arrangement with Phillip, said, "That's great because at those times I just sat back and took notes on what he was teaching, and I was able to help the students in the classroom" (personal communication, November 7, 2016). Maya reported that she created teaching notes for guidance in modifying future lessons. According to Maya, "I did make notes on how to do things a little better, to help students understand it. I have my notes from my practicum, and I just implement where I see fit" (personal communication, November 7, 2016).

Continued study of physics. In response to the study's questionnaire regarding influences on physics knowledge and practice, Maya indicated on the teacher questionnaire that sources of her physics knowledge included "Reviewing Physics Textbooks" (personal communication, November 30, 2016). After completing her certification coursework, Maya mentioned she supplements her ACTS preparation using college textbooks, to review specific topics before presenting them. The reasons Maya gave for referencing supplemental resources included anticipation of students' questions and her own study of the material:

> I go back to my college textbooks and college notes and take more notes to make sure that I have information at hand, so that I can respond logically and at a level where they [students] can understand— because I don't remember everything in physics. So I like to go back (personal communication, November 7, 2016).

For example, Maya stated that she used her college textbooks to prepare for teaching a kinematics lesson in which students would study the motion of free falling objects under the influence of gravity. Maya explained her thinking at the time as:

> I used my college notes and read up on weight, because I knew that I would be receiving questions from students asking why are we using positive 9.8 meters per second squared when gravity is going down, and isn't it supposed to be negative? So, I wanted to give them a very honest and educated response where they can understand it (personal communication, November 7, 2016).

While Maya does not anticipate she will have an answer for every student question, she does her best to prepare.

Summary of the Influences on Teacher Knowledge

Maya’s previous academic backgrounds in both mathematics and engineering served her well as she prepared for physics. During the methods course, Maya also drew on her mathematics teaching experience, and she began taking notes on what student difficulties to anticipate. Maya’s note-taking continued during her practicum. Here, she had the opportunity to observe her co-teacher when he took over lessons. Once Maya was assigned to her own physics class, she not only referenced her notes, but she also referenced college texts in order to prepare for lessons.

Sources of Influence on Teacher Practice

Knowledge of physics content and curriculum. Maya’s practice in physics is closely aligned with her preparation. In Maya’s physics class, she organized lessons around problem solving, supported by labs, practice, homework, and assignments, all sourced from ACTS curriculum materials. Maya, on her use of ACTS curriculum materials when assigning tasks for students to practice solving problems, said:

> Basically, I stick to the [homework and classwork] packets. If I have to go outside [of the ACTS materials], I do it based on my students, based on my understanding of why I need to help them. But for the most part, I stick to the packets (personal communication, November 7, 2016).

Regarding Maya’s use of the ACTS lab investigations, she commented she assigns them based on when they are sequenced in the curriculum:

> It depends on when it [a lab investigation] is scheduled. With this [ACTS] program, everything is written out, as far as the instruction, how to deliver the instruction, what types of labs there are for a particular section, and when you

> should implement or try the lab. Everything is already written out, and all we have to do is execute the script written (personal communication, October 25, 2016).

Maya also emphasized that lab assignments support vocabulary development, by saying, “When we do a lab, it helps them [students] have a more hands-on approach to the content, and I am able to link some key terms to the lab then connect that to the lesson” (personal communication, November 7, 2016). Maya also viewed lab activities as ways of reinforcing recently taught concepts and principles. According to Maya, “The purpose of the labs is to relate the pencil and paper [lectures and practice problems] that we do [during non-lab lessons] to the physical [world], and show them [students] the physical of what we are actually doing [during non-lab lessons]” (personal communication, November 7, 2016).

Maya provides another example illustrating how she uses problem solving in her current teaching practice:

> When we get to the kinematics tasks where the students pick one of the three kinematics equations to solve a particular problem, I am not giving them any information, as far as which equation they should use. They are going to have to do that on their own. For example, like today—I give them the guidelines: read the problem first, write the givens, write the equation that is appropriate for the problem, and substitute their correct values to solve mathematically. So, that’s the script that I have them follow every day. If they don’t follow it, then they plan to get lost (personal communication, November 7, 2016).

Maya's above comments suggest she believes that some of her students, especially those who have "extremely low math skills," need to follow the procedures or "script," as described above in order to experience success in problem solving (personal communication, November 7, 2016). Maya said, "Follow that script, and doing that every single time you solve an equation, you will be more successful—that increases your chance of being successful. So, most of them are getting it" (personal communication, November 7, 2016). Maya's recommendation that her students follow a "script" conflicts with her views about encouraging students to use multiple ways to solve problems. Above, Maya suggests that "following the script" is the only way struggling algebra students can learn to solve physics problems.

When I followed up with Maya three months after visiting her class, she was nearly halfway through her first year of teaching physics. Without solicitation, Maya described how her practice was changing. Reflecting back on her first few months, Maya reported how increased confidence has led to changes in her current teaching practice:

> When I initially started, I didn't have a lot of confidence teaching physics because it was my first time, and I wasn't sure how much information to give or how little information to give [to the students]. But now that I am more comfortable, I realize that I have to focus more on the concepts piece, so that is what I am doing with my students. Making sure that they understand all the major concepts that they need to know for physics and just making sure that they know them (personal communication, March 29, 2017).

With Maya's confidence increasing, she shifted focus away from how much information to present in a lesson to the quality of the lesson in relation to what physics students need to know and be able to do.

Relating to physics colleagues. Maya reported she received curriculum implementation support from her physics colleagues. Besides Phillip, the most experienced of her colleagues, Maya discussed her relationship with two other teachers from the department who also completed ACTS. Maya reported she has been "leaning" on her colleagues for guidance with implementing the ACTS curriculum, especially on how to sequence the topics for teaching (personal communication, November 7, 2016). Maya said she wanted practical information such as, "Have they had an opportunity to skip some chapters, abbreviated chapters, or change the order of the topics ACTS outlined? I'd ask them, hey, what are you teaching next? I wanted to know whether my next step was logical and that type of thing" (personal communication, November 7, 2016). Maya added, "This is my first time teaching physics. Right now, they are the knowledge experts, as far as the flow of the content. So I am going to do what they are doing" (personal communication, November 7, 2016).

Relating to physics learners. Maya also reported she began to question whether it was enough to continue to focus most of her efforts during instruction on teaching students how to solve physics problems. "Now, I am using more of the language, and instead of the variables just being letters, I am reminding myself that they are actually vocabulary" (personal communication, March 29, 2017). Maya explained that her most notable change is organizing her teaching less around math. She is now emphasizing the "language" of physics and "actual concepts":

> I am putting more emphasis on making sure that they understand all of the major concepts that they need to know for physics, and just making sure that they know them. So, the math piece is now secondary and the physics concepts are primary. For science, they need to know the actual conceptual ideas behind the science so that they can justify why their math does work or why it makes sense. So, I am focusing more on that (personal communication, March 29, 2017).

In addition, Maya mentioned she has been taking her students' feedback into consideration. "In some classes, they are telling me let us try it first, or you are going too fast. I said okay" (personal communication, March 29, 2017). Maya said she is "opening up the floor and encouraging them to share" their own problem-solving method (personal communication, March 29, 2017). "If you found another method, it is okay. It is fine. In fact, come and show us what method you used and how you got your answer" (personal communication, March 29, 2017). Another shift involves how Maya uses the classroom clicker. She said, "I am encouraging student participation beyond the responders, so that the students can feel comfortable justifying their solution and their reasoning to me and to their peers and being confident in that (personal communication, March 29, 2017). That's basically it, it is just constant self-assessment after every class" (personal communication, March 29, 2017).

Reflection. Maya commented that she frequently performs "self-assessments" of her teaching by being mindful of her thoughts and actions before, during, and after a lesson. "I go over what I am saying to the students, and I hear myself" (personal communication, March 29, 2017). Maya, reflecting on her teaching, described the moment she realized her tendency to model physics problem solving, only referencing the physical variables, such as velocity and acceleration, in an equation by their letter symbols. Maya noted she understated the value of the variables in students' understandings of the meaning of the equation, as well as the relationships among the physical variables in the equation to each other. Maya said:

> Because I constantly self-assess my teaching, and I review what I have said to my students—I heard myself say "v" initial plus "a" multiplied by "t," but I had not said that the "*at*" represents the total amount by which the initial velocity is changed. So now I am using more of the language [of physics] (personal communication, March 29, 2017).

Maya reported she often reflected on ways to improve on a previously taught lesson:

> I am always looking at it as like, what could I have done differently? Why aren't they getting it? Is there another way that I could teach it differently? Is there another way that I could teach it to make it easier for them, simpler, or [the lesson] to make more sense? So, I think about those things all the time (personal communication, March 29, 2017).

Maya explained she reflected on her teaching because, "My whole purpose is to give my students the information that they need so that they could move forward and be successful. I want 100% to understand what I teach and use it to their benefit so that they can be successful in the future" (personal communication, March 29, 2017). Maya mentioned that reflection has always been a part of her teaching practice, and even more so now that she is new to teaching physics.

Summary of the Influences on Teacher Practice

Maya's teaching practices were consistent with those espoused in the ACTS physics curriculum and preparation. As a novice physics teacher, Maya's experience of engaging with the ACTS physics curriculum as learner in the methods course served her as a model of physics teaching. In addition, Maya also drew from her experience of teaching mathematics. Maya found similarities between her previous approach to teaching problem-solving in mathematics and how she currently teaches it in physics. In either case, Maya felt it important to show students there are multiple ways of solving a physic problem and she also encouraged her students to use the methods that they prefer. Maya noted that her teaching practice is evolving in large part through reflection and her willingness to invite and consider students' feedback.

Summary of Maya's Case

Maya is still relatively new to teaching. She views education as a competitively growing field, and saw becoming physics certified as a way to maintain an advantage over the competition. With an academic background in engineering and mathematics, and now physics, Maya sees herself as a role model for students.

Through her family, Maya identified positively with mathematics and science. And in relation to Maya's mathematics and physics identities, she has resisted the negative positioning of others, including her peers in the ACTS methods course. Maya's physics teacher identity is still emerging. Even now that Maya primarily teaches physics, her mathematics identity has a stronger influence on her teaching practice.

Maya's teaching practice is closely aligned to her preparation. Although Maya generally relies on her preparation to inform her physics knowledge, she also references her notes and textbooks from college. Maya sometimes turns to online physics websites, dedicated to teaching and learning ideas, for labs and handouts. Physics colleagues provided her with guidance on curriculum implementation.

Maya's knowledge of physics teaching includes: algebra and trigonometry in learning physics, content representations, curriculum resources inclusive of—and—beyond those learned during her ACTS preparation, topic-specific knowledge of students' difficulties in learning physics, and educational technologies for use in supporting and assessing student learning.

When I asked Maya what her thoughts were about her professional learning goals related to physics, she believes that at this point, the classroom provides plenty of learning opportunities for a novice physics teacher (personal communication, March 29, 2017).

Chapter V: Cross-Case Analysis and Findings

Before presenting the cross-case analysis, it is important to note that given the intertwining of relationships between teacher knowledge, identity, and practice, although discussed separately in this chapter, these factors were not presented separately by the participants as they described their learning-to-teach experiences. The intertwining of relationships between the factors and the situated nature of the participants' experiences learning to teach physics, made for a difficult time in parsing out the content of each section comprising this chapter. However, separately discussing the sources of influence on teacher knowledge, practice, and identity were necessary for the purpose of organizing this cross-case analysis.

This chapter begins first, with a comparison of the sources of influence on teacher knowledge. I then compare sources of influence on teacher practice. Next, comparisons of sources of influence on teacher identity are presented. This chapter is concluded with a summary of the key findings related to the identified patterns of influence on the physics teachers' knowledge, practices, and the identity.

Sources of Influence on Teacher Identity

In this section, the sources of influence on participants' identities as physics teachers are discussed. The findings suggest that subject-matter identity, self-efficacy beliefs, school variables, and teacher knowledge all played a role in shaping teacher identity.

This section begins by comparing how the participants' relationships to subject-matter identities and their self-efficacy beliefs shape their teacher identity. Second, the teachers' experiences within their school and classroom contexts and the influence this has on their teacher identity is compared, with a focus on their relationships with members of the school community, such as the physics learners and their colleagues. Third, how the participants' knowledge of physics influences their teacher identity is compared. Last, this section of the chapter ends with a summary of the key findings related to the influences on the participants' teacher identities.

Subject matter identity. Subject-matter identity considers that the experiences of the participants prior to their switch to physics, such as experiences as learners and previous teaching roles, are related to the self-efficacy beliefs they have developed in relation to specific subjects, which may or may not serve as a support during their transition to physics.

Looking across the data of all four teachers, all had relationships with other subjects, including physics, which they developed prior to their experience in ACTS. Thus, the participants brought with them to the ACTS experience several subject-matter identities and related self-efficacy beliefs that developed through their academic experiences, which appear to inform how they related to their experiences as physics learners and teachers.

Alex, a science teacher of sixteen years, and Maya, a teacher of mathematics for five years, both identified positively to physics and mathematics. When Alex was in elementary school, he described developing a positive mathematics identity centered around the ability to be a disciplined student. Alex attributed his successful completion of one year of undergraduate physics to his having a strong mathematics foundation.

Compared with teaching biology, Alex described that his role as a physics teacher more aligned with his professional view of himself. He said, “I felt more comfortable as a physics teacher” (Alex, personal communication, October 6, 2016). Alex prefers physics because of its close relationship to mathematics. He said, “I like the mathematical aspects of that whatever happens, you have to use some kind of mathematical equation” (Alex, personal communication, October 6, 2016).

Maya’s positive relationship to mathematics and science developed through her family. Like Alex, Maya attributed her mathematics foundation to her having successfully completed three years of physics coursework as an undergraduate student before switching to mathematics and earning a bachelor’s degree in the subject.

Both Maya and Alex identified knowledge of mathematics and related skill sets as being valuable to their identity as physics teachers. The results show that, as novice physics teachers, both Maya and Alex relied heavily on their mathematics skills, because it brought them the most confidence until they were able to gain their footing with physics, and it eventually supported them developing positive self-efficacy beliefs about their roles as physics teachers.

Ian held positive self-efficacy beliefs about his competence in history and less so in physics. Ian, realizing that there is little in common between the skills required for history and physics, struggled to feel as competent in physics as he did in history. As a child, Ian was a “junior military historian,” and in high school, Ian studied history and commented that he was not challenged in the course. Ian said of this experience, “So history was effortless, absolutely effortless, without even trying I was like a straight "A" student" (Ian, personal communication, January 22, 2017).

In college, Ian majored in and earned a bachelor's degree in history, and described his undergraduate experience by highlighting his role as one of the "smarter kids in the room" who would bring a debate to the lesson (personal communication, January 22, 2017). Ian commented, "And at the university level, you can take over a room. I would play devil's advocate in certain situations and start pulling out historical events to back up an issue, and you look like a genius" (Ian, personal communication, January 22, 2017).

However, unlike Maya and Alex who connected to physics through mathematics, Ian struggled with his physics-teacher identity because he was switching from history. Ian realized he did not have the mathematical skills or knowledge base in physics, which he associated with physics teaching. As a result, Ian's comparison of himself to his cohort peers in ACTS, as well as his PhD colleagues Smith and John, caused him to align his physics-teacher identity with being an imposter or fraud.

Of all the teachers, Paul negatively identified with physics, prior to his participation in ACTS, because of his undergraduate experience. After two attempts, Paul passed the course. While completing physics coursework in ACTS, Paul lacked confidence in his abilities to successfully complete the program and looked to the program staff for affirmation. As Paul grew into his physics teacher identity, he drew from his experience as a performer, focusing on building relationships with students.

Like Alex, Maya's positive self-efficacy beliefs about mathematics was central to her physics-teacher identity, and it gave her confidence in her abilities in her new role. As Maya grew comfortable in her knowledge related to physics teaching, she began shifting in her practice, and aligned her instructional goals with teaching physics, instead of just mathematics. Maya admitted that because she initially lacked confidence in teaching physics, she focused on developing students' problem-solving skills, as compared to teaching physics for conceptual understanding:

> I am putting more emphasis on making sure they [students] understand all of the major concepts they need to know for physics, and just making sure they know them. So, the math piece is now secondary, and the physics concepts are primary (Maya, personal communication, March 29, 2017).

Maya's shift to focus on developing students' conceptual understandings may signal a change in her own beliefs about her teaching practice. Maya's reported shift seems to suggest that, despite her background in mathematics, she now sees value in having students reason about physics concepts.

Similar to Alex and Maya, Paul's positive self-efficacy beliefs as a performer and as a research scientist influence how he related to his role as physics teacher. For example, Paul's focus on building relationships with students is consistent with his performer identity, which is motivated by his desire to connect with the students by encouraging participation, and with his use of Socratic methods. Paul said the following about his use of Socratic questioning:

> Socratic questioning allows you to deliver the material in a way that is constantly engaging. If you just go ahead and spoon feed someone an answer, really what is

> the need for them to think deeply? They might just say, [the teacher] is just going to give me the answer anyway, let me just ask (Paul, personal communication, November 2, 2016).

In addition, Paul related his analytical skills to trouble-shooting issues while teaching. Paul analogized that the role of a physics teacher working with students who struggle with a physics problem is like a car mechanic's ability to diagnose a customer's engine problems. He commented, "[If] I have a problem that has to be broken down in certain ways, and if I know only one way to solve that problem—how am I going to keep teaching it to my students?" (Paul, personal communication, January 19, 2017).

Mastery of content knowledge for physics teaching. The study's results show that all of the teachers identified mastery of physics as a professional goal. All of the participants reported they supplemented their coursework during preparation and after becoming physics certified. The most cited reasons for continued physics study involved strengthening their physics content knowledge and developing fluency in physics problem solving.

For teachers such as Ian and Paul, who were without a strong mathematics foundation, their main concerns were about not only knowing how to solve physics problems, but being able to teach students how to do the same, as well as to accurately respond to content-related questions from students. Paul reported that he found resources which presented the "same general topics [as the ACTS curriculum], and they presented all of the same formulas and laws," but the information "was presented differently through the wording of questions, and they provided different ways of looking at things," which he found “very valuable” (Paul, personal communication, November 2, 2016). Paul later explained that he feels most effective in teaching physics when, “I teach my students—if they have a question, I can present it in a different way and try to use all of these different examples. I think about how to reteach the same concept, but maybe from a different angle” (Paul, personal communication, November 2, 2016).

Learning the mathematics behind the physics was key for Ian. He said, “I was unique because not only was I learning the science, but I was really learning all of the mathematics at the same time” (Ian, personal communication, November 15, 2016). For Ian, in order to ensure that he would demonstrate competence in physics teaching, Ian focused on developing his problem-solving skills by modifying the approach learned in acts to create his 4-step technique. He said, “I just changed to this solution style for myself out of desperation. I had to learn how to do math again and maybe that really helped with the kids. I was like them” (Ian, personal communication, November 15, 2016). For Ian, mastery of physics teaching was so important that he devised a way for himself to feel capable in mathematics.

For participants with strong mathematics foundations, like Maya and Alex, their strategy was to focus their efforts on supplementing their understanding of specific physics concepts and principles. For example, although Alex was able to correctly apply specific equations to a given multi-step problem, he needed a physics colleague at work to explain the relationship between the equations. Alex explained, “I did not see the connection between the two different equations” (Alex, personal communication, October 6, 2016). Alex was also concerned about improving his knowledge of content representations beyond those learned in ACTS. For instance, he was reportedly concerned with finding additional instructional resources, such as lab activities and physics simulations. When preparing for a lesson on uniform circular motion, Alex conducted additional "research" to prepare for students' anticipated questions related to the concept of pi (π). Alex, realizing he had gaps in his own understanding, exercised agency in supplementing his preparation.

Similarly, Maya explained how, in preparation for teaching and anticipation of students' questions, she referenced her college notes and textbooks to review specific concepts prior to a lesson:

> I go back to my college textbooks and college notes and take more notes to make sure that I have information at hand, so that I can respond logically and at a level where they can understand, because I don't remember everything in physics, so I like to go back (Maya, personal communication, November 7, 2016).

For Maya, mastery in physics teaching also included being prepared to accurately respond to students' questions. In addition, as the school year progressed for Maya, she became concerned with improving her ability to help students develop conceptual understanding and their ability to reason about physics concepts.

Physics colleagues and learners. The results of the study show that members from the participants' teaching contexts influenced their physics-teacher identity. Among the study's participants, willingness to collaborate with their physics colleagues varied, and it was expressed in relationship to the department cultures and their beliefs about being collegial. Those members of the school community that appear to have a significant impact on the teachers' physics identities were their physics colleagues and learners. The following themes emerged from the participants' interactions with members of the school community: collegiality, isolation, and credibility or reputation. Isolation was consistent in at least three of the four cases, and seeking credibility was consistent across all four cases. The participants positioned themselves to gain credibility with students and their physics colleagues, who they saw as a resource because of their colleagues' professional expertise and insights.

Relating to physics colleagues. Although Alex identified with being a collaborator, the condition of his department made collaborating with his physics peers difficult. Alex was isolated, but not by choice. Alex reported that his school context offered few opportunities for him to collaborate with peers in his department, and Alex is disappointed about the way teachers in his school were being isolated. He said:

> We should have some consistency as a science department. Most folk around here work in isolation. Working in isolation does not help the teachers nor does it help the students, you know. It is a big community, why should I or any other teacher start from scratch? When I first started teaching physics, I was spending so much time researching looking for what laboratory activity that I could do, what are some video clips I can incorporate into my lessons (Alex, personal communication, December 11, 2016).

For Alex, opportunities to collaborate with peers were seldom available in his department, but Alex reported taking the initiative to learn from physics colleagues. Alex learned about the magic triangle by sitting in on a lesson taught by his physics colleague.

Similar to Alex and Paul, Maya's switch to physics did not result in her transferring to a new school. However, like Ian, Maya's switch form mathematics to physics resulted in her transferring to science, making her the most novice teacher in the department. Like Alex, Maya was interested in collaborating with her physics colleagues. Maya described how she looked to her colleagues for guidance relating to their experience with curriculum implementation, including Phillip, the veteran physics colleague with whom she co-taught during her practicum.

Paul's emerging physics teacher identity developed in relation to his one-year teaching experience in Earth and environmental science. For Paul, teaching physics allowed him to remain employed at Westlake High School. Remaining at Westlake, Paul did not have to adjust to a new teaching context altogether. Unlike Alex and Maya, Paul did not identify with being a collaborator. Not only did Paul's response on the questionnaire show that he did not visit the classroom of his peers to observe them teach, he indicated that teaching in isolation is not a concern. Paul said the following about his interest in being collegial:

> I hear teachers say sometimes that they are on an island, and they feel very isolated when you close the classroom door and you don't have adult interaction, sometimes for the rest of the day. I never feel like that. The interactions that I have with my students are so fulfilling that I never feel isolated or feel like I cannot wait to have adult communication, I never feel that way because [laughter] (Paul, personal communication, November 2, 2016).

Besides the young physics teacher who tutored Paul on free-body diagrams as he prepared for physics teaching with ACTS, Paul did not describe having any other collegial relationships with physics colleagues, except that school leadership assigned him lead teacher of the science department.

Of all the teachers who participated in this study, Ian was the only one who had transferred to a new school after becoming physics certified. In Ian's previous position, he was the lead teacher of the history department and shared his teaching materials, including lecture presentations, with history colleagues. During our interview, Ian proudly highlighted how his teaching materials were still being shared among teachers of the history department after his transfer. He said, "My friends at my previous job are telling me that everybody, the whole history department, is still using all of my PowerPoints" (Ian, personal communication, January 22, 2017).

Conversely, at Ridge High School Ian viewed himself as the "rookie." He often compared himself to his physics colleague Grace, who was more experienced, as well as to John and Smith, who were both experienced and experts in applied physics. As a result, Ian was not confident that he had anything of value to share with them. For this reason, Ian limited his interactions, especially with Smith and John. He said, "I am still a bit quiet about things. I usually give a little nod, oh yeah, yeah, and get out of the room before anybody asked me a real question [about physics]" (Ian, personal communication, January 22, 2017).

Rather than sharing teaching materials, Ian was happy to receive them from Grace, whose teaching practices appeared to align with his own beliefs about his practice over the models represented by his other physics colleagues. After visiting the classrooms of all three physics colleagues, Ian decided that because of some of John and Smith's practices, they represented the types of physics teaching he criticized as not being good for students. Ian said he felt most physics teachers "can't teach or they teach way over the heads of students" (Ian, personal communication, January 22, 2017). Ian elaborated on his opinion following his observation of his colleagues' teaching practices:

> Looking at what they were doing in their rooms, I can say that I did not like everything, but Mr. Smith makes it [physics] too complicated than it needs to be. He appeared to like increasing the degree of difficulty just for the sake of increasing the degree of difficulty. As for my other colleague, John, he just talked over his students' [heads] (personal communication, January 22, 2017).

The participants' interactions with their physics colleagues highlighted how the teachers continued to identify with or to suppress characteristics they associated with their teacher identity from their previous teaching positions. Alex and Maya continued to identify with being collaborators. Similarly, Paul did not report collaborating with physics teachers, and Ian was selective about who he collaborated with and how he collaborated.

Relating to physics learners. Interactions with students influenced the participants' emerging physics teacher identity. Ian described how he acted to perform competently in the eyes of his students. Ian wanted to develop a similarly positive reputation he had as a history teacher at his previous school with the physics learners at Ridge High School. For example, Ian had hoped that by modifying the ACTS lecture presentations, rather than reading from them verbatim during lessons, would earn him positive recognition from his physics students. Ian was concerned that by reading the lecture content off the whiteboard word-for-word during the lesson would cause his students to think he did not know the material that he was presenting. In Ian's first year of teaching physics, he was assigned to teach an honors class, which he lightheartedly described in the following way:

> Oh, God! That class was like running down a hill at full speed—just petrified that you were going to trip and just crash [laughing lightly]. Everybody is looking at you with their pens in their hands—and I'm thinking that I better start saying something and not mess up. Alright, here we go! (personal communication, January 22, 2017).

Ian described how he panicked the first time he had to teach a lesson on projectile motion, particularly because he struggled with the concept during his training, and he did not have confidence in his ability to teach to honors students.

Ian recounted the day of the projectile lesson:

> I remember standing up at the board in front of the class saying to myself, all right man, here we go. I hope that I do not mess this up—and you did not want the kids going, "You're a fraud. I'm telling my mom you don't know what you are doing." I felt I could not go to Smith and John because they might say, "Dude, you should know how to do this." So I muscled through it [preparing and teaching the lesson], and actually came up with a good system (Ian, personal communication, November 15, 2016).

Ian's statements demonstrate his emotional investment in being recognized by his students as a competent physics teacher. For Ian, who was switching from history to physics, his physics-teacher identity centered around his students finding him competent in this new and unfamiliar role.

Similarly, for Paul it was important to establish credibility with his students and he believed that demonstrating mastery in physics was one way to achieve this. Further, Paul modified his first lessons by removing some of the problems he did not know how to solve:

> So, my first modifications came from omitting questions or making them easier. I wanted to give the right answers rather than winging it. So it doesn't mean that I omitted a lot, but there are some highly rigorous questions, even at the freshmen level, and until you understand the concepts strongly, it is hard for you to be able to solve it on your own and be able to answer when someone asks you a question (Paul, personal communication, November 2, 2016).

Paul was not prepared to jeopardize his reputation in the eyes of his students.

Like the other study's participants, Maya's relationship with her physics students influenced her physics-teacher identity. Also, Maya's beliefs that her teaching practice ought to respond to the learning styles of students influenced her physics-teacher identity. As a result, Maya focused on developing her physics-teacher identity accordingly, which involved mentoring students and encouraging them to exercise greater agency over their own learning. Maya's efforts are consistent with how she identified as a mathematics teacher. Maya described when one of her middle-school students earned his first passing grade in mathematics, and it was a “C”. Maya, in highlighting this break-through experience for her student, demonstrates how much being able to reach students means to her.

Sources of Influence on Teacher Knowledge

Physics preparation. After comparing the teachers’ experiences learning to teach physics, the data suggested the methods-course curriculum featured prominently as the primary contributor of the teachers’ subject-matter knowledge for teaching physics. All of the study’s participants considered the methods coursework an essential component of their content preparation for high school teaching. All described similar learning outcomes in physics and mathematics.

Paul and Ian, who did not have strong math or physics backgrounds, reported knowledge gains in both subjects. Paul, a second career teacher who switched to physics after one year teaching environmental science, said, “I became proficient in algebra and proficient in physics through the methods course” (Paul, personal communication, November 11, 2016). Similarly, Ian, who switched to physics after over ten years of history teaching, commented that he learned “the science” and “all of the mathematics at the same time” (Ian, personal communication, November 15, 2016).

Previous college physics experience notwithstanding, both Maya and Alex also reported gains in their knowledge of physics. Maya, whose academic background includes physics and engineering, mentioned that methods course resulted in her “gaining more knowledge and understanding about physics” (Maya, personal communication, November 25, 2016). Alex, who also took physics in college, voiced a similar opinion, saying, “I think that this program well prepared me to teach physics” (Alex, personal communication, October 6, 2016).

Working through challenging content. Despite the participants’ reported overall gains in learning to teach, they also encountered challenges, though not all of the same type. In Alex’s case, he was reportedly skilled at solving most of the physics problems. However, initially his biggest challenges were conceptual and occurring in the first unit of the ACTS (physics) curriculum, which featured several derivations of the kinematics equation that define motion at either constant velocity or at constant acceleration. Alex described difficulties working with problems that had multiple steps, such as those that entailed first solving for velocity before solving for acceleration. He said, “I did not see the connection between the two different equations” (Alex, personal communication, October 6, 2016).

While Alex’s difficulties were conceptual, Ian’s challenges were related to his limited skills in mathematics and centered on him learning the fundamentals of algebra and trigonometry. Ian reportedly did not use algebra in his work with students. Without the mathematical skills in algebra and trigonometry to solve physics problems, Ian struggled. Ian reported he almost quit the program because he was convinced he would never learn the trigonometry needed to solve projectile-motion problems. In Paul’s previous career, he did not use the mathematics skills he was asked to apply to solving physics problems. Like Ian, Paul’s challenges were also based on limited mathematics skills. However, Paul’s challenges were also conceptual, and he learned to use free-body diagrams to solve problems involving multiple forces. Maya did not describe any challenges applying her skills in mathematics to solving physics problems.

Although Paul said he experienced difficulty learning various topics, including free-body diagrams, he felt the concept became easier to teach “because I struggled with it myself,” and he reported that it was “one of my favorite topics to teach now” (Paul, personal communication, November 2, 2016). For Ian, switching from history to physics was particularly challenging. Ian highlighted how learning physics was different for him. He said, “I was unique because not only was I learning the science, but I was really learning all of the mathematics at the same time” (Ian, personal communication, November 15, 2016).

Given Ian’s limited problem-solving experience, he explained he learned to modify the solution’s procedure taught in the methods course by reducing the number of steps. Ian noted his modified procedure was helpful not only for himself, but it was especially useful for struggling physics students, with whom he could now relate. He said, “I just changed to this solution style for myself out of desperation. I had to learn how to do math again and maybe that really helped with the kids. I was like them” (Ian, personal communication, November 15, 2016). Similarly, Alex described applying what he learned from his own challenging experiences with the physics content to planning for lessons. He said, “What was difficult for me to understand, I figure there has to be a way for me to explain it to them” (Alex, personal communication, October 6, 2016). Alex, Ian, and Paul all reported that struggling with challenging content primed them to act more responsively to the needs of struggling students. Maya did not report any specific challenges with learning physics. Maya did explain how she began applying her topic-specific knowledge of algebra developed during her methods course experience:

> Already having taught algebra for a few years and knowing the challenges that students may have just doing algebraic equations and knowing that they will have to do the same processes in physics, I already knew that they would have challenges (Maya, personal communication, November 7, 2016).

Based on the teachers' reported challenges, learning to teach physics related to their understanding of mathematics, and in this regard, a key similarity emerged. That is, all of the teachers developed empathy for physics learners who struggled with the course material, especially mathematics. The teachers reported their first-hand experience of learning physics in the ACTS methods courses translated into the knowledge they now apply in working with struggling learners, such as being able to anticipate and intervene by addressing identified challenges. These findings suggest that the transition to learning physics may be less challenging for someone with a mathematics background.

Continued study of physics. The data indicated that all of the participants supplemented preparation to address gaps in their subject-matter knowledge in mathematics and physics. While participants like Paul, Alex, and Ian reported that the pace of the methods course was fast, Maya and Alex described an unwelcoming culture, which not only negatively impacted how they participated in the course, but contributed to gaps in their understanding. As a result, many of the teachers had to supplement their methods-course experience after completing the program requirements.

For example, Paul and Alex described using online tutorials featuring problem-solving approaches. Paul also reported using physics study guides by the Educational

Testing Service (ETS), a resource for supplementation as well as for preparation of the Praxis examination in physics. Maya, the most recent college graduate of all the participants, still had all of her physics notes and textbooks from college. She used them to supplement her preparation. For example, Maya explained that to prepare for lessons, she referenced these materials in anticipation of students' questions:

> I go back to my college textbooks and college notes and take more notes to make sure that I have information at hand, so that I can respond logically and at a level where they [her students] can understand— because I don't remember everything in physics, so I like to go back (personal communication, November 7, 2016).

Ian recounted one of his experiences during his first year as a physics teacher. While teaching honors physics, Ian recalled having to review before teaching a lesson on projectile motion in two dimension, a topic he struggled with during his preparation. Realizing he did not know how to solve two-dimensional projectile problems, Ian had to supplement his preparation before teaching this lesson:

> For the honors guys [students], you are actually introducing trigonometry, because they have to use the angles of the launch to calculate distance and the rest. And I was at total loss for how to teach this. I think I barely got through that section in the training, and I went into full panic mode because I have to come into the honors class tomorrow and teach them a section of the material that I'm really weak on (Ian, personal communication, November 15, 2016).

Ian's experience gives support to Maya's expressed need to go back and supplement her preparation with reviewing notes and textbooks from college.

Internet resources. Most of the participants reported using online resources during their preparation and as classroom teachers. Using the Internet, these teachers performed searches for physics content to supplement their content preparation, as well as find materials for planning and instruction. Problem-solving tutorials and lesson-activity ideas were by far the teachers' most accessed resources. For example, Paul reported he accessed websites such as Khan Academy and physicsclassroom.com for problem-solving variations. Both Alex and Ian used the Internet to find similar instructional tools. Alex searched for and found representations of math concepts such as pi (π=3.14…), simulations, and lab activities. Similarly, Ian used the web to find YouTube videos, lesson ideas, and activities.

Sources of Influence on Teacher Practice

In this section, findings are discussed that are related to the influences on the teachers' practices in physics. After reviewing data on the teachers' experiences learning to teach physics in relation to their teaching practice, the findings suggest that four significant factors are coalescing to contribute to the teaching practices of these physics teachers: teachers' knowledge of the high school physics curriculum; beliefs about their practice as physics teachers; the school variable, including interactions with physics colleagues and learners; and the participants' previous teaching experiences.

The findings' discovery begins by comparing how the teachers' experiences with the physics preparation curriculum appear to influence their practices. Second, the teachers' experiences within their school and classroom contexts, focusing on interactions with their physics colleagues, learners, and science-department leadership is compared. Third, how the participants' previous teaching experiences influence their teaching practice is compared. This section of the chapter ends with a summary of the key findings related to the influences on the participants' practices in teaching physics.

Knowledge of physics content and curriculum. The study's findings indicate that participants' knowledge of the high school physics curriculum and its instructional goals, featured prominently in each participant's teaching practice. However, intricately linked with the teachers' knowledge of the physics curriculum, are their beliefs and conceptions about teaching and learning science. Given the participants' experiences in the methods course, and specifically their experience using the ACTS physics curriculum and its materials including activities and assessments, the participants found it useful in their work with physics learners. Not only did the participants make repeated reference to their use of the curriculum materials in their teaching, but their assertions were further explored through my visits to their respective classrooms to observe them teach. As the participants noted in their interviews, their lessons generally featured assignments involving physics problem solving, and they used the ACTS curriculum materials to help them meet their instructional goals, including lab activities as well as practice problems they assigned to the students to complete for classwork and homework.

During my visits to Alex's class, he used the ACTS curriculum materials, except for the lecture presentation because the computer and electronic whiteboard were in disrepair. Alex assigned practice problems, reviewed an assessment he had administered to the students prior to my visit, and assigned a lab activity featuring the Atwood machine. Alex's teaching strategies were consistent with his beliefs of teaching and learning. Alex believed the teacher is responsible for leading instruction. As a result, Alex's lessons were teacher directed. He generally only used small groups when students were working on a lab, and on the occasions when Alex encouraged his students to talk with a peer, they were not required to report out the details of this discussion. He followed-up the student discussions by highlighting key ideas of the topic under discussion himself.

In Alex's practice, lab assignments were a way for students to confirm physics concepts or principles previously taught. Alex gave the following reason about his use of lab activities, "Doing a lab is really to reinforce the concepts, it makes learning hands-on. It is a fun way to learn because it helps the students to make connections" (Alex, personal communication, October 27, 2016).

Like Alex, Ian used teaching strategies that were consistent with his beliefs about teaching and learning. Ian described himself as a nonconformist and open to "different approaches" to teaching (personal communication, January 22, 2017). Ian used a combination of teacher and student-directed strategies. Ian used lectures, as well as cooperative student groups. The students in Ian's physics class worked in small groups when solving practice problems, and they used their personal whiteboards to display their 4-step solutions for members of their group. When students worked independently, Ian selected volunteers, who raised their hands, to present their solutions to the class by coming to the board and outlining their procedure.

Like Alex, Ian also used the ACTS curriculum materials to support instruction, and he also used lab activities to reinforce physics concepts and principles taught in class.

For example, Ian assigned the freefall lab for students to investigate the acceleration of falling objects. Students conducted the lab outdoors by dropping balls of different sizes from a platform of some distance off the ground and then timing the fall. The freefall lab took place after students had several days of practice solving freefall problems. Assigning lab investigations after teaching students specific concepts or principles, reflects a traditional view of science teaching.

However, unlike Alex, Ian used the digital-presentation slides during the lesson to display physics problems for students to solve and to support explanation of related concepts. Although both Alex and Ian appeared to have taken up the practice of formatively assessing their students during the lesson using the ACTS curriculum materials, they did so without using the polling devices, because they did not have this equipment in their respective classrooms. In Ian's case, in place of the polling devices, his students solved problems on their personal whiteboards. Alex's students worked out the problems in their notebooks or on the board for the rest of the class to see.

Like Alex and Ian, Maya's beliefs about teaching and learning were sometimes not aligned with her teaching methods, which made her choice of strategies appear to conflict at times. For example, Maya believed in using strategies that are responsive to the learning needs of individual students. However, Maya viewed and followed the ACTS curriculum as a "script," and she used the curriculum materials with fidelity—rarely combining it with materials from other sources. Maya explained how she decided when to assign a lab activity:

> It depends on when it [a lab investigation] is scheduled. With this [ACTS] program, everything is written out, as far as the instruction, how to deliver the instruction, what types of labs there are for a particular section, and when you should implement the lab or try the lab. Everything is already written out, and all we have to do is –and all we have to do is execute the script written (personal communication, October 25, 2016).

In another example, Maya suggested her students follow the procedure for problem solving that she had taught them, saying, “Follow that script and doing that every single time you solve an equation, and you will be more successful—that increases your chance of being successful. So most of them are getting it” (personal communication, November 7, 2016).

Although, Maya had not planned to assign a lab during my visits to her class. She held similar views as Ian and Alex about the purpose of labs. Maya also believed labs are used to reinforce principles and concepts taught. Maya said, “The purpose of the labs is to relate the pencil and paper [lectures and practice problems] that we do [during non-lab lessons] to the physical [world], and show them [students] the physical of what we are actually doing [during non-lab lessons]” (personal communication, November 7, 2016). Maya also added that labs support vocabulary acquisition, saying, “When we do a lab, it helps them [students] have a more hands-on approach to the content, and I am able to link some key terms to the lab then connect that to the lesson” (personal communication, November 7, 2016).

Unlike Ian and Alex, Maya took up and enacted the ACTS formative assessment practices similarly to the way she experienced it during her preparation. Specifically, Maya used the polling devices, but she allowed her students more time to submit their response. Maya's practice was consistent with her preparation partly because she had access to the ACTS recommended technological equipment to support her efforts. Maya's classroom was equipped with an electronic whiteboard and projector, several computers, a classroom student-response system, and enough polling devices (clickers) for each student to use.

Like Maya, Paul's teaching strategies sometimes appeared to conflict. For example, while Paul claims to experiment with "student led-strategies" that support an inviting classroom culture for students, during my visit he led the lesson (Paul, personal communication, November 2, 2016). Paul said, "I am trying to get more student-led strategies—and I tell them, I boost them up, I say, 'It is your classroom, not mine, I am just part of it'" (Paul, personal communication, November 2, 2016). However, during the lesson I observed, the entire lesson was teacher led with Paul asking almost all of the questions and the students complying. For example, during this lesson, Paul combined Socratic questioning and cooperative groups featuring student discussions. Together, these strategies were intended for students to reason about their own ideas of physics concepts and principles, in light of those presented by their peers.

Paul, like the other participants, used the ACTS curriculum materials to support his instructional goals. For example, he assigned activities that provided practice with problem solving, and he used the slide presentation as a visual aid during the lesson.

Although Paul did not assign a lab during my visit, his interviews suggested he shared a similar concept about the purpose of lab activities with all of the other participants in the study. Paul's description of one of his favorite labs was a projectile lab in which students apply the concepts, principles, and formulas learned in previous lessons to launch an object and have it land in a desired position. Paul said:

> I will say to them, well, "Now you know a lot of the concepts you need. I want you to design a problem that is a cannon shooting at a wall, and you make that cannon shoot at the wall and you make that cannon shoot at any velocity that you want, at any angle, and put the wall at any distance and at any height that you want." (Paul, personal communication, November 2, 2016).

Although Maya and Paul both took up ACTS formative assessment via the polling devices, they structured the process differently. For example, both Maya and Paul timed students when polling them. Maya was lenient with the amount of time she allotted for students to submit their responses via the clickers allowing them to take additional time. Maya explained that this approach came out of her experience in ACTS, when her peers called her out for being one of the last people to submit answers while the instructor polled the class. When polling his own students, Paul adhered to the allotted time. After Paul polled his students, he instructed them to have discussions about the answers they submitted.

One theme associated with these findings, which was repeated across all four cases, is the impact of the school and classroom context on the teachers' practices. This theme will be further elaborated on in the following sections.

Relating to physics colleagues. The teachers' relationships with their physics colleagues varied. As the "rookie" in the department, Ian was hesitant to ask his colleagues for help. He was concerned they would perceive him as unprepared for the position. However, after a year, one of Ian's colleagues, Grace, shared all of her teaching materials with him. These resources included her teaching notes and copies of student assignments. Besides receiving a cache of teaching materials from Grace, Ian observed all of his colleagues from the department, hoping to strengthen relationships and take up new teaching strategies.

Ian noted that each of his colleagues had different teaching styles, and that observing them was beneficial, even if he was not interested in integrating all of their approaches into his own teaching practice. For example, Ian appraised the practice of John and Smith:

> Looking at what they were doing in their rooms, I can say that I did not like everything, but Mr. Smith makes it [physics] too complicated than it needs to be. He appeared to like increasing the degree of difficulty just for the sake of increasing the degree of difficulty. As for my other colleague, John, he just talked over his students' [heads] (Ian, personal communication, January 22, 2017).

In addition, Ian explained how he learned to modify the second kinematics equation after observing Grace and reflecting on the lesson afterwards. Ian described how he compared the approach he learned during his preparation with the one Grace demonstrated while teaching:

> Over the summer, when I sat and reflected on how I did—I decided that I would

teach it like Grace, with taking off the first half of the equation, initial position (x_o) and initial velocity times time ($v_o t$), and I am just going to use the one half "a" "t" squared ($1/2at^2$) (Ian, personal communication, November 15, 2016).

Ian admitted that teaching the equation his way was not helpful for the physics learners in his class, as they were weak algebra students:

> I never used to do this [shorten the second kinematics equation while teaching it], but one of my colleagues [Grace] did it, and I thought it was kind of silly at first when I started, but I was younger and arrogant. I was like, oh yeah, I can definitely do without this (Ian, personal communication, November 15, 2016).

Ian's experience teaching the second kinematics equation is another example of how he was flexible in letting go of some components of his preparation.

Apart from Ian, only Alex observed and expressed an interest in observing physics colleagues teach. When Alex observed his colleagues, he found the magical triangle helpful, and he integrated it into his practice to help struggling students learn how to isolate the three variables of the speed equation: time, distance, and speed. Outside of Maya's practicum experience, she did not observe her physics colleagues while they taught a lesson.

Of all the participants, Paul reportedly had the least amount of interaction with his physics colleagues. Paul explained that he never felt isolated:

> I hear teachers say sometimes that they are on an island, and they feel very isolated when you close the classroom door and you don't have adult interaction, sometimes for the rest of the day. I never feel like that. The interactions that I

> have with my students are so fulfilling that I never feel isolated or feel like I cannot wait to have adult communication. I never feel that way because [laughter] (Paul, personal communication, November 2, 2016).

I explored Paul's statements above with his response on the questionnaire regarding whether he had ever visited the classroom of his physics colleagues to watch them teach a lesson. Paul's response indicated that this activity was not a part of his experience.

Relating to physics learners. The study's findings reveal that despite working across varied school contexts, most of the teachers described similar experiences with physics learners. Modifying the ACTS curriculum was a consistent theme in the teachers' narratives. The most common reason teachers cited for this modification was student difficulties in mathematics. Similarly, the most common types of modifications to the ACTS curriculum were creating and adding mini-lessons, formed by breaking down large assignments into smaller parts in order to teach single skills.

For example, both Paul and Alex described a similar practice. Before requiring students to perform tasks related to graphing, Paul and Alex created a mini-lesson designed to introduce students to the Cartesian system. Paul and Alex created the mini-lessons after realizing that some ACTS assignments assume students are prepared to independently graph and interpret the motion of moving objects.

The second most common example of the types of modifications participants made to the ACTS curriculum resources included removing items they perceived too difficult for students and reducing the number of practice items assigned for homework and classwork. It is important to note that these modifications were reported by Paul, Ian, and Alex. Comparatively, as the most inexperienced of the teachers, Maya did not discuss making these types of modifications. In fact, when I asked Maya whether she had been modifying the ACTS resources for her students, she responded that she did not depart from the ACTS curriculum and teaching resources. She then qualified her response by saying:

> Basically, I stick to the [homework and classwork] packets. If I have to go outside [of the ACTS materials], I do it based on my students, based on my understanding of why I need to help them. But for the most part, I stick to the packets (Maya, personal communication, November 7, 2016).

Maya, however, stuck closer to the curriculum when it came to lab investigations:

> It depends on when it is scheduled. This program everything is written out as far as the instruction, how to deliver the instruction, what types of labs they are for a particular section, and when you should implement the lab or try the lab. Everything is already written out, and all we have to do is –and all we have to do is execute the script written (Maya, personal communication, October 25, 2016).

Compared to the other participants, Maya's practicum experience did not offer her as many opportunities to modify the ACTS curriculum. Maya co-taught with an experienced physics teacher, and she (Maya) was responsible for most of the planning and preparation. Unlike Maya, during the practicum, Alex and Paul were assigned to teach their own classes. As a result, they were responsible for not only implementing the ACTS curriculum, but finding solutions to unanticipated problems, which led to Alex and

Paul learning how to make the types of modifications they reported. Similarly, Ian had opportunities to make modifications to the ACTS curriculum, such as introducing struggling learners to his 4-step technique, although he was not assigned to his own class.

Confidence in appropriating physics curriculum materials. The participants' narratives were not only filled with emotions, but also highlighted the role of confidence in taking up and enacting subject-specific teaching practices. Despite their academic backgrounds in mathematics and physics, both Alex and Maya reported that initially they followed the ACTS physics curriculum as a script because they were not "comfortable" and "did not have confidence on how much information to give the students" (Alex and Maya, personal communication, 2016; 2017). Similarly, Paul explained he initially modified assignments featuring practice problems by omitting the most difficult items, because he did not know how to solve them, and he did not want to confuse the students:

> So my first modifications came from omitting questions or making them easier. I wanted to give the right answers, rather than winging it. So it doesn't mean that I omitted a lot, but there are some highly rigorous questions, even at the freshmen level, and until you understand the concepts strongly, it is hard for you to be able to solve it on your own and be able to answer when someone asks you a question (Paul, personal communication, November 2, 2016).

As shown here, Paul felt strongly that until he had confidence in his ability to solve specific problems, he did not present them to his students.

Ian's confidence appeared to be more situational. On one hand, reading off the ACTS lecture presentation, which provided Ian with support during the lectures, challenged his confidence. On the other, Ian admitted there were certain topics, such as teaching projectile motion in two dimensions, that he did not feel prepared to do. Yet despite the usefulness of the ACTS lecture materials, Ian was not happy. In comparison, when he taught history, he took pride in creating his own lecture presentations.

All participants reported that over time they developed confidence in their physics-teaching practice. As participants' confidence in their subject-matter knowledge grew, participants like Alex and Maya reported that they began taking risks in their teaching practice by departing from using components of the ACTS curriculum in a scripted way.

Science department leadership. The findings of this study suggest that, outside of the relatively uniform teacher evaluations, departmental leadership influence on participant teachers' physics practices varied. Of all the study's participants, only Ian and Alex reported having interactions with department leadership in ways that influenced their teaching practice.

Ian explained that at Ridge High School he was no longer responsible for the administrative duties he had performed at his previous school, because his current department leader performed these functions. As a result, Ian reported he was able to focus his efforts on "concentrate[ing] on being a good teacher" (Ian, personal communication, January 22, 2017). In Ian's case, now with less responsibilities, he could focus on getting acclimated to his new role and environment.

Alex explained that department leaders had asked him to shift his instructional focus from teaching physics mathematically and through problem-solving, to now emphasize conceptual understanding. Alex commented, “They told me, teach more conceptual. They said, too much algebra-based problems. We don’t want you to teach so much of the math” (Alex, personal interview, October 6, 2016). Despite this recommendation, Alex reported he did not receive additional support on how to teach conceptual physics from the department leaders who made the recommendation.

Alex also reported that department leadership did not provide him with all of the instructional resources and equipment needed for teaching physics. According to Alex, the quality of his lessons sometimes suffered because he did not have the materials and equipment he needed:

> When you are the one that has to go out to get it, it is easy to procrastinate because you have so many other things to do. Sometimes I put it off and say, I will do it next week, and the next thing you know the marking period has ended and I didn’t even get to it [buying materials for a lesson]. Students need hands-on. They tend to remember the concepts more (Alex, personal interview, December 11, 2016).

The role of school facilities in students’ access to quality instruction in science is a matter of interest because we know that, “What students learn is greatly influenced by how they are taught” (National Research Council, 1996, p. 28). Outside of the teachers’ beliefs about their practice and their motivation to employ student-focused approaches, the methods they employed are influenced by the kind of resources available in the schools. Inadequate resources limit students’ access to quality instruction, their levels of engagement, and their performance.

Access to instructional resources and equipment. Access to adequate facilities and resources not only varied among the teachers, but accounted for the variations observed in their practices. For example, all of the participants did not use the polling devices or clickers to formatively assesses their students during a lesson. Of all the study's participants, the classrooms of Maya and Paul were the most technologically equipped to support their practice with instructional tools, such as polling devices, an electronic whiteboard, and a projector.

Unlike Maya and Paul, Alex's classroom was not equipped with polling devices, and while his classroom was equipped with an electronic whiteboard and a projector, he could not use them for teaching because they were in need of repair. Ian's classroom had a functioning projector, but he only had a traditional whiteboard, and, like Alex, he did not have any polling devices.

Aside from facilities and instructional tools, the teachers' beliefs about the usefulness of combining their formative assessment practice with the polling devices influenced the extent to which they took up this practice and enacted it within their classrooms. For example, of all the participants, Maya was the only teacher to formatively assess her students in the way that she had experienced it during her preparation. Similarly, Paul used the polling devices to formatively assess students almost exactly as he experienced them in his methods course. However, Paul mentioned that he made the practice his own by "putting his own spin on it" (personal communication, November 2, 2016). When Paul used the polling devices to assess his students' learning, he combined the strategy with student discussions and his Socratic questioning techniques. Paul integrated these strategies into his assessment practice in order to have students reason about their preconceptions of physics concepts and principles in relation to, not only, the correct answer, but also in relation to the ideas of their peers.

In comparison, based on Ian's own negative experience using the polling devices with students during his practicum experience, it became unlikely that he would go on to make polling devices a part of his formative assessment practice. Pedagogically, Ian had his own ideas of how best to formatively assess students in physics. Specifically, Ian found the polling devices less effective than other assessment methods. He said, "I found the whiteboards is a more hands-on approach, especially when it comes to them learning and showing the math. And collaboratively, I feel that it is more effective than the clickers" (Ian, personal communication, November 15, 2016). Ian said, "I would forget that they [clickers] were there, and I would have them [clickers] out on everybody's desk and a couple of minutes later, oh yeah, the clickers. Alright everybody, do this problem with the clickers" (personal communication, November 15, 2016). Ian also explained that after a short time with using the polling devices, his students lost interest, and after about two weeks "the students were just mashing the buttons" (personal communication, November 15, 2016). Ian described his experience with formatively assessing his students using the ACTS recommended polling devices:

> So the clickers—it works for a little while, and then you get those buttons mashers. For the first week or two, students are into it. There is a lot of peer pressure. They compare answers. At first, they don't want to be that one in the

> small percentage of the names [who got a question wrong], and that works for about two weeks. And after two weeks, nobody cared. They were just mashing the buttons (personal communication, November 15, 2016).

Ian's statements show that his strong beliefs about his teaching practice and about the usefulness of the polling devices in assessing student learning, influenced his decision to take up this practice with fidelity.

Overall, the participants' experiences with using polling devices (clickers) to facilitate their formative assessment practices, varied. Although the participants would likely agree on the benefits of formatively assessing students, their distinctions lie in their beliefs about the usefulness of making polling devices a part of the process.

Summary of Findings

The participants' subject matter identities and self-efficacy beliefs helped to shape their teacher identity. The findings from the participants in the study show that having positive physics identities and self-efficacy beliefs were not enough to influence positive teacher identity. The participants need to have had affirming experiences centered on learning physics and physics teaching, in order to develop positive teacher identity. Therefore, the participants identified a positive teacher identity with subject-matter mastery, and focused their efforts on leveraging this expertise in gaining recognition from physics colleagues, as well as physics learners given their central role in informing the teachers' practices.

The school variables, such as the department culture, positioned the participants to draw on or suppress specific identity characteristics. For example, Alex's department was isolating and it offered few opportunities for him to collaborate with his physics colleagues. Conversely, when Ian, who identified as a collaborator, transferred to Ridge High School, he was hesitant to collaborate with his new peers. Alternatively, Maya, who identified as a collaborator, found opportunities to collaborate with physics colleagues, and this provided her support with curriculum implementation. Similarly, Maya viewed herself as a mentor to students and continued to pursue mentoring relationships with students in her class.

These findings suggest that for the study's participants, teacher learning and development in and beyond their participation in an alternative certification program for physics was facilitated by pursuing mastery of the subject matter, as well as by interactions and relationships with physics learners and colleagues. Teacher learning and development in and beyond an alternative certification program for physics is also facilitated by whether the participants view the practices taken up and enacted, as physics teachers, as being consistent with held beliefs about their teaching practice and their self-concepts as learners. The participants' beliefs about their enactment of practices taken up during their preparation is also understood in relation to models of teaching from previous teaching experiences. Additionally, to a large extent, for the participants of this study "rather than merely implementing a given set of curriculum materials, the teacher becomes an agent in its design and enactment" especially when they believed it essential in their efforts toward meeting the needs of physics learners (Davis & Krajcik, 2005, p. 6).

Across all four cases, the participants' descriptions of their methods-course experience provides an account of not only what they learned, but how this knowledge was acquired and what they valued about the learning opportunities offered by methods-course curriculum. For the participants of this study, two findings emerged from their preparation experience. First, the data suggests having a strong foundation in mathematics is a positive influence in learning physics and learning to teach algebra-based physics. Second, the data suggests that participants own struggles with the physics content contributes to their claiming an empathetic physics-teacher identity.

Specifically, with respect to the influence of the methods-course curriculum and the teachers' interactions with colleagues on their learning outcomes, the findings show that across all four cases, the participants developed knowledge in curriculum implementation, knowledge of students' difficulties, knowledge of content representations, and subject-matter content knowledge in physics and algebra, and physics problem solving.

CHAPTER VI: Discussion and Implications

In the preceding chapters I examined the influence of a policy allowing for a shift into physics teaching from another discipline with respect to such teachers' knowledge, practices, and identity. In this final chapter, I will identify the key findings that characterize the way that the teachers in this study experienced their physics preparation and development. These findings provide the basis for discussion as to the implications for research, policy, and practice in relation to the preparation of such alternatively certified teachers. The chapter concludes by considering possible directions for further research.

The findings of this study suggest that, for the participants, teacher learning and development in and beyond their participation in an alternative certification program for physics, is not solely facilitated by one's respective mastery of the subject matter, interactions and relationships with physics learners and colleagues. For, clearly, a teacher's beliefs about their practices, as well as their beliefs about the nature of knowledge, appear to predominate and to also influence teacher knowledge, practices, and identity. Hence, in this section, I present an argument that delves into four facets of this key finding in relation to the participants' development as physics teachers: the participants' experience with course work, the shared characteristics of the participants' practices, their relationship to their physics colleagues, and the participants' relationship to physics learners.

The Methods Course Viewed as a Key Preparation Component

This study investigated high school teachers from various non-physics areas of specialization who yet moved to the teaching of physics in the course of their teaching career. The participating teachers' transition to physics was precipitated by their respective districts' aim to fill physics teacher vacancies through a partnership with ACTS. All four of the participants studied were candidates in ACTS, albeit at different times. This program focuses on the preparation of teachers in order to teach all levels of high school physics. Given the non-physics backgrounds of the enrolled teachers, ACTS designed the curriculum to address all of the content knowledge needed to do so, including improved ability in mathematics. These specific program features represent what Stoddart (1990) described as "context-specific preparation," such as job-embedded preparation and a specialized curriculum aligned to meet the needs of the participants as well as their high school physics learners.

Like Stoddart (1990), various researchers have also linked specific program components to the respective participants' positive perceptions of their preparation (Darling-Hammond et al., 2002; Flores et al., 2004; Johnson and Peske, 2005, Tournaki et al., 2009; Kee, 2012). Kee (2012) found that those alternative certification candidates who were equipped with three or more methods of teaching courses and who had field experience of 12 or more weeks, reported feeling better prepared than teachers who did not. Similar to Key (2012), Humphrey et al. (2008) found that the coursework studied mattered to the teachers' sense of preparedness and self-efficacy to perform in their roles, particularly when it "was designed to be relevant to the immediate needs of the participants" (p. 520). The teachers in this study not only cited the methods coursework as a significant component of their preparation experience, they also identified the ACTS physics curriculum as a major influence with respect to their knowledge of physics content and pedagogy. They often emphasized that having access to the ACTS curriculum resources gave them initial confidence in their teaching practices.

The Participants' Teaching Practices Shared Similar Features

Despite the participants' varying years of physics teaching experience, their in-class practices shared similar features. All such teachers taught physics through problem-solving, using the ACTS curriculum materials and by modeling problem solutions before assigning independent practice to students. Surprisingly, the practices of the most experienced physics teachers, Alex and Paul, shared much in common with the most novice physics teachers, Maya and Ian. Though this finding was initially puzzling, in reconsidering the role of confidence and self-efficacy beliefs on these teachers' practices, it became evident that all of the participants had referenced an initial lack of confidence in teaching physics. Indeed, Ian and Maya reported that their confidence was increasing, while both Paul and Ian indicated that their confidence had increased with experience. This finding gives support to that of Flores et al., (2004) who reported that experience has a positive influence on a teacher's sense of efficacy. However, the fact that Paul and Alex's practices remained relatively unchanged and were closely aligned with their preparation is at odds with the findings by Flores et al., (2004) and Humphrey et al., (2008). Since these researchers proposed that positive self-efficacy beliefs influence a teacher's willingness to experiment in their teaching practices, if experience increases teachers' confidence and overall sense of efficacy, it seems reasonable to ask why is it that the practices of Paul and Alex mirrors that of Maya and Ian?

This question led me to consider what role, if any, teachers' beliefs about teaching and student learning had on their teaching practices. I noted that Maya, Paul, and Alex held similar views on teaching and learning yet Ian did not. Ian was convinced that no single approach to teaching is better than another and described his role as raising the students' interest in science. On the other hand, the beliefs expressed by Maya, Paul, and Alex in this regard were consistent with traditional and transmission-centered beliefs. When Paul and Alex described their role as physics teachers they spoke about "delivering" the course material to their students. Similarly, Maya also described her intentions as "delivering" or "giving" content to students but, like the others, she was also concerned with being responsive to students' needs and personal development.

In some cases, I found inconsistencies in terms of alignment between the teachers' beliefs about their practices and how they enacted these beliefs. In other, I found that teachers' beliefs were consistent with their practices. Observations of Alex and Paul's teaching and follow-up interviews revealed a strong alignment between the practices enacted and the views that they expressed. Both of these teachers appeared to be satisfied with their approach to the teaching of physics. On the other hand, Ian and Maya expressed unresolved conflicts between their beliefs about their teaching practices and those they were enacting, and this led to the shifts in practice that they described. Both of these teachers explained how they were beginning to take risks and to experiment in their practices. Ian has turned to the engineering-based STEM challenges as a way to promote the types of discourse that he facilitated among history students. Ian viewed his shift to the open-ended engineering-based activities as “giving them the reigns,” as the lesson tasks involved here gave students a role in setting the conditions for their learning by default.

Similarly, as Maya also wanted to promote physics discourse among her students, she began using probing questions in order to encourage them to reason. Maya explained that she began to see a distinction between teaching mathematics and science, the latter of which having encouraged her to shift focus away from procedural fluency in problem-solving to conceptual understanding. Maya also sought student feedback with respect to her lessons and reportedly began inviting them to provide feedback on both the pace and quality of such lessons. For Maya, it was important that students believed their needs were being addressed and that they developed confidence in their knowledge of physics. Ian, whose chief intention was to “spark” students’ interest in science, was drawn to the STEM challenges because he valued lessons in which students participated “actively” and had “fun” while learning. Both Ian and Maya’s reported shifts are consistent with their expressed beliefs about their practices.

The participants’ teaching practices shared similar features that were not only related to their preparation but also to in regard to their beliefs about the nature of knowledge and how it is acquired. Faced with teaching a subject that was outside of their main area of expertise, the teachers initially experienced similar challenges that mainly stemmed from their limited subject matter knowledge in physics. The findings of this study provide support for the work of Hashweh (1987) and Halim & Meerah (2002) who found subject matter knowledge to be an essential component with respect to developing pedagogical content knowledge and transforming it into lesson plans and accurate content representations. There is consensus among researchers in the realm of teacher knowledge that subject matter knowledge influences pedagogical content knowledge (Shulman1986, 1987; Grossman, 1990; Magnusson et al., 1999; Parks and Oliver, 2008). In regard to the study's participants, limitations in their subject matter knowledge helps to explain why the teachers all initially expressed a lack of confidence, and why they went on to develop strategies to deal with this challenge. They continued to study physics and they closely aligned their approach to physics teaching to their preparation through use of the ACTS curriculum materials and a focus on mathematical problem-solving.

The Participants Desired to Master Physics Subject Matter

The continued study of physics was a consistent theme in the narratives of all four participants. Given the demands inherent in the careful study of subjects like physics, it is not uncommon for individuals to experience gaps in their subject matter knowledge (Baubeng, 2016*;* Zavala & Alarcon 2007). However, when the aforementioned physics teachers were assigned to schools with an acute physics teacher shortage, the students who most needed access to a quality education in physics were at a disadvantage yet again (American Physical Society, 2012). Nevertheless, the participants did not attribute any gaps in their knowledge of physics to lead to a deficiency in their physics preparation and they assumed full responsibility to address this challenge on their own. In fact, all of these teachers reported that they were satisfied with their preparation to teach and that they felt well-prepared as a result of their special training (Nyre & Talbot, 2012).

Similarly, Ian, Paul, and Alex all perceived the coursework as preparation for the Praxis content exam: “they are not so worried that you teach it in this method or that method, it was more like, I got to get all of this physics in your head so that you can pass the Praxis” (Ian, personal communication, January 22, 2017). This finding gives support to Baubeng (2016) who found that “responsibility for learning content was mainly given to the aspiring student teachers to remedy any gaps in their subject matter content knowledge” (p. 49).

In light of the participants perceived gaps in such knowledge, they all desired to master the content in their assigned physics courses and to demonstrate this in their teaching practices, particularly with respect to their capabilities in basic mathematics, algebra, trigonometry functions, and graphing. The findings here also indicate that those with a strong mathematics foundation, like Maya and Alex, had an easier time learning the course materials than those who did not. This link between understanding mathematics and learning physics is consistent with well-documented findings in physics education research (Redish, 1994; Tuminaro and Redish, 2004).

Relationships with Physics Colleagues Changed after Preparation

These teachers’ relationships with other physics teacher colleagues changed after their preparation. While enrolled in ACTS, the teachers’ physics colleagues provided tutoring in both physics and mathematics. However, once some of the participant teachers completed their preparation they sought support that was in relation to pedagogy more than content. In fact, none of the four described an experience with formal mentorship or coaching. The findings of this study lend support to previous research on alternative teacher preparation that investigated the role of formal mentoring relationships during their induction. Carter & Keiler (2009) and Foote et al. (2010) noted having observed insufficient mentoring and coaching support for new teachers, and that this was a cause of frustration or even of such individuals leaving teaching altogether. Unlike the teachers cited in Carter & Keiler (2009) and Foote et al. (2010), who felt "under-supported," the teachers in this study received support from their physics colleagues, who served as content coaches or as informal mentors.

It is interesting to note that the participants in this study were similar to teachers identified by Carter & Keiler (2009) and Foote et al. (2010) in regard to having "relied heavily upon peers in their alternative certification program as people who could best understand what they needed" (Carter & Keiler p. 451). With respect to the participants of the latter noted study, the colleagues who they turned to for help were also enrolled in an alternative certification program. However, Carter and Keiler (2009) found that the teachers in small schools had to ''go it alone'' or seek assistance from friends in other schools" when they were the only one teaching a subject in their buildings (p. 451).

Ian's experiences at Ridge Regional High School add another dimension to informal coaching and mentoring relationships. Although Ian had experienced colleagues in the department who could help him, he initially decided to "go it alone" until he made a connection with Grace, who supported him. This specific experience highlights the importance of supportive departmental cultures. At Ridge, for teachers to visit each other's classroom was a common part of the departmental culture. Comparatively, Alex wanted to have a more collaborative relationship with physics colleagues but with respect to support, the conditions in his department were found to be lacking.

In following the teachers' transition to interactions in regard to the teaching of physics, such were observed to be based on practice-related needs (e.g. curriculum implementation, content representation, and lesson assignments). In some cases, the teachers observed the practices of their physics colleagues and selected strategies from among those that were modeled in their classrooms. For instance, Alex took up the practice of using the magic triangle from a colleague, while Ian followed Grace's example and shortened the second kinematics equation.

In addition, Ian, Maya, and Alex sought physics teaching model to emulate but Paul did not. While Paul appeared to prefer to work independently and in isolation, Ian and Maya looked for colleagues in the department to model their practices after. Bandura's (1977) Social learning theory helps to explain why such participants sought models to emulate with respect to the teaching of physics. The theory proposes that learning to teach through direct experiences is not always beneficial. Rather, Bandura (1977) proposes that new practices are generally acquired through the influence of models. Bandura (1977) argues that the process of learning through "trial and error" is not only ineffective, it leads to "costly" or "dangerous" mistakes. It is reasonable to envision that once the study's participants took over their assigned classes as new physics teachers that, in order to avoid presenting error-filled lessons, they sought opportunities to learn from peers. For doing so through the use of such models presented the teachers with a low risk way to develop in regard to their individual teaching practices.

Relationships with Students Based on Shared Experience Learning Physics

Given these teachers own challenges learning physics, they more readily related to struggling physics learners. All four participants reported transferring elements of this experience into their teaching practices. They drew on their own learning difficulties and applied that information to modifying or adapting their lesson plans. By knowing what makes a principle or concept difficult for a student to learn, the teachers learned to break down larger tasks into their smaller component parts. This finding is supported by previous studies that linked teacher practices to personal attributes, such as dispositions toward a student's ability or cultural background (Stoddart, 1990; Stoddart, 1993, and Scriber & Akiba, (2010). Stoddart (1990) and Stoddart (1993) emphasized that when a teacher is able to relate to a learner's academic talents or struggles, they are likely to develop or use responsive instructional practices.

Although the participants reported feeling better prepared to relate to struggling learners, they were still guarded in their interactions with students. More specifically, the participants avoided interactions with students where they may have appeared underprepared for their role. For example, Paul and Ian avoided assigning physics problems to students that they did not know how to solve themselves. Similarly, Maya and Alex used the physics curriculum and related resources as a type of script. When Alex reflected on how such scripting affected his teaching practices, he noted that "I was really the focus" rather than his students. My observations of Alex's in class practices confirmed that he remains the focal point of the lesson, which was actually found to be the case for all of the study's participants.

Indeed, while they all expressed the value inherent in ensuring that active student participation or the encouragement of students' agency is a key part of their teaching methods, their practices did not fall in line with these beliefs. Previous studies have documented that the beliefs expressed by practicing teachers that were not consistent with those in regard to their teaching practices (Prawat, 1992; Schraw and Olafson, 2006 as cited in Buehl and Fives, 2009) and Gess-Newsome & Lederman (1995) found that secondary subject teachers' use of curricular materials were related to their beliefs and values.

To better understand how interactions between the participants, their students, and the ACTS curriculum play out during observed classroom lessons, let us turn to the work of Lederman and Morrison (2011), Larkin (2012), and Yamakawa (2014). While Lederman and Morrison (2011) found that teachers are tend to be unable to distinguish the difference between eliciting students' ideas and asking them for the correct answer, Larkin (2012) identified five diverse ways that the candidates perceived students' ideas. Yamakawa (2014) noted that teachers positioned students as a type of mathematics learner. This research found that teachers' responses to student contributions during instruction placed learners in silenced or advanced positions, which promoted or hindered opportunities for them to learn. When the participants in this study focused their attention on the evaluation of students' contributions as either right or wrong, they were aligning certain students with science and not others.

Across all four cases, the participants enacted lessons that were centered around problem-solving in physics and on students arriving at the right answer or, as Lederman and Morrison (2011) characterized this, as "suppliers of the right answer" (p.863). For example, all of these teachers formatively assessed student ideas during the lesson. This practice was mainly used by the teachers to decide whether they would reteach in a concept-based manner rather "than helping students to think about their ideas in relation to the ideas that they are trying to understand" (p. 863). This finding supports the work of Larkin (2012), who found that, although preservice teachers took up the practice of eliciting student ideas, they held different reasons for doing so, and that this practice primarily served as way of looking for "evidence of content coverage" (p. 954).

Similarly, with the exception of Paul, the study's participants used students' ideas much in the same way as the preservice teachers in Larkin's study. For instance, while visiting Paul's class, it was observed that he often dedicated a significant portion of the review lesson to having students revisit their ideas on the concept of inverse proportionality. Several volunteers went up to the board to present their ideas on the concept, as Paul encouraged the remaining students to carefully consider the ideas being proposed in relation to their own ones, and to identify any contradictions in the arguments presented by their peers. Paul's use of student ideas here is consistent with what Larkin describes as "priming students for thinking about the content," and, in Ian's case, he was preparing the Advanced Placement students for a lesson on projectile motion in two dimensions wherein they would have to apply the second law equation.

Further linking Larkin's work with research on teacher beliefs about their knowledge, offers additional insight into understanding teachers' expressed anxieties with respect to unanticipated student questions, or their desire to depart from using the

ACTS curriculum as “script,” particularly during their early development. The participants’ response to these challenging moments are what Fuller (1969) describes as “teaching concerns”. These concerns or frustrations fall within the realm of incidents that individuals like Ian described, such as the time when he had to teach a lesson to honors students on projectile motion, a topic he struggled with and “barely” got through during his period of preparation (Ian, personal communication, November 15, 2016). Some key concerns for Ian were in regard to the presentation of the course material and to ensure that his students were convinced that he was prepared for the task. Fuller’s hypothesis helps to explain what happened when these teachers encountered new challenges in relation to their subject matter knowledge: “the behavior is initially governed by concerns about oneself and the demands that the situation makes upon the individual. If self-concerns are resolved, the individual then moves to concerns which focus on the task and the quality of performance” (p. 66).

Yet Fuller’s hypothesis helps to explain only part of the participants’ response to their “teaching concerns.” Although the participants in this study were experienced teachers, they were new to the teaching of physics. Thus, it is reasonable to consider that their response to such “teaching concerns” would mirror that of early stage teachers. However, the hypothesis does not explain why these teachers continued to position themselves as the primary source of knowledge. In her work on the epistemological perspectives of teachers, Lyons (1990) argues that “teacher’s work cannot be conceptualized primarily in terms of subject matter knowledge or defined solely by content and pedagogical knowledge” (p. 175). Rather, she advances the insightful notion that teachers' views about the nature of knowledge and of their students as knowers determine their relationships with them. I, in fact, saw this play out in both Ian and Maya's case, as each sought to expand their students' views on physics concepts and principles.

Maya and Ian's pedagogical shift suggests that, as they began to think differently about what it means to know about physics, this changed how they wanted to present the subject matter and so they began to consider alternative ways for their students to engage in their respective courses. This finding is supported by that seen in the studies of Brown et al. (2013) and Friedrichsen et al. (2001) who found that new science teachers held strongly transmission-oriented beliefs about teaching and learning that influenced their instructional practices.

On the other hand, the findings with respect to this study add an interesting dimension to the literature on science teacher beliefs. For both Ian and Maya, who became science teachers for the first time, appeared more responsive to the context of science teaching, than Paul and Alex, who were science teachers before physics. To Ian and Maya, physics was distinctly different from the subjects that they have previously taught, so they found it necessary to make adjustments to their practices, thereby forming what Lyons (1990) describes as new "learning relationships" with students.

These findings also encourage a reconsideration of the role of science departments in regard to the socialization of teachers, which Grossman and Stodolsky (1995) describe as "disciplinary ways of thinking." School departments, such as in the realms of science and mathematics, have their own subcultures and beliefs about a discipline that bind individuals of the department together (Grossman and Stodolsky, 1995). Hence, these researchers hypothesized that individuals' ways of thinking about the subject that they teach have been mentally absorbed from their own experiences in higher education.

Grossman and Stodolsky (1995) argue that institutionalized practices in higher education socialize individuals who enter teaching into specific ways of thinking about their discipline. For instance, these researchers assert that those who major in subjects like physics are institutionalized by the way that individuals are sorted into these higher level courses (p. 9). They explain that high level education with respect to math and science courses are designed to weed out all but the students who perform well in such courses, and that this practice teaches those who remain in higher level math and science courses to believe these subjects are not for everyone (p. 9). According to these researchers, the result of this practice is "a problematic lesson for prospective high school teachers" in their work with learners in the subject who are academically different from themselves (p. 9). More particularly, Grossman and Stodolsky (1995) suggest that teachers adopt similar beliefs about learners and form relationships with their discipline such that they too become gatekeepers in their respective teaching roles. Lyons (1990) emphasizes that teachers, either explicitly or implicitly, are aware or unaware of how they interpret and assess students as knowers. Similarly, Villegas and Lucas (2002) assert that the perspective of teachers about students' abilities is shaped by their own sociocultural positioning which, in turn, influences their pedagogical beliefs and enacted practices. Altogether the various arguments offered here provide a line of reasoning highlighting how teachers' socialized views about students as knowers may contribute to them being denied access to certain science arenas, especially physics (Villegas and Lucas, 2002, p. 22).

Though the focus of alternative teacher preparation in physics is centered on content and pedagogy, my findings lend support to the recommendation by Lyons (1990) and Brown et al. (2013) that coursework experience include opportunities for candidates to explore and question beliefs that stem from their epistemological perspectives, as well as to have those beliefs challenged as well. Attention to teacher beliefs throughout the continuum of their career, and especially in regard to those who move on to teach a new subject, seems likely to have significant impact on professional learning and development. In addition, partnerships between districts and alternative certification programs should strongly consider the role of mentorship and the impact of the respective department's culture and environment on the development of such newly appointed science teachers.

Implications and Policy Recommendations

The following section provides recommendations and directions for future policies, research and practices. I first present my recommendations with respect to policy of teacher education and development of endorsement physics teachers. I then go on to present recommendations for better practices in teacher development for school districts to consider. Lastly, I present the limitations inherent in this study in conjunction with some recommendations for future research.

Implications. The findings of this study offer some important implications for subject-specific preparation in the realm of science and teacher development, especially with respect to when teachers change specializations during the course of their career. As part of this study's findings, I have reported on high school physics teachers' perceptions of their preparedness. The four participant teachers described how they adjusted to their new roles during the earlier stages of their development. Most of the teachers' perceptions included descriptions of their confidence levels in relation to their knowledge of physics content and pedagogy, while also highlighting the accelerated pace of the coursework.

The implications with respect to the study's findings suggest that, just as the experience of such individuals in fast-paced, accelerated courses led to some gaps in knowledge that had negative consequences on teacher development and student learning, this may well be the case with others in a similar situation. Teachers with insufficient knowledge, particularly in their main area, are challenged during their early stages of development, causing some to give up such a quest altogether. Moreover, teachers who lack confidence in their degree of knowledge in the subject matter they will teach are less likely to create quality learning opportunities for students. The overall implication and take away here is that alternative certification programs would do well to extend the length of subject-specific preparation and give such candidates the option to revisit their coursework as needed. In addition, given that there were few mentions made by the study's participants about their own sociocultural consciousness and awareness of its influence on their beliefs about how students of diverse ethnic, language, and socioeconomic backgrounds should be taught, suggests that programs for preparing inservice teachers to teach physics to underserved student populations, ought not take for granted that these individuals already hold a well-informed awareness of educational inequities and that they are therefore prepared to act as change agents in this regard (Villegas and Lucas, 2002). Instead, as these researchers have suggested, teacher preparation programs need to included components that addresses the issue of preparing individuals who are culturally responsive to the needs of all students (Villegas and Lucas, 2002).

Second, the findings indicate that formal mentorship played little, if any role in the teachers' development and those department leaders, who were mentioned, also had but a small presence in these teachers' experience. For instance, Alex's department chairperson told him to teach conceptual physics while not providing any additional support or resources to better do so. Third, the teachers' development is also related to the courses that they are assigned to teach. In Ian's case, for example, he was assigned an honors course during his first year of teaching physics. Hence, not only did he have to teach concepts that he struggled with during his period of preparation, this deficiency was not remedied until preparing to actually teach the concept. This finding thus raises an important question: Is it reasonable to assign honors courses to first year teachers? As noted, Ian was assigned to honors physics during his first year of teaching, while Paul has taught all levels of physics, including Advanced Placement, yet Alex, who has had the most physics teaching experience, has still never taught an Advanced Placement course. The findings here illustrate a good deal of variation in how the teachers experienced the teaching of physics and such disparities were based on their academic backgrounds, previous teaching experiences, and workplace variables, including course assignments and department leadership.

Overall, this study has illustrated that it is essential to better understand and address the needs of inservice teachers who transition to specializing in physics from another subject area. Such findings are in harmony with previous alternative certification program literature, for example, in highlighting that mentoring, even for inservice teachers, still remains an essential component of the alternative certification program and that coordination of efforts between these organizations and partnering school districts is truly key (Humphrey et al., 2008; Carter & Keiler, 2009; Foote et al., 2011). In addition, the study's findings concur with those in previous literature that investigated the relationship between teacher beliefs and their classroom practices (Lyons, 1990; Friedrichsen et al., 2011; Brown et al., 2013). These studies call for more opportunities to be given with respect to the taking of methods courses that invite teachers to explore their epistemological beliefs regarding the nature of scientific knowledge, as well as the nature of knowledge and learning in general. Teacher preparation, then, that is focused on challenging teacher beliefs is as significant to a teacher's education as that of their focus on preparation in the subject matter and pedagogical content knowledge.

Recommendations. The findings of this study are significant to individuals who are interested in addressing the major problem of high school physics teacher shortages using the much discussed alternate route as one strategy to do so. The practice of filling high school physics teacher vacancies with non-physics or non-science inservice teachers is rapidly growing in parts of the country where the need is the greatest (New Jersey

Senate and General Assembly, 2014). In this regard, policy makers should give major consideration to the notion of extending the amount of time for such teachers to prepare in advance of doing so. For the most part, one year is unlikely to be a sufficient amount of time to learn how to teach a difficult subject like physics.

In the meantime, the findings of this study suggest that policy makers should also plan to address the way that these teachers are supported during their first years of physics teaching. For this reason, I recommend that policymakers offer incentives in the form of grants for post-secondary institutions to partner with school districts to provide continued professional development for such alternatively certified teachers of programs similar to ACTS. Such grants could be tied to afterschool or weekend tutoring programs for physics students and scholarships for students to later go on to study physics more in depth.

Universities have resources that can be offered to school districts to assist them in the support of such alternatively prepared physics teachers. This support can include visiting faculty who are physics professors, teacher educators, who in some cases may be the same person, as well as offering continuing education coursework at the district level or online. Short-term research opportunities that are related to physics and physics teaching and learning that take place during the summer or over the weekend throughout the year are other ideas. However, in order to do this, it is important for district leadership and institutional leaders to collaborate in assessing and aligning organizational resources to address the needs of the alternatively certified physics teachers.

As part of this partnership initiative, it would be highly beneficial to alternatively prepare inservice teachers for institutions by creating opportunities to specifically support the use of action-research or self-studies in physics teaching and learning in which teachers explore the impact of their beliefs on their teaching practices. Coursework related to the continued study of physics should include experiences in learning that have to do with the nature of science, and of physics, particularly for individuals who have non-physics and/or non-science backgrounds (Zavala et al., 2007). Other coursework should include those that focus on physics teaching pedagogy, which also focuses on what makes physics difficult for students to learn (Etkina, 2008; Redish, 1994; Ornek & Haugan, 2008; Windschitl et al., 2011).

It is also important to note that none of the four participants in this study had any affiliation or membership with physics teacher organizations, such as the American Association of Physics Teachers (AAPT) or took part in any physics related professional development opportunities after becoming physics certified. Thus, alternatively certified teachers would likely benefit from being exposed to and participating in AAPT sponsored events, such as conferences, and having access to research journals.

Lastly, administrators should provide opportunities for the newly certified physics teachers to collaborate with master teachers within their school community or a nearby district. This study's findings suggest that it is beneficial for newly certified physics teachers to interact and engage with more accomplished physics teachers and those willing to serve as professional mentors to assist with the needs of these individuals, including the role of coach with respect to both content and pedagogy. Retired physics teachers that are willing to mentor newly certified teachers, could well be an ideal group that should be encouraged to do so.

Limitations of this Study and Recommendations for Future Research

There are two specific limitations in relation to this study. Firstly, that the teaching practices and beliefs expressed by the teachers are not broadly generalizable beyond the four participants of this study. Secondly, unlike some others, all of the teachers here persisted through their challenging period of preparation and are currently practicing physics teachers. This was a case study in regard to inservice teachers who switched to physics and who were still teaching physics at the time of this study. Therefore, by design this study did not examine experiences of teachers who were unsuccessful in transitioning to physics teaching

Future studies may consider investigating the experiences of individuals who become physics certified but no longer teach the subject. Such researchers may thus choose to investigate, for example, how contextual factors in the alternative certification program (e.g. specific program components) or the teachers' workplace influence their decision to leave physics, particularly in regard to mentorship, leadership, student readiness, and specific teaching assignments. In addition, it is also worth knowing what personal characteristics, such as academic background, one's beliefs about the nature of teaching and learning and about the nature of physics (which encompass sources of knowledge or how physics knowledge is acquired), as well as previous teaching experiences influenced how the teachers' experienced physics teaching.

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Appendix A: Methods of Data Collection

- Interview Guide
- Physics Teacher Questionnaire

Interview Guide

Participant pseudonym: ____

Interview location: ____

Interview date: _________

Interview #: ________

1. Review interview process.
   - The interview will take 60-to-90 minutes.
   - The discussion will be audio recorded, I will be taking notes, but your individual identity will be kept confidential.
   - When the recordings are transcribed, your name will be replaced with a pseudonym.
   - You will be provided with a copy of the interview transcript for you to review clarify (previous) statements and/or add comments to interpretations.
   - You can choose not to answer a question.
2. I will start the recorder now—begin interview
3. I will stop the recorder now—stop interview
4. Confirm next interview.

The goal of the first interview is to focus on the details of each participant's education/professional background and professional learning experiences up to the present time.

1. Could you please share about your current teaching responsibilities at this school, teaching load per week, as well as your personal and educational background.

2. How did you decide that you wanted to be a (initial subject teacher)? Had you always wanted to be a teacher?

3. How did you decide that you wanted to be a physics teacher?

4. Tell me about the actual physics preparation program; please describe it in as much detail as you can remember. How was that for you?

5. You've had experiences in two alternative certification programs, please compare and contrast them for me.

6. If you would describe a typical physics lesson that you have taught, what would it look like?

7. Is there anything you would like to add?

Second Interview

The goal of the second interview is to focus on the details of each participant's current experience as a physics teacher and to understand how they have developed their practice over time.

1. What is it like to be a physics teacher? What have you found is just essential for you to know and be able to do? How do you generally prepare to teach a lesson?

2. Please describe your thoughts about what a physics teacher should know and be able to do?

3. How would you generally prepare to teach a lesson?

4. What teaching method(s) do you think is/are effective for helping students to understand physics content?

5. What are your professional learning goals related to physics teaching? What are your plans for achieving them? As you think ahead and continue teaching physics, what are your own professional learning goals? What would help you achieve these?

6. Follow up and clarify response on questionnaire or previous interview(s)

7. Is there anything you would like to add?

Third Interview

The goal of the third interview is for the participants to reflect on the meaning of their experience as a physics teacher and physics teacher identity.

1. How does teaching physics compare to teaching initial certification subject?
2. Follow up on previous lesson and take the participant back to parts of the lesson that seem interesting to revisit. How did you decide to focus on this concept/skills.
3. Is there anything you would like to add?

Fourth Interview

Ask follow questions related to previous interviews.

Teacher Questionnaire

Participant pseudonym: ______________________________ Date: _________

Directions: please circle the one response that best represents your experiences while learning to teach physics.

1. As you worked toward completing your physics preparation requirements, to what extent did your experience include the following?

   a) Plan lessons with a group of colleagues from cohort members:

   Never, Sometimes, Not enough, Very often, Always

   b) Opportunities for active learning methods (not only listening to a lecture):

   Never, Sometimes, Not enough, Very often, Always

   c) Collaborative learning activities with other teachers:

   Never, Sometimes, Not enough, Very often, Always

   d) Received support in the form of written feedback on my teaching, coaching or mentorship during the first year of teaching physics:

   Never, Sometimes, Not enough, Very often, Always

   e) Developing subject matter content knowledge of physics:

   Never, Sometimes, Not enough, Very often, Always

   f) Learning how to use technology in science instruction:

   Never, Sometimes, Not enough, Very often, Always

   g) Learning how to assess student learning:

   Never, Sometimes, Not enough, Very often, Always

   h) Learning how to facilitate collaborative student group learning:

   Never, Sometimes, Not enough, Very often, Always

   i) Learning how to use direct instruction as a method of teaching:

   Never, Sometimes, Not enough, Very often, Always

   j) Understanding student thinking about physics concepts:

   Never, Sometimes, Not enough, Very often, Always

   k) Learning multiple ways to presenting content to student:

   Never, Sometimes, Not enough, Very often, Always

2. For each of the following statements, please indicate the degree to which the listed activities were helpful to you after completing physics preparation.

    a) Experience gained teaching the course over the years:

       Never, Sometimes, Not enough, Very often, Always

    b) Teaching observation data/feedback from school leader(s):

       Never, Sometimes, Not enough, Very often, Always

    c) Mentor/coaching from subject matter specialist/more experienced peer:

       Never, Sometimes, Not enough, Very often, Always

    d) Planning lesson for teaching:

       Never, Sometimes, Not enough, Very often, Always

    e) Visiting the classroom of physics colleague to observe a lesson:

       Never, Sometimes, Not enough, Very often, Always

    f) Additional coursework in physics content:

       Never, Sometimes, Not enough, Very often, Always

    g) Additional coursework in physics pedagogy:

       Never, Sometimes, Not enough, Very often, Always

    h) Reading physics textbooks:

       Never, Sometimes, Not enough, Very often, Always

    i) Reading articles about physics teaching:

       Never, Sometimes, Not enough, Very often, Always

    j) Reviewing student work:

       Never, Sometimes, Not enough, Very often, Always

    k) Reflection after teaching:

       Never, Sometimes, Not enough, Very often, Always

    l) Collaborative teaching/co-teaching:

       Never, Sometimes, Not enough, Very often, Always

    m) Collaborative plan lessons with a colleague:

       Never, Sometimes, Not enough, Very often, Always

    n) Other activities not mentioned: Please describe.

3. Aside from physics preparation, on a scale of 1 to 10, rate the following factors that have influenced your knowledge of physics teaching:

____ Experience teaching physics over time

____ Graduate level physics coursework

____ In-district workshop

____ Internet resources

____ Out-of-district workshop

____ Reading a physics textbook

____ Received tutoring from colleague or cohort peer

____ Reflecting on one's practice

____ Other___________________________________

Appendix B: Teacher Practice Rubric

Table 6

Teacher Practice Rubric

Low Content Fidelity	**Moderate Content Fidelity**	**High Content Fidelity**
The subject matter content encompassing the observed physics lesson was loosely consistent with the written physics curriculum.	The subject matter content encompassing the observed physics lesson was moderately consistent with the written physics curriculum and there is moderate variation or supplementation.	The subject matter content encompassing the observed physics lesson was highly consistent with the written physics curriculum and there is little to no variation or supplementation.
Practice Fidelity	**Moderate Practice Fidelity**	**High Practice Fidelity**
The observed practices were not consistent with those the participants described as being part of their physics preparation.	The observed practices were moderately consistent with those the participants described as being part of their physics preparation.	The observed practices during physics lessons were highly consistent with those the participants described as being part of their physics preparation.

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