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Quality teaching practices: portraits of award-winning secondary school chemistry teachers

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Dissertation

QUALITY TEACHING PRACTICES: PORTRAITS OF AWARD-WINNING SECONDARY SCHOOL CHEMISTRY TEACHERS

by

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DEDICATION

I dedicate this work to Danielle and Joey, who continue to teach me about the joys of parenting, to the award-winning teachers and mentors I have learned from over a lifetime, and to the countless students I have shared with across my teaching career.

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QUALITY TEACHING PRACTICES:

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ABSTRACT

Quality Teaching (QT) is a sought-after professional goal for educators and schools alike. It is easy to observe, harder to define, and hardest to understand how to achieve. This study attempted to identify QT amongst a select group ($N = 6$) of Boston-area award-winning high school chemistry teachers. Participants were selected based on having received at least two American Chemical Society-sponsored awards within the past ten years. Data were collected through survey, personal interview, classroom observations, post-observation debriefs, anecdotal information provided by teacher colleagues, supervisors, and past students, student success on externally administered chemistry examinations, and a capstone focus group interview with the teacher-participants. These data were then coded and cohered with two measures of exemplary teaching: The Massachusetts Department of Elementary & Secondary Education Educator Evaluation Rubric and the American Chemical Society Guidelines for Middle-and-High School Chemistry Teaching. Definitions for QT in general and high school chemistry teaching in particular are detailed from references in the Literature Review.

Surveys and interviews were conducted via email and Zoom chats, and

observations during COVID were conducted also by online facetiming. Colleague, administrator, and past student anecdotes were obtained through these award-winning teachers' award nomination letters that I had access to in my role as a member of the Northeastern Section American Chemical Society's (NESACS) High School Awards Committee and as Chairperson for the HS Education Committee. I also had access to student results on externally administered local and national chemistry exams in my role as co-administer of the Ashdown Exam and Section Coordinator for the US National Chemistry Olympiad (USNCO).

The findings of this study showed that these award-winning teachers (AWTs) took varied pathways and educational backgrounds to arrive at their profession. Participants all agreed that there is no one best way to teach, but many right ways to get to award-winning teaching. These teachers all possessed "It," that elusive, mystical, some say innate, art of teaching born of passion, charisma, and love of working with children alongside a continual drive to improve pedagogical practices. This study identified that drive as "relentless expectations," both for themselves as constant lifelong learners and their students for whom they set high standards. Though recognized by these awards, all of these teachers expressed humility and claimed that other colleagues were equally qualified to be award-winners. Colleagues shared that this study's participants were "teachers' teachers" and selfless collaborators. Supervisors related that these great teachers made great schools, and past students exclaimed that these teachers transformed students' lives and career pathways.

The data suggest that award-winning status as a secondary high school chemistry teacher must incorporate a variety of factors, including a love of science learning, a mastery of the study of chemistry with an on-going interest to forward this learning, a passion for teaching and seeing teenagers succeed in learning chemistry, the ability to create a classroom of caring and trust to allow students to take academic risks, self-motivation to collaborate with colleagues through meeting, programing, and publication, self-confidence with a strong voice, and empathy. This study identified two overlooked factors that maintain award-winning teachers: relationships and reflection (the "R & R" of AWT). Other factors that contribute to AWT include supportive school and community with resources available to both teacher and student, freedom and professional trust to be able to innovate and create curriculum, and teachers' creation and participation in collaborative venues such as collaboration time, workshops, presentations, and conferences. Participants in this study came to chemistry teaching as a second career and state that they acquired their award-winning pedagogy through a combination of most of these factors. Though each of their voices, classrooms, and school buildings looked different, these factors in total provided a common set of criteria to produce the award-winning teaching portrayed in this study.

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COMMON ABBREVIATIONS

ACL	Active Class Learning
ACS	American Chemical Society
AP	Advanced Placement
AWT	Award-Winning Teacher
DESE	Department of Elementary and Secondary Education
FRQ	Free Response Question
IChO	International Chemistry Olympiad
LDC	Law of Definite Composition
LDS	Lewis Dot Structure
LMP	Law of Multiple Proportion
MCAS	Massachusetts Comprehensive Assessment System
NBCT	National Board-Certified Teacher
NERM	Northeastern Regional Meeting
NESACS	Northeastern Section of the American Chemical Society
PhET	Physics Education Technology
POGIL	Process Oriented Guided Inquiry Learning
PUCES	Picture, Unknown, Change, Equation, Solve
QT	Quality Teaching
SEI	Structured English Immersion
STEBI	Science Teaching Efficacy Beliefs Instrument
STEM	Science Technology Engineering Mathematics
UDAVE	Unit, Definition, Abbreviation, Vector, Equation
USNCO	United States National Chemistry Olympiad.

CHAPTER ONE

INTRODUCTION

Background

This study portrayed quality teaching (QT) as identified through externally determined awards for six secondary chemistry teachers in the greater Boston area. Throughout this study, I equated QT to best practices or exemplary teaching. The organization of this dissertation includes an introduction, a literature review, research methods with threats to validity, findings, and discussion. Appendices include an explanation of the teaching awards established by the American Chemical Society (ACS), my observation protocols, a system of interview coding, and interview questions for my subjects. Finally, a listing of the references used for this study is presented.

On a continuum of teacher's skills, unqualified, adequate, effective, and exemplary are terms used to represent the spectrum of the level of competency of a teacher's practice in the classroom. In this study, I examined teaching practice far beyond adequacy or effectiveness. Practice, as in medicine or law, is meant to imply "acts of thinking and working through enormously complex demanding tasks that professional obligations place upon them" (Shulman, 2004, p. 253). In current literature, QT is used to signify the profession's peak performance and ability, and it is the standard pedagogical measure to which evaluators hold teachers (Reville, 2011). The study of QT in practice and the development of portraits of award-winning chemistry teachers is intended to more explicitly reveal the characteristics of excellence in teaching.

Schools and professional organizations typically use awards to recognize QT. These awards identify excellence in teaching but do not actually portray it. This research study revealed the QT that such awards have identified. Specifically, I developed a classroom-based description of excellence and best practices in award-winning teaching (AWT). The participants were selected from among teachers in the greater Boston area who received established and recognized awards within the discipline of secondary high school chemistry.

The American Chemical Society (ACS), the recognized national professional organization of academic and research chemists, has established teaching awards with specific criteria for what is meant by quality teaching. The ACS has created guidelines and recommendations for the teaching of high school chemistry, which include clear and effective communication of fundamental chemical concepts (as observed by a teacher's evaluator) and contributions to the discipline both in and out of the classroom (American Chemical Society Publications, 2018). Following the meeting of the Task Force on Secondary Chemistry Education in 2010, this ACS Committee, made up of award-winning veteran high school chemistry teachers, was charged with identifying and codifying quality high school chemistry teaching. From this task force came the ACS's Guidelines and Recommendations for the Teaching of High School Chemistry (Appendix A), a 2012 document, last updated in 2018 to the Teaching of Middle-and-High School Chemistry, detailing a set of best pedagogical practices associated with QT. Though this document refers specifically to secondary chemistry teaching, a question arises whether these best pedagogical practices might apply to other high school science teaching and, by extension, to teaching in non-science disciplines. Yeigh (2008) suggests that portrayals of QT in one discipline, such as secondary chemical education, might serve as models for excellence in teaching in other Science Technology Engineering and Mathematics (STEM) disciplines as well.

By understanding QT, educators can hold it as a standard of achievement and excellence by which teachers are evaluated and for which teachers-to-be can strive. By analogy to Sarah Lawrence Lightfoot's (1983) *The Good High School,* which portrayed five very different outstanding high schools in the United States noting their commonalities, I attempted to portray a small group of award-winning educators within the same discipline, noting commonalities and distinctions among this select group. Analyzing award-winning teaching has value for fellow educators, schools of education, evaluators of teaching practice, teachers-to-be, and educational policy.

Research Questions

The broad questions addressed by this research are: What characteristics related to quality teacher do award-winning high school chemistry teachers exhibit and share? And, what deeper questions related to relational, aspirational, or pedagogical qualities may be answered from this study's data? Relational attributes, as I describe them, refer to the relationships formed amongst a teacher and students in the classroom. Aspirational qualities describe a teacher's sense of self and who he or she hopes to be as an educator. Pedagogical qualities refer to the specific instructional elements of a teacher's practice (Shulman, 2001). These different types of attributes might, in fact, be at times contradictory to one another, but might still serve in the final analysis to promote student learning. I looked for attributes such as these as I described the teaching practices of chemistry teachers who have been recognized as exemplary by their professional associations. Specifically, the research questions were:

Overarching question: What QT characteristics do award-winning high school chemistry teachers exhibit and share?

1. How do the award nomination process and language found in these nominations match the language found in the "Exemplary" standards of the Massachusetts Educator's Evaluation Rubric?
2. What beliefs about learning drive the work of these award-winning educators?
3. What aspects of their teaching do these teachers say are more likely to lead to good learning for their students?
4. What personal and career experiences contribute to becoming an award-winning teacher?
5. Do these teachers feel supported by their colleagues, administrators, and community?
6. Which attributes from these award-winning chemistry teachers might be distinctive to chemistry or science teaching?

Awards highlight teachers' attributes and pedagogy but do not provide specific acts or depth in detail to understanding QT (Shulman, 2001). This study's intention is to document and analyze the QT that comprise AWT's practices and understand QT from these portrayals.

Definitions

QT frequently refers to the gold standard of teaching practices described in the Massachusetts Educator's Rubric as "Exemplary" teaching. "Adequate" or "Effective" teaching might be understood as merely getting the job done without an award-winning status attached to these practices. These definitions will be further discussed in the next chapter.

CHAPTER TWO

LITERATURE REVIEW

Introduction

This chapter provides definitions from the literature for how quality teaching (QT) is observed and understood, how quality teaching is found and awarded, the specialness of teaching secondary science, and what award-winning secondary chemistry teaching might look like. The discussion focuses on references to research on teacher observations, teacher reflection, teacher evaluation, and teacher improvement deemed important in devising this study.

Observing and Documenting Teaching

Works cited here are examples of both how-to guides for observation and evaluation and teacher portraits created through observations; these were important to my study for attempting to portray quality teaching. While observing teaching can be like viewing art, those who monitor the teaching profession demand an objective, communicable form of observation methodology for evaluating individual teachers and helping them improve their practice.

Time-honored methods of observing teaching range from recording word-for-word interactions between teacher and student to electronically capturing interactive classroom moments and summarizing these interactions as a narrative. Standardized forms of these observation methods have been codified in numerous evaluation methods guidebooks, notably, *The Skillful Teacher* (Saphier, 2008). Still, subjectivity exists in observing best teaching practices. Many states have created updated standardized methods of observing teaching as part of educators' evaluation process. The Massachusetts Educator's Evaluation Rubric was adopted in 2014 across the state and updated in 2018.

My experience with this system of observation and evaluation has been in the Brookline Public Schools, using the commercial Teachpoint® site, an online data collection site for data entry that allows educators to upload evidence from classroom practice (student work, video or audio snippets of class lessons, artifacts, and conference or collaborative work with other teachers). After nearly eight years of using this system, my experience has been relatively positive in that the technology has been easy to use and the goals (self-selecting aspects of teaching practice to share) clear. In turn, supervisors upload to this site their summative and formative evaluations, which are also accessible by the human resources offices in a district. Whether these sites will then become public for the district's community to access remains a matter of current controversy (Reville, 2011).

Descriptions of how to observe and describe QT range widely (Hutner & Sampson, 2015). One struggle with the difficulty of observation is finding a common language for noting classroom actions. In a more general survey of how to observe teachers' practice, Brophy (2006) offers important definitions for the language of teacher description, making the point that education as a profession has hardly had a common language in the same way that the medical and law professions do. Moreover, if there were a common language it would be far easier to produce commonly accepted definitions for best practices, make reproducible methods of observing these practices, and implement standardized teacher evaluation. Both Acheson (1997) and Saphier (2008) codify many common classroom practices, using understandable language about teaching for both teachers and supervisors. Both of these researcher-authors acknowledge the lack of a universal coherent language in teacher observation and attempt to fill the gap. Saphier's (2008) importance to understanding QT is his introduction of specific language describing teaching practices and methods of observing them, including phrases such as "tenacity continuum" (p. 267), used to describe the degree of interest or challenging behaviors teachers transmit, or "clarity" (p. 161), used to describe how concepts and skills are made clear and accessible to students. The language that has evolved since Brophy, Acheson, and Saphier offered their suggestions are important for the descriptions provided in later chapters, including coding and reporting classroom observations.

Saphier's (2008) methods for observing teaching have been widely adopted by supervisors and school districts in the several decades since his *The Skillful Teacher* was originally published. This work serves today as a guide for teachers to develop best practices as much as it does for evaluators to be able to make standardized, relatively objective teacher observations. Specifically, *The Skillful Teacher* method of observation is to have the supervisor or evaluator act as a lens in the classroom, chronologically recording as much as possible about a lesson by focusing on teacher-to-student interactions, student-to-student interactions, and the classroom *milieu*. Following this observation, the observer places these fine-grained observations in the context and culture of the school to create a portrait in time of the educator's practice. Saphier's analysis of teaching practice from management of instruction, motivation, and delivery of curriculum draws from current educational research in an effort to detail competency in the art of teaching. Saphier's (2008) sixth edition summarizes his understanding of this art in three terms (a) "comprehensiveness," the ability to understand teaching as a whole, (b) "repertoire," the uniqueness that each teacher brings to the classroom, and (c) "matching," the decisiveness teachers make in selecting learning experiences from their repertoire to pair with each individual student to maximize learning.

Another aspect of observing teaching is noting the context and environment in which teaching occurs. Good and Brophy (2000) draw attention to the *milieu*, the context of their classroom observations, noting school culture, socio-demography, and teacher experience as influential forces in making teacher observations. Perrone (1991) and Nieto (2003) present best-practices Baedeckers as how-to manuals to develop good teaching. Instead of telling what excellent teaching looks like, they show quality teaching through sets of teacher portraits that reveal the many-layered complexities of work in classrooms through careful, thoughtful, nuanced observations. These observers document classroom practices through narrative, anecdote, and presumption of understanding of the intents of these teaching moments. How teachers are observed and hence evaluated varies widely. As baseball player-philosopher Yogi Berra notes, "You see a lot by just watching" (Berra, 2008). Observing the larger contexts of school and community culture, the *milieu* in which a teacher performs, is relevant to understanding the actions of teaching practice in a classroom.

Good (1983) asks and then answers the question, “How do we really know what we know about classroom teaching?” He does so by presenting methods of observation, interviewing, and evaluating techniques used by supervisors, peers, and educational researchers such as himself. Instead of using examination data or value-added measures of assessment, Good suggests that understanding how learning occurs in classrooms informs educators best about the effectiveness of their pedagogy. Because of the limitations of the scope of my dissertation research, an in-depth study of how students learn effectively in QT settings was not undertaken, but I did look for teacher behavior that was likely to engender good learning.

Corcoran (2012) questions the use of examination scores as valid indicators of a teacher’s effectiveness. He addresses current use of value-added measures, such as standardized test scores, to measure the quality of teachers’ work in the classroom. Corcoran refutes the use of value-added measures where other studies in this literature review suggest these measures are accepted methods for teacher evaluation, works that lean heavily on test scores as direct measures of a teacher’s effectiveness. Portraying characteristics of strong teacher effectiveness through direct teacher observation versus identifying such teaching indirectly through student outcomes remains a tension in teacher evaluation.

Fenstermacher and Richardson (2005), noted for their exhaustive mixed-methods study determining characteristics of quality teaching, ask if we can “unpack the conceptual subtleties and nuances of quality teaching so that we can proceed in consistent and systematic ways to identify and foster it or [if] we are required instead to acknowledge its elusive nature and depend upon some sort of cultivated intuition to reveal quality teaching" (p. 2). They analyze QT from the delivery of curriculum to the assessment of student learning. This mixed-methods study uses examination results following units taught and a detailed analysis of teacher pedagogy. Student learning, a response to QT that the authors argue must be taken into account to fully determine quality, is not as vital a criterion in their research as is teacher cognition, facilitation, and the dual occurrence of both good (internal qualities) and successful (external measures) teaching. No other study in this annotated list of references attempts to so thoroughly and systematically understand identified quality teaching. Time-consuming and comprehensive in its attempts to portray high-level teaching, Fenstermacher and Richardson's research utilizes the necessary mixed-methods required to justly portray QT and was a useful guide in my study.

Understanding Quality Teaching

In this section, I will begin with definitions of quality teaching, how QT might lead to quality learning, on becoming a quality teaching teacher, how we know QT through observation and evaluation, on being a QT science teacher, and finally what QT chemistry teachers look like.

Definitions of Quality Teaching

Much has been researched and written about QT (Berliner, 1987; Corcoran, 2010; Gage, 1978; Green, 2013; Kenny-Kennicutt, 2008). Authors have attempted to define and distinguish terms such as adequate, effective, and quality teaching along a spectrum of increasingly valued teaching practice, with QT being the gold standard for educators. The most outstanding form of teaching has been termed best practices (Schön, 1983), award-winning teaching (Stone, 2015), and exemplary teaching (Massachusetts Educator's Evaluation Rubric, 2018 see Appendix B).

The field of education has historically seen a number of definitions and category systems for describing good teaching (Tate, 2013). As pedagogy became more systematically studied, educators beginning with John Dewey in the early twentieth century thought to apply scientific methods and analysis to the classroom. Effective teachers were historically defined in terms of the relative achievement of students in their classrooms as compared to building, district, or state norms. Later, in the mid-twentieth century, researchers identified a good teacher by his or her personal characteristics such as flexibility and sense of humor. The 1960s-1970s saw the advent of the "effective teacher with more of an eye toward teacher behaviors with an increasing value placed on student achievement as a measure of teacher quality" (Fenstermacher & Richardson, 2005, p. 22). Cognitive research contributed to the definition of the expert teacher in the 1980s, describing a skilled educator as one whose practice was characterized by "knowledge about students' individual progress and the use of this knowledge in instruction" (Fenstermacher & Richardson, 2005, p. 27).

Since the 1990s, researchers have focused on the transformative teacher, a reflective and experienced educator whose effects on students are examined for evidence of gains in academic and life successes (Gordon, 2001). One current version of defining the transformative power of teaching is found in the use of a value-added model, where the teacher's name is attached to individual student achievement and success (Corcoran, 2012). There is great debate currently about this evaluative system because of its reliance on quantitative measures of student outcomes over more traditional qualitative measures gathered from supervisor observations.

Without consensus about what to call this highest form of teacher, there should be no surprise that how to know when QT has been observed is also problematic. To draw from Justice Potter Stewart in his 1964 dissent to a Supreme Court pornography ruling that he may not be able to define pornography but he knows it when he sees it, QT can be thought of similarly as something that can be recognized more easily than it can be defined. To further complicate the topic, judgments about QT have different meaning in public, private, and international school settings, and in schools in urban, suburban, and rural districts. It is not clear that a quality-designated teacher in one school might also be similarly rated in another school or that quality teaching, however it is defined, translates to producing quality learners the same way in different contexts.

Even with these problems of context and effect, researchers have attempted to define QT. The definitions vary greatly, probably because how exactly we know QT when we see it remains elusive, and more so because how QT is produced is still a mystery (Lantos, 2009). Ewing (2002) provides a good general definition of QT as the production of student learning directly connected to the pedagogy a teacher brings to the teaching and learning process.

Fenstermacher and Richardson (2005) posit that in the current era quality teaching assumes that teachers are learner-sensitive and that these "teachers have an understanding and assessment of individual student constructions of meaning, asking teachers to establish an environment that allows students to develop willingness to and responsibility for learning" (p. 32). They claim that three elements must be present in quality teaching: the logical, the psychological, and the moral acts of teaching. The logical acts include such practices as "defining, demonstrating, explaining, correcting, and interpreting" (p. 16); psychological acts might include "motivating, encouraging, rewarding, punishing, planning, and evaluating" (p. 17); moral practices might include teacher demonstrations of "caring, honesty, courage, tolerance, compassion, respect, and fairness" (p. 17). According to Fenstermacher and Richardson, these three measures have both internal (the teacher's thinking and actions in the classroom) and external (how the teaching is received and responded to) criteria. They conclude that excellent teaching occurs when "each of these activities meets or exceeds the standards of adequacy that attach to each category or activity" (p. 19). Their terms, categories, and explanations have proven useful for this research to determine when I was observing QT in my participants' practices.

Quality Teaching and Quality Learning

The literature supports two theories in understanding QT. The first holds that educators attain QT by a mixture of personality, beyond-classroom experiences, and learned practices over time as an educator (Darling-Hammond, 2002; Engel, 2009; Green, 2014). The second theory maintains that we care to understand QT because it is a basis for strong student achievement (Herron, 1996; Smith, 2013; Tobin and Fraser, 2008;). I will discuss this second theory first.

Brophy (1986), the well-known author-researcher of teacher attitudes and practices, and Fenstermacher and Richardson (2005) draw connections between strong practices such as active student learning, didactic recall, personalizing the curriculum, and force of personality that all lead to increased student achievement. These findings are foundational in understanding QT and student outcomes, with the assumption that award-winning teaching leads to strong student measures of achievement. However, the idea that good teaching causes good learning is loaded with conjecture and presumption. If student achievement is the ultimate goal in the mission of education, then the correlation between strong teaching practices found in QT and high student achievement is still mostly an unproven supposition. The assumption is that QT automatically translates to quality learning, which then translates to successful student outcomes (in this era, as measured on standardized examinations). This assumption recalls the old teacher aphorism that if I taught something well then students must have learned it well. Student learning has many facets not measured by testing alone or not even well understood during contact time with a teacher.

Rockoff (2004) uses mixed-methods with standardized test scores and qualities of individual teachers and their practice (types of pedagogy, force of personality, engagement, active learning) to argue that exemplary teaching matters as an indicator for successful student achievement. Rockoff, noted for applying economic principles to trends in teaching practices, uses panel data from several charter schools in Chicago to maintain that there are connections between exemplary classroom practice and student achievement.

Many educators and researchers share a belief that understanding and promoting best teaching will directly improve schools. Engel (2009) reductively attempts to theorize that schools' ills can summarily be solved through good teaching. Her opinion piece argues that producing the best teachers comes from rigorous pre-professional preparation. Perhaps no one more eloquently and publicly makes this case than Linda Darling-Hammond (2012), who uses numerous studies of individual teachers and specific varied teacher preparation programs to argue that a more rigorous, reflective, coherent program of teacher preparation will lead to obtaining more QT in the field.

In this study, though I recognized other factors such as challenging curriculum, good professional development, keeping current with best teaching practices, and state and professional oversight as contributing to student achievement, I focused on teachers' pedagogical practice in revealing QT as an important factor in student success. What effect QT had on student achievement was explored anecdotally and was noted in a set of data relating participants in this study to the success of their students on externally administered local and national chemistry examinations. But student achievement was not the focus of this study. Instead, I portrayed QT among a select group of award-winning teachers with the same discipline, and analyzed what commonalities existed among their practices.

Being or Becoming a Quality Teacher

Theories as to how QT arises can be understood as points on a spectrum. One end is the belief that QT is inherent, like an art, appearing in the individual teacher as a set of qualities that shine in the classroom, the unknowable, undefinable "It" of QT; on the other end of the spectrum is a defined set of specific learned acts and practices, skills that might lead any teacher toward QT. Here I draw from the literature from both ends of this spectrum as well as studies that fall somewhere in between.

Vanderkam (2014) claims that QT can be found in educators who bring to their practice an amalgam of intelligence, passion, skill, and dedication. She argues that to find teachers with these inherent qualities, schools must go beyond the traditional pathways to the occupation through schools of education to look for prospective teachers in less traditional fields such as the military or the public sector workplace. Hammerness (2006) draws from numerous studies and observations made by fellow evaluators of teaching practice by portraying teachers as more than just deliverers of curriculum but as visionaries with long-term aspirations for students and for their own personal improvement. An implication of her study is that teachers who demonstrate characteristics of QT tend also to share broad goals of demonstrating human values that reach beyond the curriculum, displaying more of the psychological and moral acts as described in Saphier (2008). From the detailed portraits of four teachers, Hammerness tweezes out from the day-to-day routine individual teachers' thoughts about practice and how teachers view themselves as constantly improving professionals. Her examination of teaching practice was important to my study in demonstrating a more complex, personal passion and professional commitment to maintaining award-winning teaching than perhaps standard methods of measuring QT might have revealed.

Stone (2004, 2015) provides narratives of the pedagogy of nearly forty award-winning secondary educators with widely varying backgrounds. A conclusion from her works is teachers' personalities, life experiences, and background knowledge collectively contribute to QT. Stone's portraits vary greatly in their descriptions of these teachers' personalities, experiences, and schools. Yet, to cite Saphier (2008) again, all of Stone's teachers seem to have strong elements of comprehensiveness, repertoire, and matching in their practices. These portraits suggest that award-winning teachers arrive in their classrooms with important visions, philosophies, and ideals that drive their successes as quality practitioners.

Bringing one's entire self into becoming an educator is the theme of Palmer's (1998) *The Courage to Teach*. This passionately written reflection might be summarized by saying that the "It" in best teaching comes from within a teacher's soul, much like Saphier (2008) identified "repertoire" as those unique qualities that each teacher brings to the classroom. Palmer repeatedly emphasizes the moral and courageous acts of revealing the teacher's self in the classroom. Others have spoken of the true origin of QT as an "innate drive of ability or even voodoo" (Green, 2010, p. 2).

On the other side of the spectrum lies the argument that QT can be scientifically analyzed and taught as a set of learned skills. These include best practices and professional development models and programs such as the High Leverage Practices at the University of Michigan and the work of educator Robert Marzano, whose instructional strategies checklist inspired the *Classroom Instruction That Works* (2012, 2nd ed.) series. Danielson, who first published *Framework for Teaching* in the late 1990s, has developed a model for teaching best practices that attempts to produce quality teaching by following frameworks that analyze instruction.

Kenney-Kennicutt (2008) plumbs the visions, motivation, and aspiration of an identified award-winning high school science teacher. His classroom goals seem singly focused on constant improvement, never quite succeeding but always mindful that his students must be better served. I attempted to portray examining award-winning chemistry teachers with the same depth and revelation that drive Kenney-Kennicutt's work. Tate (2001) illustrates award-winning teachers' beliefs and visions, finding commonalities through observation and interview that extend beyond just secondary science teaching. These include a constant need to improve upon curriculum and delivery and a belief that no lesson is ever perfected. Award-winning teachers often exhibit a humility that they are no more deserving of receiving a teaching award than other teachers. This had significance for my study in drawing possible generalizations about award winning teacher's shared personal characteristics across disciplines.

Numerous authors conclude that quality teaching involves each of the mentioned elements in some measure, including (a) knowing the subject well, (b) engaging students in a *milieu* suited for high level learning, (c) being reflective, (d) staying active in the profession and collaborating with colleagues, and (e) demonstrating an eagerness to go beyond the job description and to take educational risks (Lantos, 2012; Saphier, 2008; Stone, 2004, 2015).

Learning how to become a quality teacher has become a cottage industry that turns out published tracts, guidelines, methodologies, and research-based systems that purport to instruct how to ultimately become an outstanding educator. One popular guidebook is *Teach Like A Champion* (Lemov, 2009). Lemov is controversial in his single-mindedness about obtaining and promoting certain exemplary teaching practices, while discounting others' methods and practices for his almost spiritual revival-like teacher induction field guide. The reductive how-to list of nearly 50 pedagogical techniques mostly contains teaching tips for managing time and student behavior, great for beginners but perhaps not much help for experienced teachers. According to Lemov, following these rules will assuredly produce QT. He maintains a firm belief in analyzing QT into discrete acts that can then be taught as a series of practices.

Gage (1978) and later Fosnot (1993) suggest that QT is an art that can be observed and studied scientifically yet is dependent upon a serendipitous blend of personal characteristics and experiences alongside the acquisition of specific classroom skills. Green (2014) explores several currently popular venues for teaching teachers quality practice and pedagogy including the work of Lee Shulman, Magdalene Lampert and David Cohen. Green's perspective in writing about QT is how the education profession has historically struggled to give definition to the highest form of teaching practice, let alone to prescribe a method for how to achieve QT. Even Schön (1983), who writes authoritatively about the value of reflection as bettering professional practices not only for teachers but doctors, lawyers, and businesspeople, suggests that "the art of teaching can be learnable" (p. 18).

These findings suggest that inherent personal qualities and learned practices together can lead teachers to QT, and the findings of my study point to an enhanced understanding of how these factors interact. Most likely, definitive studies of QT must rely on mixed methods analyses that address far more than student outcomes alone. Such studies demand far more time than most supervisors and evaluative processes provide.

Ladson-Billings (2012) notes that more expansive notions of quality teaching have to do with what is seen in classrooms where teachers are actually teaching, but for lack of time authentic observations are nearly impossible.

Evaluating and Researching Quality Teaching

Award-winning status is only one criterion to identify individual exemplary teachers; other methods have been used, such as value-added measurement, supervisor evaluation, and measures of student learning. Each has a measure of validity and bias. Though these methods were not part of my study, I note these here as other ways of identifying outstanding teaching to promote teaching's best practices that also appear in the literature.

Cohen (2010), a harsh critic of value-added measures for teachers, argues that there are too many biases involved in judging teacher performance, and such measures as standardized exams cannot adequately judge best teaching practices. In this opinion-based article, the author uses his critical assessment of value-added measures to address policy makers considering using this form of teacher evaluation. The value of this criticism to my study was to highlight the continued tension around identifying and measuring QT. Despite this tension, few would disagree that striving for quality teaching is essential in promoting student achievement and bettering our schools. Collins (2005), who writes primarily about bettering business practices, addresses improving teaching and achieving quality in the classroom. He maintains that, as in the business world, constant reflection, reevaluation, and never-ending modifications can move teaching from adequate or effective to quality.

Soar, Medley, and Coker (1983) provide a critical review of teacher evaluation. They look at several models, including the once-every-two-years spot visit by a supervisor, the Saphier methods of analytical observation, peer evaluation, and portfolio. Until recently, the supervisory visit was the method of observing and evaluating teachers most commonly adopted in secondary schools. The authors conclude that too little time in the school schedule is a culprit in short-changing honest, reflective, open evaluation procedures for teachers. This helped me realize that there has been sufficient varied observation to reveal the essence of QT from a small sampling of award-winning secondary chemistry educators.

Standards for effective teaching practice are identified in numerous studies including Amback (1996), who argues for a common set of standards. These include guidelines, criteria, benchmarks, and goals by which teachers can be evaluated as professional educators. Though mention is not made in the article of quality teaching, the author's intent is to promote a common set of criteria for practice and evaluation much in the same way doctors or attorneys adopt common professional language and practices in their trades, and in doing so maintain a professional status that teachers might hope to achieve one day. Darling-Hammond (2000) uses mixed-methods research over one year to assess over fifty Bay Area public high school teachers' practices as classroom educators. The staggering amount of time involved in interviewing, observing, conferencing, and reflecting with these teachers over the year is what the author calls authentic and admits that the time involved is hardly afforded by typical observations by evaluators. Her assessment speaks to the lack of genuine evaluation time and depth most teachers are afforded in their daily practice. Jacob and Lefgren (2008) note the value (or lack of value) that typical teacher evaluations are given. That this article appeared in a labor economics journal speaks to the interest workplaces have in authentic and subjective supervisor evaluation. The authors argue that most of the time supervisors' subjective criteria and evaluation are sound and justifiable, with some error an inevitable factor in the human enterprise of judging others' performance. The use of multiple forms of observation in my study address these authors' conclusions.

Olsen (1992) provides rich, contextual classroom observation and thoughtfulness about the lives and practices of several outstanding teachers (identified by evaluators and awards as exemplary in their practices). Through teacher profiles, Olsen highlights the characteristics of "It," the elusive, undefined spark that award-winning teachers all seem to possess is portrayed in the author's teacher profiles. In my portraits, I try to reveal and probe this spark, assumed present in already-named award-winning teachers. Definitions that attempt to define "It" range greatly. Gage (1978) attempts to delineate the process of teaching, from curriculum development and delivery to student learning and assessment. The art here is described as an idiosyncratic set of connected skills that teachers interpret and execute with great individuality. The author details commonalities across widely varying methodologies and pedagogies, including caring, high degree of preparation, force of personality, and genuine interest in moving minds. Attempts to foster QT in the workplace abound.

Finally, some researchers suggest that a search for standardized methods of defining and observing quality teaching may be for naught. Berliner (2005), a noted critic of many statewide and national reforms such as No Child Left Behind (NCLB), rejects current evaluation methods such as value-added systems, student achievement, and testing for teacher knowledge because they do not directly address the "art" of teaching practice. To paraphrase David Tyack (1974), perhaps there is no one best way to understand or portray quality teaching. A major challenge for my study was to understand and acknowledge these criticisms of teacher evaluation, varying definitions of QT, and the flaws inherent in seeking simple definitions for the immensely complex, contextual practices of quality teaching and then to attempt to describe QT anyway.

Excellence in the Teaching of Science

Teaching secondary science presents educators with a special set of challenges, practices, and rewards. I know this as a veteran of the high school chemistry classroom for more than 30 years. Hutner and Sampson (2015) argue that good secondary science teaching should include five pedagogical elements: (a) creating a need to learn, (b) making student thinking visible, (c) engaging in activities before delving into content, (d) practicing science, and (e) negotiating meaning. These teaching notions are supported by earlier science education best practices, notably in Mortimer and Scott (2003) and Tobin and Fraser (1990). Creating the need to learn in science classrooms often begins with the use of a discrepant event or demonstration of a phenomenon that creates a sense of wonder or curiosity. These teaching events, often referred to by science teachers as "eye candy," excite students and can serve as segues in a lesson or as the climactic end to class lesson. Making student thinking visible through writing, call and response, and answers in inquiry-based activities, presumes that teachers have some understanding of the scientific notions with which students enter class. Where correct notions and answers are the goal, science teaching makes important use of making predictions, trying and correcting weak and incorrect ideas, and error analysis to promote the understanding of scientific concepts. For this reason, an error analysis or discussion section is an important part to any laboratory report. Almost all secondary science courses include a hands-on, or at the least a simulation, component, typically a laboratory period where students engage in activities that model or demonstrate a scientific event. Use of these activities is best done before fully understanding the concepts according to Hutner and Sampson (2015), who refer to this as the activity before content (ABC) approach. The effect here is to heighten curiosity and increase motivation so that students can more fully understand the activity. To be sure, teaching some chemical concepts lend themselves to an activity after content presentation as a means of validating the content, but these authors think that this approach creates passive student learning and low expectations for known outcomes. Activities with open-ended procedures and opportunities for students to design activities more resembles practicing real science in that scientists must first create the experiments from which they will then acquire data and draw conclusions. Finally, negotiating meaning refers to a continuum. At one end is the teacher, who makes meaning from the chosen curriculums; on the other end are the students who are responsible for constructing understanding and learning the curriculum. Traditional science classroom learning where teachers lecture and students take notes and perform cookbook-style activities with anticipated outcomes are now considered past practice (Spencer, 1999).

Negotiating meaning falls more on the students who, through guided inquiry and skilled teacher support, take more responsibility for their science learning. *The Journal of Research in Science Teaching* promotes this vision of science learning and is comprehensive in its breadth of literature on the subject of best practices in science teaching and was important to me in framing QT in the secondary science classroom. I saw many of these best practices in my participants' classrooms.

Recognizing Quality Chemistry Teachers

Specific to secondary chemical education, Mason (2010) highlights coming trends and anticipated changes to practice in secondary chemical education. Mason, a well-known award-winning high school chemistry educator and author on best practices in the high school chemistry classroom, outlines what high school chemistry teaching should look like in the new century. This includes expanded use of technology both in the classroom and laboratory, more references to the evolution of the field of chemistry and its history, modern applications of chemistry in our post-industrial society, the added use of inquiry and hands-on methodology to allow students to practice science more realistically, and regular reflection on concepts just learned. These characteristics are encouraged in best-practice high school chemistry teaching and were found amongst my study's participants. *Chemists Guide to Effective Teaching* (Pienta, Cooper, & Greenbowe, 2005) expands these practices in a detailed summary of what best teaching practices should include in current secondary chemistry education. This description includes both pedagogical and curricular elements such as guided inquiry, teaching to achieve conceptual change, cooperative learning, use of visualization in modeling chemical concepts, peer-led team learning, and model-observe-reflect-explain (MORE) thinking frames instruction.

The American Chemical Society (ACS), as a professional organization, devises awards presented annually for local, regional, and nationally recognized quality teaching (Appendix D). In addition, The American Chemical Society provides Guidelines and Recommendations for Effective Chemistry Teaching (2018). The Task Force on Secondary Chemistry Education, of which I was a member, comprised of a dozen award-winning veteran high school chemistry teachers from across the United States, was charged with identifying and codifying high school chemistry teaching best practices. The Task Force's first document that has since been updated in 2018 and disseminated amongst the 185 American Chemical Society sections across the United States. It is the professional organization's definitive document detailing what best practices secondary chemistry teaching should look like.

This manual serves to promote high standards for the teaching of middle school and secondary chemistry. It is divided into three main sections: Pathways to Learning, Physical Plant, and Professional Preparations and Responsibilities. Of interest to my study, the Pathways section includes a subsection, Effective Strategies for Teaching Chemistry. These strategies include focusing on and repeatedly spiraling the big ideas in chemistry, including such topics as the conservation of matter and energy, building on previously learned concepts, using inquiry and open-ended laboratory procedures to allow students opportunities for experimental design, promoting active student participation in both responding to and asking questions, developing critical thinking throughout the curriculum, guiding students to become good problem interpreters and solvers, allowing for reflection on just-learned concepts, and connecting learned concepts in the classroom to real-world phenomena and issues (American Chemical Society, 2018, pp. 2, 5–7). I found these strategies in my classroom observations.

In Massachusetts, the Department of Elementary and Secondary Education created the Guide to Rubrics and Model Rubrics for Teachers in in 2012 and updated it in 2018, by coincidence the same updated year as the ACS's Guidelines. The levels of competency published by the state standards (see Appendix C) are unsatisfactory, needs improvement, proficient ('effective' in other measures), and exemplary. It is this last level of practice that I used as a guideline to view award-winning teaching.

I cohered these two critical documents in my study, the ACS's Guidelines and the Massachusetts Department of Elementary and Secondary Education Evaluation Rubric for Teachers, drawing from both documents' descriptions of exemplary/best teacher practices detailed in each. Descriptors of these practices include "spiraling curriculum, providing wait time, use of inquiry, asking probing questions, high degree of student engagement, cooperative learning, and use of visual demonstrations" (American Chemical Society, 2012, p. 5) and creating "well-structure and highly engaging lessons, appropriate student engagement strategies, pacing and grouping to attend to individual student's needs" (Massachusetts Department of Elementary and Secondary Education, 2018, p. 3). By using indicators from these two different documents based on professional norms, I validated the award-winning practices I observed among the participants in my study. It should be noted that the rubric also includes standards for working with colleagues, administrators, and parents as part of the evaluation system. Though these are important in an overall teacher evaluation, I did not pay much attention to these important interactions in my observations, instead focusing on classroom teaching.

Award-Winning Secondary Chemistry Teaching

What teaching might have looked like in most secondary chemistry classrooms until the mid-1990s was mostly lecture with supplementary cookbook-style hands-on laboratory activities. Since then, the advent of teaching science within a social context, the green chemistry movement, the development and use of micro-scale laboratory techniques, innovative experimental design, research that shows that students learn best when they own their science experience (Gallagher-Bolos, 2004), the active classroom learning (ACL) approach, and the flipped classroom are examples found in guides to best secondary chemistry teaching (Herron, 1996). I looked for all of these elements of best practices. Examining recommendations offered to the awards committees (on which I have served in the Northeastern Section American Chemical Society for many years beginning in the 1990s), it was evident to me that award-winning chemistry teachers are guided by some of these student-centered educational philosophies in their practices, as well as by other strategies such as presenting clear objectives, demonstrating love of subject, insisting on rigor, modeling, using appropriate analogies to make the concepts relevant, and making the subject engaging with the use of chemical demonstrations (Pienta, Cooper, & Greenbowe, 2005). Taylor (2009), from the American Chemical Society K-12 Education Office, details the awards available to secondary chemistry educators at the local, regional, and national level and the criteria used to evaluate and offer these awards. These include strong content knowledge, experience in the secondary high school classroom, strong recommendations from supervisors and colleagues, and imparting a love of the subject to students, among other characteristics.

Teaching chemistry provides a special opportunity to allow students to own their learning through the use of the laboratory practical. A true exercise in scientific inquiry, a laboratory problem is presented to individual students or groups of students working together, and students must create a laboratory procedure from their understanding of the problem, complete the experiment, and draw their conclusions. Experienced, creative chemistry teachers over time can tweak these open-ended laboratory problems to maximize the chemistry content and understanding conveyed. In addition, students' grappling with devising procedures, manipulating equipment, and coming to conclusions on their own is more like practicing real science (Gallagher-Bolos, 2004).

Disciplinary groups in public secondary education maintain teaching standards, or frameworks, that delineate expectations for curriculum and instruction. In the field of secondary chemistry education, the American Chemical Society has set the standards in this discipline. The American Chemical Society Guidelines for and Recommendations for the Teaching of High School Chemistry (2012, updated 2018) are the basis of the American Chemical Society's current re-examination of its expectations of secondary chemistry educators. These guidelines served as a checklist for participants in my study (see Appendix A).

Perhaps the one best source for detailing best practices in chemistry teaching is

The Chemistry Classroom: Formulas for Successful Teaching (Herron, 1996), published by the American Chemical Society. It most resembles Saphier in its comprehensive breakdown and analysis of teaching chemistry; if a follow-up edition were to be published might be renamed "The Skillful Chemistry Teacher." Herron provides much of the why and how we best teach certain ideas, concepts, skills, and even values in the high school chemistry classroom. Examples of these best practices are several different methods for teaching the concept of the mole, how and why a teacher might choose to illustrate an example of the solution process instead of just describing it, and how best to inculcate the importance of recognizing patterns and finding meaning in ordering these patterns while teaching periodicity. Herron's examples were useful in giving meaning to the nuances in the observations of the teachers made in my study.

The Journal of Chemical Education is the American Chemical Society Educational Division's monthly professional publication. It is invaluable for keeping up with current educational research regarding the delivery of chemical knowledge at the secondary and higher education. Dating back to Spencer (1999), a number of then-current curriculum features and pedagogical practices began to be seen in secondary high school chemistry classroom and laboratories. Spencer's article is seminal in that it points to the new directions best practices secondary chemistry instruction must take to address current trends in chemistry and science education. Specifically, these practices include the use of inquiry and open-ended problem solving and laboratory work; process oriented guided inquiry learning (POGIL) adopted from innovative college level chemistry classrooms for use in high schools; a move to using microscale, using smaller amounts of chemicals in experiments in the secondary chemistry classroom where students need to learn to be mindful of the production of chemical waste in the environment; the flipped classroom which places less emphasis on teacher lecture and more on student-to-student learning; and achieving chemical knowledge literacy by teaching the subject more in context of society and the environment. It is no surprise that from these then-new directions in secondary chemistry teaching, the American Chemical Society piloted a new innovative secondary curriculum *Chemistry in the Community* (ACS Publications) in the 1990s and the *Living by Chemistry* (W.H. Freeman) in the 2000s, courses I have taught.

Through my observations in the classrooms of award-winning chemistry teachers, I expected to confirm much of the information found in the letters of recommendation written by students, colleagues, and supervisors. My access to these letters came from my service on ACS secondary chemistry teaching award committees over many years. Anecdotal phrases that support QT from these letters include “goes beyond,” “in school after hours,” “tireless,” “teaches to every student,” “maintains the highest standards,” “loves the subject,” “encourages learning,” and “collaborates with colleagues” (NESACS Award Nomination Letters, 2006–2020). These quotes, among other exemplary phrases, related to exemplary teaching, were used to form some of the codes of the observations and interviews described in Chapter Three.

CHAPTER THREE

RESEARCH METHODS

Choice of Methods

Classroom observations and interviews were used in this research as case studies to portray teachers in the context of their award-winning practices. Merseth (1996) writes that case studies as narratives serve as a descriptive research document based on real-life observations that attempt to portray a multidimensional representation of the context, participants, and reality of the situation. Case studies and portraits tell stories that can be used as analysis and interpretation by users with different perspectives. Case studies as portraits, rich narratives that offer a window into a teacher's classroom, were my anticipated outcome so as to glean what Geertz (1973) refers to as "thick description," to reveal what might not be readily seen or understood in casual observation.

I collected qualitative data to provide a narrative of the award-winning teaching (AWT) practices I observed. I did not ignore curriculum, but instead focused on method, practice, and pedagogy. I was well familiar with the chemistry curriculum so not concentrating on curriculum did not impede in any way what I observed. Though I know and recognize QT through my own experience as an award-winning teacher, my role was to be the camera or lens to teaching already identified as quality teaching; I was not further evaluating the teachers I observed as they had already been named as AWTs. Instead, my narratives served to provide a rich context with multi-dimensional data sources. These included interviews with each teacher prior to classroom observations. Electronic surveys were used to elicit background and biographical information from each participant. Digital recordings of the participants' interviews were made to capture their beliefs and aspirations as teachers, and recordings of their classroom teaching allowed me to capture teacher-student and student-student interactions. Student artifacts were selected by each participant with an explanation of the assignment, why they chose to submit these artifacts, and how these selected artifacts were representative of that teacher's beliefs as an AWT.

The purpose of this study was not to correlate award-winning teachers' practices with their students' achievement, but to portray their QT and seek possible commonalities between their practices. I solicited anecdotal evidence of these teachers' QT from colleagues and students as well as from language used in in the nominations and announcements honoring these awardees.

Pilot Studies

I conducted four pilot studies. The first pilot was a face-to-face interview with an award-winning high school chemistry teacher unaffiliated with this study. She was selected from a nearby public school. Her interview was audio recorded and transcribed. Using the draft of the participant interview protocol, this pilot study was useful in fine-tuning the wording of the questions in the protocol to elicit more targeted responses.

The second pilot study was to validate the selected codes from the participant interviews. A teacher at my school unaffiliated with this study was asked to view two of the six participant interview recordings and code them. The results were similar to my own coding (Table 3), suggesting I had devised a credible system for coding the participant interviews.

The third pilot study was a focus group interview. This involved five participants unaffiliated with this study. They were chosen from the Brookline High School Science Department where I teach. All five were veteran chemistry teachers. Two have won the *Aula Laudis* award described in Appendix D. All have been effective teachers with strong reputations. Having never run a focus group with a recording device for later coding, I found this pilot useful in judging the open-endedness of the questions I used for this study and the degree of comfort the participants felt in responding to these questions. The relatively general questions seemed to leave room for a degree of differences of opinion. These results led me to the finalized focus group protocol (Appendix M). Patton (2002) recommends piloting interviews and focus group discussions for just these types of protocol adjustments.

The final pilot study was to test the electronic student survey (Appendix K). I created the survey using Zoom's polling function and asked a group of my students not in any way affiliated with this study to take the survey. Student feedback allowed me to gauge the time to complete the survey electronically and to adjust several of the questions for clarity.

Selection of Participants

Participants were selected based on their teaching in the Boston area for over ten years, considered veteran status, and having received at least two teaching awards sponsored by the American Chemical Society (ACS), the recognized professional organization representing academic and applied chemists in the U.S. So called "Teacher of the Year" awards were not included here as they might too often serve as recognition of popularity or longevity.

Access to the lists of ACS-related awards was obtained through the Northeastern Section of the American Chemical Society (NESACS) website, www.nesacs.org. Once I identified awardees within the past ten years who had won two or more ACS-sponsored awards, I was able to narrow my possible teacher pool and recruit my participants (for recruitment letter and follow-up email, see Appendix G). Notification to supervisor/principal of my intent to have one of their teachers participate in this study with a brief overview of the study and the importance of anonymizing both the teacher and the school was emailed to each school (see Appendix H). Where I was able to hold an email or face-to-face meeting with a participant's colleague or administrator, an informed consent form was used (see Appendix I).

At the secondary school chemistry teaching level, the ACS awards include the *Aula Laudis* Award, the Theodore Richards Award, the Henry Hill Award, the Northeastern Regional Meeting (NERM) Award, and the awarded position of USNCO Mentor. Electronic announcements of the ACS awards were sent to all science department heads of public, private, and parochial high schools in the Northeastern Section ACS. Department chairs were the only nominators. Past awardees served on the selection committee. The specific criteria for each award are detailed in Appendix D. Each award is a local section or regional award presented by either the Northeastern Section of the American Chemical Society (NESACS) or NERM.

Though participants may have known one another through Boston-area professional development or other professional associations, none of the participants knew about others' participation in this study until the final focus group interview when all joined together in a pre-arranged online group chat.

Sample

This study consisted of a series of observations and interviews using six ($N=6$) teachers from greater Boston-area high schools. Each teacher was selected based on his or her receipt in the past ten years of at least two ACS-sponsored awards at the local, state, regional, or national level in the area of secondary high school chemistry instruction. Certainly, there are more teachers further years back who might be considered for this study, but the thought to reaching back to this time limit is that the awards are relatively recent and thus still remind and inform these teachers of their recognized best practices. Using the NESACS lists of past awardees, this narrowed group led to six teachers who fit these criteria. All of the teachers in this study had veteran status as defined as beyond ten years of experience. The selected teachers' schools in this study included mostly suburban public schools in the greater Boston area. The socioeconomic and demographic status of these communities and the school culture and community is detailed as a context for visualizing these teachers' practices and the support they have received from their colleagues, schools, and from their communities. The lack of diversity in the student populations in these schools is discussed in Chapter Five.

In preparing for conducting this study, I took the CITI course on research with human subjects and passed in December, 2014. Valid for five years, I re-took and passed the course in August, 2019. I submitted the recruitment letter, student assent form, sample themes, interview protocols, and the exempted application for approval to the Boston University IRB in July, 2017, and these forms were approved in August, 2018. Consent was obtained from each of the teachers to be used in this study by contacting them initially by email to inform them of my hope to have them participate in this study (Appendix I). I presented teachers with my criteria used to identify them each as participants. To protect the confidentiality of the teacher participants, their actual names have not been used and aliases have instead been used (Appendix E). No students were directly identified in this study. Permission from the schools/school districts to conduct this study involving interviews and in-class observations and digital audio (not video) recordings was requested by email from the building principals and/or superintendents. An example of this permission approval form is found in the Appendix O (with the school's name redacted). With the IRB approval, I provided each district with my study's objectives, procedures and methods for data collection, risks/benefits, and participant consent forms. In addition to the permission request, I provided each district with a two-page summary of my proposed research study (see Appendix F).

Data Collection

The methods for data collection included surveys conducted through electronic mail, face-to-face or online interviews with the teachers, classroom observation and recording, collection of teacher-selected student work, student surveys (without student names), and a focus group interview.

Teacher Surveys

Surveys were distributed electronically to each subject prior to face-to-face interviews and observations (see Appendix J). The survey questions involved biographical and background information so I could get to know the subjects and bypass soliciting this type of factual information in the face-to-face interviews (Corbin, 2008). The survey questions were returned electronically.

Included on the teacher surveys were questions that were inspired by STEBI Science Teacher Beliefs. These questions were modified to address my study, substituting "chemistry" for "science" and "quality teaching" for "good." The questions asked were, "I am continually finding better ways to teach chemistry," "The inadequacy of a student's understanding can be overcome by good teaching," "The teacher is generally responsible for the achievement of students in chemistry learning," "I know what to do to increase students' interest in learning chemistry," and "Award-winning teaching translates to high student achievement." The answers to these questions were in a Likert-like scale of SA = strongly agree, A = agree, N = neither, D = disagree, and SD = strongly disagree.

Student Surveys

Student surveys used a Likert scale to rate the following characteristics of teaching qualities as a) explain things well, b) enthusiasm, c) challenges students academically, d) humor (see Appendix K). Similar student data collection used in Thompson, Warren, Foy (2008) allowed these researchers to see differences in what teachers versus what students thought about specific qualities among outstanding teachers. Although that study addressed a student population of African-American students and their perspectives on QT, the construction of the study and the voices students gave to their perceptions of QT were useful to my study. As in that study, I informed the students that at no time would their teacher see the completed surveys so as to not bias the students' ratings.

My original intent was to distribute hardcopy student surveys following notification to each teacher that a brief eight-question student survey was to be taken during one of my classroom visits. However, given lack of live access to teacher classrooms once COVID moved classes to remote learning, this procedure was impossible to implement. Instead, I used the same survey to sample students live at Brookline High School using students from colleagues' classes through the use of Zoom polling function. All students remained anonymous electronically. The same eight questions from Appendix K were set up on Zoom using the same Likert-style scale. Data were taken and tabulated in Chapter Four.

Teacher Interviews

Asking online or face-to-face questions and recording answers is at the heart of probing, developing provisional answers to research questions, and becoming acquainted with the data (Corbin, 2008). The participant interviews in this study followed an interview protocol (See Appendix N). The seven questions in this protocol were somewhat more open-ended than the background survey questions. These questions were created by examining other protocols used to elicit information about teachers while reflecting on their practices (Kenney-Kennicutt, 2008; Schön, 1990). The nature of these questions were somewhat semi-structured in order to leave room for talk (Patton, 2002). The hope here was to allow the participants to expound on an answer and provide personal and in-depth reflections to these questions. Each interview lasted roughly forty-five minutes. As suggested by Seidman (2006), each teacher was provided with a copy of the interview protocol in advance of the online or face-to-face interview so as to allow for thought-out and thoughtful responses during the online interview (Appendix N). A follow-up interview was conducted through email within 24 hours of a classroom observation for the teacher to assess the lesson observed (Appendix L).

Observations and Classroom Recordings

Using both the Saphier method of classroom teacher observation (Saphier, 2008) and the current Massachusetts Educator's Evaluation Rubric (2018) criteria as benchmarks for objective observations, 15–20 minute observations from the start of class were made while digitally recording these classroom moments. A 10–12 minute classroom observation has been used as part of the current state evaluation system, but I chose mostly whole class period observations to see the entirety of a lesson. Saphier's observational methods protocols have been well known to teachers and supervisors for years and are detailed in *The Skillful Teacher* (Saphier, 2008). Saphier focuses his observational protocol on the observer acting as a camera lens, recording by hand exactly what is heard and seen by the observer, while writing interpretative possible explanations for these observations in the margins.

I made at least three class period observations over a semester to deepen my understanding of each participant's practice. I invited my participants to provide me with a week's notice when they would be teaching a lesson or laboratory activity that was likely to show some of their award-winning practices. This served a dual purpose in that I was likely able to observe a participant-selected set of best practices, and it also was metacognitively an insight into what the participant thought were are best practices. I was also able to observed student-centered work found in the laboratory in the context of the teacher's practice. A third encounter either by telephone or by email was with the teacher to have him/her reflect on the lessons observed. These communications were transcribed and coded (Appendix C).

Describing the classroom *milieu* is important in any teacher observation. In particular, observing chemistry classroom teaching has inherent features unique to this discipline as described in the literature review (Hutner & Sampson, 2015). Beyond the classroom, describing the context of a teacher's practice within the school culture and larger community is important. Descriptions of both school culture and community can add to the narrative of each teacher's best practices. Producing the descriptions in this study came from school data provided to me by the school department and by my presence in the classroom and about the school building during my visits to each school.

Since students were not direct participants in this study, they were not recorded for purposes of data collection; the digital recording focused only on the teacher subjects in this study. In video recording, audio portions of teacher-student interactions were recorded, along with hand-recorded notes of these interactions for the purpose of transcribing these classroom moments for data analysis. Patton (2002) emphasizes the dual use of note-taking alongside recording to allow the note-taker to provide context for what is being recorded and to note important quotations heard.

Student Work and Instructional Artifacts

Pieces of student work were used as another data source for this study. Without speaking with students directly, collecting student work provided tangible evidence of best teaching practices through the products of student's efforts in these teachers' classrooms. Beyond evidence of student success on ACS-sponsored chemistry exams, this study did not attempt to use student achievement in portraying QT; I again acknowledged the inability here to directly link QT with high student achievement. That was not the purpose of this research. Here, teachers self-selecting examples of their students' work revealed what the teachers thought represented their best practices.

Two or three teacher-selected instructional artifacts were collected from each participant, one of which has been described in this document as representative of the participant's beliefs as an educator. The artifacts used were a teacher-developed unit assessment, a self-written laboratory experiment, responses to a WebAssign problem set, a grade level meeting agenda, a family portrait project that connected family members with a chemical substance or formula, and a parent/teacher communication. These were the types of artifacts suggested for submission by the Massachusetts Teacher Evaluation Rubric in order to document effective teaching practices. The collection of these items added more depth to the overall data collection for each subject.

Student, Colleague, and Supervisor Anecdotes

I was in an advantageous role in portraying my participants in that I had access to award nominating letters and letters of support from former students, colleagues, and supervisors from my service over many years on the Northeastern Section American Chemical Society's High School Awards Committee. These letters detailed how each of these teachers expressed QT through such factors as their presence in the classroom, interactions with the class and with individual students, collaborative efforts with colleagues, curriculum develop both individually and with department colleagues, participation in and often creation of extra-curricular chemistry and science opportunities.

Student Qualification for ACS Chemistry Exams

Two annual chemistry examinations, the Northeastern Section's Avery Ashdown Examination Contest and the United States National Chemistry Olympiad (USNCO), serve as benchmarks for top students in chemistry from Boston-area schools. Again, I served in a useful position in collecting data from these annual exams in my role as NESACS Coordinator for the USNCO, allowing me access to top prize winners and honorable mention students for the Ashdown Exam and to qualifiers for the USNCO. I portrayed top students for both exams paired with their teachers from this study over the past decade, with the hope that QT could be exemplified by student success on externally administered examinations.

Focus Group Interviews

The use of a focus group interview for the six participants in this study was to enhance and deepen responses (Patton, 2002). Another important aspect of the focus group interview was to see to what extent there are consistently shared or divergent views about award-winning teaching. Whereas my participants may have been able to inform me about one another's practices without being together, bringing them together provided the opportunity to confirm their common beliefs and practices. I used an electronic scheduling application, doodle.com, to find a common meeting date and time. My original intent to conduct the focus group was to secure a meeting room at Brookline High School, relatively central to all six schools visited. However, following the pandemic, the focus group was held on a Zoom chat. The members of the focus group responded to the six interview protocol questions while I moderated the discussion (see Appendix M). The questions for this focus group protocol were not shared with the participants prior to meeting. To honor the time commitment beyond each teacher's workday to arrange this focus group, each teacher received a Starbucks gift card in the amount of $15.

Upon completion of the data collection for teachers, I thought I should hear more from students beyond the Student Survey and devised a student focus group interview. Because of the impracticality of conducting this with participants' students during COVID-19, I created a set of student focus group questions by adapting the teacher focus group questions to students (see Appendix P). With access to students at Brookline High School, I held a student focus group interview on January 18, 2021, with five students on a Zoom chat. This focus group interview lasted for approximately 40 minutes. I recorded the audio portion of this chat, then transcribed the audio and coded the transcript of this meeting.

Review of ACS Participation and School Demographics

After I had collected and analyzed the data, I noticed that all of the participants taught at predominantly White, well-to-do school districts. To better understand why my selection criteria resulted in a skewed sample, I interviewed the teacher participants about their, and their colleagues', connections to the ACS. I also examined the records for the past 10 winners of the Richards Award to see if there were patterns for ACS involvement and for teaching in a socioeconomically advantaged suburban school. The results are presented and discussed in Chapter Five.

Confidentiality and Security

All identifying information was removed from interviews and replaced with pseudonyms. No identifying information was included in any correspondences or publications. Audio and transcription data were stored on a Google drive as they were transcribed and anonymized. Files will be destroyed (deleted) seven years after the completion of this dissertation. Electronically transcribed interviews were completely anonymized, coded, and stored on my computer, with backups stored on a Google drive. The only others with access to these data are the two members of my Committee who are current Boston University faculty, Professors Peter Garik, and Robert Weintraub. I only collected names and places of employment, not identifiable information such as social security numbers or telephone numbers. All proper nouns (names and locations) were changed to pseudonyms. All such changes (in the form of a key) were tracked on a separate document to be stored on a password protected Cloud drive for seven years. No one else will have access to these security codes.

Data Analysis

In analyzing data sources, I used as a standard for teacher practice the current Massachusetts Educator's Evaluation Rubric and its rubrics for determining teacher effectiveness. Specifically, the four standards in this rubric include: Curriculum, Planning, and Assessment; Teaching All Students; Family and Community Engagement; and Professional Culture. Each of these standards has indicators (criteria) by which a teacher might be evaluated using ratings of unsatisfactory, needs improvement, proficient, and exemplary. Though my data were not being used to evaluate teachers, the indicators and their criteria in each of the standards were used as part of the narrative in describing best practices. I cohered the Massachusetts Educator's Evaluation Rubric's exemplary indicators as described in the rubric with the QT I observed in my study (Appendix B). In devising codes from the recorded classroom observations, I used phrases from the rubric's descriptions (see Table 1 below).

This evaluation system has used two classroom visits over a two-year period for professional status teachers as a baseline for making a formative evaluation of a teacher's effectiveness. My experience using this relatively new system to have my own teaching evaluated has led me to the opinion that it makes a greater attempt at visualizing teachers' practices than the once biannual visit that many Massachusetts districts relied on previous to 2014. As a summer school director hiring new teachers every year, a mentor for teachers-to-be for the Harvard Graduate School of Education in the 1990s, and a member of numerous chemistry teaching awards committees, I believe that more time viewing teachers in action can only deepen our understanding of QT and best practices.

I cohered and triangulated my findings both with the Massachusetts Educator's Evaluation Rubric and the ACS Guidelines for Teaching Middle-and-High School Chemistry. Both measures detail what teachers' "best practices" look like in general, and with the ACS Guidelines, chemistry teaching in particular.

The recorded interviews and the audiovisual classroom observations were transcribed and coded for common themes. Codes were determined based on the exemplary indicator criteria used in the Massachusetts Educator's Evaluation Rubric (2018) as well as from the American Chemical Society Guidelines (2018) document. Transcripts from the participant interviews, post-observation interviews, and the focus group interviews were coded based on common terms, phrases, and meanings. These included *relationship*, *trust*, *caring, resources, collaboration, strong voice/clear instruction, confidence, motivate, teachers as learners, passion(ate)/love*. With the exception of *passion/love* and *caring*, each of these phrases (or similar terms) are suggested in the "exemplary" standard of Massachusetts Educator's Evaluation Rubric and ACS Guidelines documents. *Passion/Love* and *caring* came through repeatedly in every one of the responses to the participant interview questions and from the teacher and student focus group interviews. These codes were selected based on common themes that emerged from the interviews and confirmed as valuable qualities found in various QT studies (Fenstermacher & Richardson, 2005; Green, 2013; Rockoff, 2004; Yeigh, 2008). All of these phrases were found in the Fenstermacher and Richardson (2005) study analyzing QT, which provided the internal qualities and external measures of exemplary teaching practices that greatly informed this study.

Ten major codes were drawn from the cohered language in the MA Educator's Evaluation Rubric, the ACS Guidelines, and the participant interviews. Themes emerged from coding the recorded interviews, classroom observations, post-observation interviews, and the focus group interviews.

Table 1.

Coding: Phrases and Meanings, Origins (Appendix C)

Codes	**Definition**	**MA Educator's Evaluation Rubric, Teacher Interviews, Classroom Observations**	**Teaching Middle-and-High School Chemistry**
1. **Relationship(s)**	The bond or rapport that a teacher establishes with students and colleagues	Teacher Interviews, Classroom Observations	
2. **Caring**	A thoughtfulness and compassion demonstrated by the teacher toward his/her students	MA Model Standard II-D1: "Establishes an environment in which students respect and affirm their own and others' differences and are supported to share….Models this practice for others." Teacher Interviews, Classroom Observations, Focus Group	
3. **Trust**	Having faith in, counting on.	MA Model Standard II-B1: "Uses rituals, routines, and proactive responses that create and maintain a safe physical and intellectual environment where students take academic risks and play an active role in preventing behaviors that interfere with learning." Teacher Interviews, Classroom Observations, Focus Group	
4. **Resources**	Access to supplies, and also financial, community and professional support	MA Model Standard IV-B: Consistently seek out and applies ideas for improving practice from supervisors, colleagues, professional development activities, and other resources.	p. 29: Professional and Educational Resources
5. **Collaboration**	A group effort, sharing (among students and teachers)	MA Model Standard IV-C1: "Effectively leads peer collaboration in areas such as implementing standards-based unites and well-structured lessons, examining student work and	p. 10: Cooperative learning strategies can be employed to help students solve meaningful real-life problems

		performance, and planning appropriate intervention." Teacher Interviews	
6. **Strong Voice/ Clear Instruction**	An articulate definitive power of speech and delivery of expectation	MA Model Standard II-D2: Clearly communicates and consistently enforces specific standards for student work, effort, and behavior. Teacher interviews, Focus group interviews	
7. **Confidence**	Self-assurance and conviction	Teacher interviews, Focus group interviews	
8. **Motivate/ Motivation**	Encouragement and inspiration	MA Model, Standard II-A2: "Consistently uses instructional practices that motivate and engage all students….Models this practice for others" Teacher Interviews, Focus Group	p. 9: Teachers should model their own thinking to move students to see how others think through a problem
9. Tea**chers as Learners**	Educators reflect on practice, also taking classes, attending workshops and conferences	MA Model, Standard IV-A1: "Regularly reflects on effectiveness of lessons . . . and interactions with students individually and with colleagues."	p. 30: Successful chemistry teachers will adopt the stance of lifelong learners and be willing to collaborate and share their expertise with colleagues.
10. **Passion(ate)/ Love**	A great enthusiasm	Teacher Interviews, Classroom Observations, Focus Group	

Validity, Reliability, and Limitations

I approached this study as a veteran high school chemistry teacher of 35 years, an award-winning educator at the local, regional, and perhaps national level, a teaching award committee member, a summer school principal, and a longtime teacher mentor. My interest in identifying and understanding QT practices in secondary chemistry teaching has come in part from serving on numerous committees to present awards to colleagues in the profession over many years. Indeed, my own award-winning practice and pedagogy may have looked very different from another award-winning chemistry teacher's practice, yet both of us were recognized through the outstanding teaching awards we have received. As externally developed and utilized criteria for observing best practices, teaching awards from a well-established professional organization assisted in overcoming biases throughout this study. To make sure my experience was an asset and not a hindrance, I maintained a bias journal as a method for identifying and correcting my biases as they occurred throughout this study.

Given the qualitative nature of this study, the obvious threats to validity in this study came from the reliability of observations and experimental biases in coding in interviews and definitions used to identify codes and themes (Patton, 2002). Inherent in any qualitative research study, the subjectivity of the researcher's observations and coding merit additional outside analysis of the data. For this reason, videotaping was used for portions of each interview and classroom observations in order to cohere the written observations with the video recordings. The process of coding had inherent biases. An understanding between the researcher and a second coder was established with key words and terms used from the teacher recordings. These recordings were then coded and analyzed both by me and by the second observer familiar with secondary chemical education but not directly involved in this study. This second coder, also a veteran secondary chemistry teacher, coded the first two interviews (two of the six total or 33%). Comparing our respective same observations of the same lesson and using the coding system revealed a significant degree of inter-rater reliability. This process was completed during September, 2020.

Another threat to validity is the number of observations. A single observation certainly cannot reveal the richness of a veteran teacher's practice. But several observations of each teacher's lesson, triangulated with survey, interview, and focus group interview data and coded with the language from research and awards criteria received lessened this threat.

Triangulation, here seen by the use of several different observational methods and data sources, is used to strengthen the results in any qualitative research study (Patton, 2002). Soliciting data from interviews, observations, recordings, and panel discussion led to inherent overlap in information received, but it allowed me to tweeze from these multiple data sources commonalities and differences amongst the participants' practices that might be missed with only one or two sources of data.

I acknowledge my own biases as an observer. As an experienced chemistry teacher observing chemistry teaching, I was able to exclude the pedagogical variable of unfamiliarity with the curriculum. My intimacy with secondary chemistry curriculum presented obvious subjective biases about what constitutes quality chemistry teaching practices. Noted also here was the effect of the researcher on the participant observed. To be sure, I checked regularly with members of my dissertation committee to ensure that I was not imposing my biases.

CHAPTER FOUR

FINDINGS

Introduction

This chapter reports findings according to the data from the participant surveys and interviews, classroom observations and post-observation interviews, teacher focus group meeting, student surveys, and focus group interviews. The names of participants and their schools have been anonymized.

Data collection was arranged by email with each of the participants. Most of the data collected were qualitative. Participant and school building permission letters were sent electronically to the Department Chairs and Heads of Schools (Appendix F) and permission was received from each of the schools to conduct this study (sample permission form with school name redacted, Appendix O). The class observations were arranged by email and conducted between September and December, 2020.

My original intent was to conduct the student surveys in-person and collect the completed surveys by hand, but the move to remote teaching in March 2020 and no live visitor policy all schools maintained during the pandemic prevented me from conducting the student surveys live. Given the general qualities of best practices the survey questions moved me to consider instead conducting the student surveys through Zoom with my own students and fellow chemistry teachers' students at Brookline High School, where there was no issue gaining access to these students, who remained anonymous on the electronic questionnaire (see Appendix K). The data for the student surveys will be presented later in this chapter and discussed in Chapter Five.

An analysis of these data from this selected group of award-winning high school chemistry teachers has highlighted the definitions for QT as detailed in Chapter One. Given the almost entirely qualitative aspect of these data across the participants in this study, there were some limitations to validity and some possible biases. These were discussed in Chapter Three.

Participants

In this section I introduce each of the participants, provide educational background and professional experience, describe their school and community *milieu*, and a provide a list of the awards received (for awards descriptions, see Appendix D; for a summary of participants awards, see Appendix E).

None of the participants knew of each other's involvement with this study until the final focus group when their identities were revealed. Given that all six teachers worked in the greater Boston area, attended and conducted chemistry teacher professional development, had students participate annually in the ACS-sponsored local section and USNCO examinations, and regularly attended the annual NESACS May awards meeting, there was a likelihood that several knew one another from these beyond-school professional associations.

Table 2.

Participants

Participants	**Years Teaching as of 2020**	**ACS Awards, Recognition**	**Demographics*, School Enrollment, Median Family Income****	**Teaching Assignments, Sections (2019–2021)**	**Prior Career, Degrees**
PK	20	*Aula Laudis*, Richards Award	35,000 pop. 44% White, 41% Asian, 4% Black, 4% 4.5$ Hispanic, 6.3% Multi-Race, Non-Hispanic Suburban, approx. 2200, $186,000	AP Chemistry (3)	Research Chemist, B.S., M.S., Ph.D., M.Ed.
DR	21	*Aula Laudis*, Richards Award	27,000 pop. 53% White, 35% Asian, 3% Black, 5% Hispanic, 4.5% Multi-Race, Non-Hispanic Regional Suburban, approx. 1800, $134,000	AP Chemistry (1), Chemistry I H (2), Dept. Chair	Soccer Coach, B.S., M.A.
SD	25	*Aula Laudis*, NERM Award	90,000 pop. 58% White, 23% Asian, 6% Hispanic, 4% Black, Multi-Race, Non-Hispanic, 8%. 32% Jewish Suburban, approx. 1900, $151,000	AP Chemistry (1), Chemistry I H (2), Chemistry I	Community Outreach B.S., M.S., M.Ed.
RH	26	*Aula Laudis*, Richards Award	12,000 pop. 67% White, 18% Asian, 5% Black, 4% Hispanic, 6% Multi-Race, Non-Hispanic Sparse-Suburban, approx. 650, $197,000	AP Chemistry (1), Chemistry I H (2), Physics I (1)	Researcher B.S., M.S., M.Eng., M.Ed.

EH	16	*Aula Laudis*, USNCO Mentor	44,000 pop. 75% White, 9% Asian, 6% Black, 7% Hispanic, 2% Multi-Race, Non-Hispanic Suburban, approx. 1600, $105,000	AP Chemistry (1), Chemistry I (1) and I H (2)	Researcher, B.S., M.S., M.Ed.
AM	20	*Aula Laudis*, Richards Award	35,000 pop. 89% White, 2.8% Asian, 2.4% Black, 3.7% Hispanic, 1.5% Multi-Race, Non-Hispanic Regional Suburban, approx. 1250, $109,00	Chemistry I H (2), Dept. Chair	Pharmacist B.S., M.Pharm., M.Ed.

* Based on 2020-2021 Massachusetts Dept. of Education Data
** Based on 2015-2019 U.S. Census Data

A brief portrait of each participant follows below. For more detailed portraits of each participant, see Appendix Q.

Patricia Kearns (PK): "You Can Do This!"

The first participant, who I will call Patricia, had been a chemistry teacher for nearly 20 years after earning B.S., M.S., and Ph.D. degrees in chemistry in her native Asian country. Other than serving as a teaching assistant in graduate school, she had no previous experience teaching after immigrating to the U.S. She worked for several years as a researcher but found her "heart was not in this work as it was very isolating." She missed the classroom, had always enjoyed working with children, and considered a career change to teaching. Chemistry was obvious given her background. Her school assignment has been the only one where she has taught. In her nearly two decades there, Patricia has been involved with science-related events and committee work for her building. She has mentored many first-year teachers, including one of the other participants in this study.

Patricia has also lived in the community where she taught and was deeply rooted in her school through involvement in numerous activities and events beyond her classroom. Her department chairperson shared that she was a respected collaborator and teacher-leader in her department. During the time of this study, she taught 3 AP classes, each of which meets 6 periods per week. Unusual for AP, typically a second-year high school course, PK's school offers AP as a first-year course, along with three other levels of chemistry. Nearly every AP Chemistry student is a junior. A rationale for teaching 1st year AP Chemistry is that this school has a four-year science requirement and if AP were a second-year course, most students would not be able to complete the four-year sequence of earth science, biology, chemistry, and physics. PK and her chemistry teacher colleagues said that they actually hate this arrangement, as teaching the AP curriculum as a first-year class demands non-stop speed and depth all year, creating added stress for students who already feel pressure from the high expectations and demands that come from the community and school culture. She likened this experience for students as "drinking from a firehose" and reported that there is a great deal of student stress. "My own children went through this school, so I well know the high expectations of parents and students and the stresses involved." Teachers every year push to make AP a second-year course, but parents push back in part to permit students to take more AP courses. This school offers an astounding 11 sections of AP Chemistry with class size averaging 20–24 students. This means roughly half the entire junior class takes AP Chemistry. There is a very strong work and achievement ethic at the high school and with the high expectations comes a good deal of student stress. This school has been referred by her colleagues as a “pressure cooker.” Last year PK’s overall student average scores on the AP exam were 4.3 (out of 5).

Patricia exuded a knowing wisdom in conversation and there was a gentleness in her voice that belied a firm, clear, declarative voice in her classroom. She was unflaggingly optimistic and insistently encouraging about all students’ ability to learn with her at the helm of each of her class’s group effort to master the material.

> If students put forth the effort, they can achieve anything. It’s my job to motivate them. I always say “Keep trying, you can do this!” I put a lot of emphasis on practice problems, worksheets, using additional sources for reference, the Do Now and exit tickets, and encourage one-on-one after school meetings. I also believe formative assessment is very important in my teaching. I tend to introduce a topic slowly, carefully, then build in depth and pace as we move through a unit.

Her belief in each student’s capability to master the material was evident in every class meeting. Students hung on her words in class lectures and their questions showed an interest and depth of understanding that were clearly encouraged by her. She, like several other of this study’s participants, had what I call “relentless expectations,” a knowing certainty that all of her students can and will conquer the subject matter. With the formidable task of teaching three AP Chemistry sections as a first-year course, Patricia was a task-master recognized by her students, colleagues, and the awards she had earned as a true master teacher.

Dean Rosenburg (DR): “Coaching for Lifelong Learning”

Dean (not his real name) was a 21-year veteran teacher at a public regional school about 26 miles west of Boston. He had been at this school for the entirety of his teaching career. The regional school district drew from two well-to-do towns. Many households were led by professionals who supported the school system through programs that promote high achievement. There was an expected high level of achievement amongst students who enroll in multiple honors and AP-level courses with the assumed stress that these expectations often produce in teenagers. The school continually ranked in the top 1% in the state, based on math and English proficiency test scores.

From childhood, Dean had always had an urge "to know" and was drawn to science at his public school growing up on Long Island. In high school chemistry class, he felt validated by his teacher and he recalled "clicking" with the subject material. He held a B.S. degree in chemistry from a small (approximately 4200 undergraduates) Southern liberal arts university continually ranked in the top ten amongst other small liberal arts schools its size and a M.A. graduate teaching degree.

What the students saw was a fully engaged teacher toward their learning and interacting with the curriculum. A subtext of Dean's mission as an educator was to create a *milieu* that was safe for students to wrestle with challenging chemical concepts and to do so with a trust from teacher and classmates that it is okay to take academic risks and challenge concepts for the sake of moving the individual and class learning forward. Dean prodded and nudged his students to question, often leaving questions with incomplete answers for the purpose of having students fill in the missing part of the answer. Other times he would end class with a question as a way of having the students anticipate the answer, as in the following class.

DR pulled up prepared slides that were not originally part of this lesson to illustrate orbital shapes. A student asked, "Is the electron always in its orbital?" to which DR replied “Probably,” a beautifully vague answer to emphasize the probabilities the orbital shapes represent (an answer with a wonderful double meaning!). DR then segued to the lesson by praising the class for many great probing questions, by showing a slide of atomic radii as a trend both down a group and across a row of elements on the Periodic Table, and by discussing how to interpret this graph of atom size vs. atomic number representing two trends for elements both vertically and horizontally. With class time up, DR left the students with an unanswered question, “As we go down a group, atomic radii increase, but as we go across a period the radii decrease. But why?” Class was dismissed. There was a playful smile on his face as the students departed.

Dean was self-admittedly highly competitive, having been involved in athletic competitions at various levels, and he brought a certain healthy competition into the classroom and personally as a teacher, wanting to always be the best at what he did and providing daily self-improvement opportunities for his students. Dean was every bit the coach as a teacher when he said, “I’m here to show them how to be their best selves and to give them the tools they need to be lifelong learners. In this sense I’m their encourager, their motivator, their coach.”

Stella Danes (SD): “Social Justice and Relationships Through Teaching Chemistry”

“Stella” had taught at her current mid-sized suburban public high school for 10 years and 15 years previously at a large urban public high school in Boston. Stella was always interested in science and medicine. She grew up in an upper middle-class suburb of a major Rust Belt city and attended public high school taught by all White males who, she felt, were not encouraging for girls to excel in science and math. Given an interest and talent in STEM, she completed a pre-medicine major in college which led her to medical school. Passing the boards after her second year, Stella took time off to try out teaching in the inner city in urban schools to mostly minority and socioeconomically disadvantaged youth. Having grown up in suburbia, the experience of herself being a woman of color teaching to other minority students of color giving them an opportunity to learn from a teacher possibly like themselves set Stella on her path. She returned to medical school after the year away deciding that teaching science was her calling, not medicine. She did not complete her M.D. degree, but instead transferred to a graduate science education degree program. As this study was conducted, she was planning on entering an Ed.D. degree program.

Stella, in her late 40s, admitted being somewhat afraid of public speaking, yet she was clear and direct in conversation about teaching and sharing with her students in class. She had a soft, careful, steady voice that held this listener as she guided the conversation or presentation methodically and logically through an idea or concept. To watch Stella teach, one is immediately guided by her calm, caring tone as she gently commanded expertise in presenting the curriculum. A subtext of her teaching was her firm commitment as an educator to inclusion, of bringing science to everyone, and this added a moral and righteous sense to her presence in front of her students. When conversation with Stella moved to the importance of inclusion and the push for increased minority and female enrollment in higher-level science classes, she became animated and adamant.

> I always have inclusion on my mind as a teacher. I have several students of color in this class, some others with learning disabilities, and I use my iPad to both give notes and to be able to then post notes for all students to see. I used to only do this for more important lessons but I now do it for

> every lesson so all students, present or absent, have equal access to the daily learning.

She said she firmly believes that "the purpose of education is to foster each individual's self-worth and self-esteem in order for individuals to make their fullest contribution to society." Stella's role in this endeavor has been to serve as a "positive model to challenge and motivate students to be independent thinkers and to develop students' character, habits of mind, and inner voice along with their academic talent, and embrace the diversity of cultures and backgrounds." The underpinning of her teaching philosophy stemmed from two formative experiences: being taught in high school by a uniformly White, mostly male faculty, and teaching in urban settings to mostly students of color and economic disadvantage. Though chemistry teaching is her *métier*, social justice has always been a subtext of her mission as an educator and her need for "giving back" to those students who would not normally be provided a pathway to learn and be successful with science.

Equipped to educate in the sciences, she spent the first fifteen years of her teaching at a large urban technical public high school in Boston with a demographic of 33% Black, 33.8% Hispanic, 20% Asian, 11.7% White, 2% Multi-Race, Non-Hispanic students in comparison to her current school, 4.2% Black, 6.4% Hispanic, 23.1% Asian, 59.8% White, 6.4% Multi-Race, Non-Hispanic students. It was during her teaching at previous urban school that Stella "developed her chops" honing lessons for all levels of chemistry, particularly teaching the AP Chemistry curriculum, which she created and developed there. For Stella, mastery of the material is necessary, but inspiring students who did not have the resources and support beyond the classroom was what really positively challenged her as an educator. She acknowledged that "female and minority students face many obstacles in learning math and science," and it was during her urban public school teaching time that she took up a personal mission to push all of her students, particularly young women and minorities, to maintain high standards and to succeed. Social justice has been a guiding belief in her role as an educator. Stella was at ease using various forms of technology in her teaching, including ClassKick, an interactive site for students to receive and submit work.

Roxanne Hobbes (RH): "Relentless Expectations"

The next participant I called "Roxanne." She earned both undergraduate and graduate engineering science degrees, a second graduate degree in environmental engineering all from prestigious engineering schools, and her graduate teaching degree from a Boston-area college. She grew up in the Midwest and attended a lab school where she said, her teachers were wonderful, especially her chemistry teacher who was "so smart, creative, and pushed us to always question," though she never imagined then that she could or would herself be a chemistry teacher. It was in graduate school living frugally that she thought to earn some extra needed money and began substitute teaching at the public high school near to her graduate school. She found teaching demanding in preparation and rewarding in seeing the students learn. As a physics teacher retired, she was asked to take over and by the end of the school year Roxanne chose to finish her graduate program but not pursue academic research. Instead, she decided to take up teaching, enrolling in a program toward licensure in teaching in the Boston area where she has been a teacher for 26 years, 18 at her current public school located about 16 miles from Boston. The community was suburban with acreage between single-family homes and several working farms. The town center was built around a classic 18^{th}-century New England church. The median family income made this one of the wealthiest towns in the state.

In class, she could be verbally playful and humorous in an unabashedly nerdy way: “Time to begin our unit on kinetics, a personal favorite because of what for me makes chemistry so much fun, the math!” In a snippet from one class, Roxanne fit into a brief 25 minutes what might have taken most teachers over an hour of class time to explain. Her words during this time were spare, precise, and building on one another, as my notes indicated.

Here, she is asking students to recall what class has already covered about chemical reactions (stoichiometry, energy changes, and entropy changes), but nothing so far about when and how fast a reaction occurs. She outlines on her shared electronic pad the three subtopics for this new unit: 1) rate laws, 2) reaction mechanisms, 3) models for chemical reactions, then posts the expression for rate: $\Delta[A]/\Delta t$ or dA/dt with a concise mathematical explanation, emphasizing that those students taking calculus will be well familiar with expressions like this but those students who haven’t taken calculus will learn just what you need to know here to be able to understand kinetics. This was a lot of dense content for a shortened period and RH admitted after class that she felt pressed for time and sped through the material.

Roxanne, also in her late 40s, lived with her three children in an urban community adjacent to Boston and commuted by car to her school in the thickly wooded bedroom community, a world away from her densely packed neighborhood of 2–3 family apartment buildings.

Elena Hernandez (EH): "Relationships Matter"

Elena (not her real name) had been teaching 16 years after receiving her B.S. in chemistry from abroad and her M.S. in chemistry from a New England state university. Her school was a mid-sized public high school located about 30 miles northwest of Boston. Elena lived with her husband and son in a middle-/upper-middle-class suburb several towns away from where she taught.

Elena studied chemistry as both an undergraduate and as a graduate student. She came to chemistry in part because her father was a chemical engineer and her mother an educator, yet she had not intended to become a chemistry teacher even though her mother always thought she would eventually do so. While earning her M.S. she taught both face-to-face and online as a teaching assistant. Her husband relocated to the South for a two-year position and, knowing that it was unlikely for her to be hired with her graduate degree for a short-term appointment, she was hired at a nearby school as a full-time chemistry teacher. "Mom was right in the end!" she realized. Relocating to the Boston area, she began at the same school as another study participant, Patricia, who served as Elena's teacher-mentor. There, she had very high achieving students who, she said, were more prepared than some of her college students, allowing her to teach some college-level topics to her high schoolers. When she switched to her current school 15 years ago, all of the chemistry teachers there had just retired so that the newly hired chemistry teachers were all new to the school, including Elena. This allowed them as a group to develop a new curriculum which they still use to this day and to subsequently collaborate to augment and modify the curriculum for improvement. Elena took the lead with curriculum collaboration and improvement in meetings. She enjoyed developing new curriculum with colleagues and felt a real sense of ownership with the work she and her fellow teachers shared about presenting chemistry in a relevant, meaningful, challenging way. That said, Elena was constantly tweaking lessons and modifying the initial curriculum developed years before. She was definitive about what drives this constant lesson and curriculum adjusting.

> After the first few years of teaching, I realized that it was important to adjust my teaching to include more about *how* my students learn and to get them to explain their understanding more. It was also necessary to modify my lessons so that I could better relate to what kind of learners they were, for example, auditory, visual, or kinesthetic learners. What makes teaching so exciting is that no two students are alike so that you have to figure out who you're teaching to. At the beginning of the year, I learn what each student likes and dislikes, and give them a set of test questions to inform me what kind of learner they are. Getting to know your students well and forming relationships is critical in being able to teach them well.

Amy Morris (AM): "Owning Understanding and Making It Relevant"

I will call the last participant "Amy." Amy grew up in the Midwest where her father was a Ph.D. chemistry professor and her mother an educator, though neither exerted pressure to study science. Instead, her high school chemistry teacher made the subject fun and approachable and moved Amy to consider taking her school's second-year organic chemistry elective. Attending a small midwestern liberal arts college, it was her college advisor who caused her to consider applying her chemistry study to pharmacy which she practiced for thirteen years before making a mid-career change to become a teacher.

Amy had a frank, open tone in conversation and a distinct, forthright voice matched with a nurturing, maternal presence in the classroom. Every class began with a tone-setting “How are you?” She begins by asking each student to share something fun they did during the long weekend. Ten minutes in, she’s going over dimensional analysis and converting units using a Jamboard to present the material. Jamboard is an interactive digital whiteboard presentation for classes, also popular in remote learning. Several examples are used to demonstrate the factor-label method of unit cancellations. A student asks, “What about when there’s more than one unit in a question to convert?” AM: “Aha! I can see you’re looking ahead. Great!” The last 10 minutes of class are used in small groups to work a conversion problem as an “exit ticket” (demonstration of understanding). AM’s final summary of the lesson to class was that she was teaching everyone a process for problem solving that will be necessary later in the year. The pacing and transition between the three segments of class were seamless, not rushed, and always on task with regular pauses and check-ins to affirm student understanding and answers to brief questions about how to round an answer or when to consider significant figures in conversion question.

Amy has lived two miles from her school. One of her two grown daughters, a recent mother, has lived nearby. This proximity has given Amy time to relish her new role as grandmother. Amy has also served as the science department head and therefore has had a role as evaluator for her 13 colleagues. For the past decade she has been involved in green chemistry curriculum development running workshops, writing curriculum, and creating laboratory experiments which have been published in conjunction with science textbook publishers. She has been immensely active in her school, being involved with the Honors Society, acting as a Lead Teacher, and serving in her school's mentor program, as a Class Advisor, and as Advisor for the school yearbook. She was well known through the school building by students and colleagues across departments. Among her ACS teaching awards, AM was Massachusetts Teacher of the Year Top Five Finalist and was Nationally Board Certified.

Codes

I created ten codes based on the terms found in the Massachusetts Educator's Evaluation Rubric "exemplary" standard, ACS Guidelines for Teaching Middle-and-High School Chemistry, and observations and interview data from this study (see Table 1). Codes were selected based on commonly heard words and phrases from interviews and confirmed as valuable qualities found in various QT studies (Fenstermacher & Richardson, 2005; Green, 2013; Rockoff, 2004; Yeigh, 2008). Analysis of the data and how these codes were demonstrated from the classroom observations and compared to both the Educator's Rubric and ACS Guidelines were explored in the Answered Research Questions section of Chapter Five. I note here that presenting coded data in this manner did not provide depth of analysis, which might be captured with a frequency of codes, but instead these show the breadth of codes used for each participant.

These codes were intertwined with one another and could be defined in terms of each other. Collectively the qualities they describe make up the QT seen in this study.

Relationships

The relationships that teachers cultivate with their students matter. They provide the trust and buy-in for students taking academic risks and can be seen in DR's encouragement of debate with formulas, with the emotional support and constant check-ins that EH offered her students, and the compassion SD provided to her students of color.

Caring

Empathy is a noted AWT characteristic demonstrated by all of these participants and seen in AM's daily pre-lesson check-ins, RH showing her students about her constant attention to getting the curriculum right for her students (here, caring was not only a relational quality also demonstrated transparent attention to practice), and in SD's and AM's demonstration of caring toward their students' emotional well-being at the beginning of classes.

Trust

This quality is cultivated from a strong, caring relationship between teacher and student and was demonstrated by the ease and comfort SD's student shared in making tangential jokes and inferences in class, by RH's students knowing that she would march them successfully through a challenging curriculum, by DR's student's trust in being able to provide risk-taking answers while debating concepts; and in SD's access to school funding for AP workshops and collaboration with colleagues.

Resources

This code has several meanings throughout this study, including access to teaching materials, support from school, parents, and community, and professional development. All participants reported having access to community funding for workshops, collaboration, and curriculum development through district-wide non-profit entities that support teachers.

Collaboration

This code also has several meanings, including work among colleagues to improve each other's practices, work among students in small groups (seen in DR's student groups working on open-ended questions and in SD's breakout rooms drawing molecular structures). All of the participants have been involved in both attending and running professional development workshops both within their schools and at local and regional conferences.

Strong Voice/Clear Instruction

These phrases, identified as important qualities from the literature in Chapter Two, were heard among all of the participants' classroom observations and were an important quality identified in the student survey. Each of the participants demonstrated their declarative voices and clear expectations, qualities that were highlighted by colleague, supervisor, and former student anecdotes in the award nomination letters, as in RH setting the agenda and goals for the lesson at the beginning of each class.

Motivate/Motivation

Found in both the Massachusetts Educator's Evaluation Rubric and the ACS Guidelines, this standard says that teachers must be strong motivators for student learning and do so in varied ways with the use of strong voice/clear instruction, humor, and passion. All of these participants clearly met these criteria.

Teachers as Learners

Related to collaboration, this code was identified as an AWT quality related to teachers as lifelong learners. All of the participants continue to take coursework and two have begun continued graduate study. As RH noted, “If I am learning, my students are learning.”

Passion(ate)/Love

Though this code was not found in the Educator’s Evaluation Rubric or the ACS Guidelines, it was heard repeatedly in the teacher interviews, classroom post-observations interviews, and focus group interviews. Specifically, all participants communicated this code in response to identifying “It.”

Data

The following sections present the data collected in the STEBI-like questions survey and teacher interview responses; anecdotes from colleagues, administrators, and former students; and classroom observations, post-observation interviews, and focus group interviews. This was the chronological order in which I collected these data, with the focus group interview serving as the capstone to hearing from the participants.

Teacher Survey Questions

The Science Teaching Efficacy Belief Instrument (STEBI) is a tool used to measure science teachers’ efficacy and outcomes, developed in 1990 and considered a standard amongst psychometricians learning about science teachers’ educational and pedagogical beliefs. The instrument goes well beyond my needs, but I used five STEBI questions that pertain directly to my study. I modified these items to say "chemistry" instead of "science" and "award-winning" instead of "good." Participants were asked to respond to each question with a Likert-like set of answers: SA = Strongly Agree, A = Agree, UN = Uncertain, D = Disagree, SD = Strongly Disagree. Questions were sent by email and were collected in late August, 2020. From *N* = 6 participants, the results were as follows and are explored further in Chapter Five.

Table 3.

Teacher Survey Responses

Question	**SA**	**A**	**UN**	**D**	**SD**
I am continually finding better ways to teach chemistry	3	3			
The inadequacy of a student's understanding can be overcome by good teaching	3	3			
The teacher is generally responsible for the achievement of students in chemistry learning.		4	2		
I know what to do to increase students' interest in learning chemistry	4	2			
Award-winning teaching translates to high student achievement		2	2	2	

Participant Responses to Interview Questions

In this section, I present participant responses to interview questions (Appendix N). Participants were sent these questions via email in advance of our scheduled interviews in August, 2020. Interviews lasted approximately 35–40 minutes and were video recorded then transcribed. The italics here are my own and added as emphasis to several responses where a participant highlighted a certain thought or belief.

How did you find your way to teaching chemistry?

DR: I come from a family of teachers and have always been surrounded by education. I have always liked science and finding out "Why?" I was seriously into soccer coaching after college and at some point, I couldn't see this as a career so I went back to school for my teaching degree and was lucky to find a school pretty similar to the one I attended where I went to high school and it's where I've been ever since.

SD: I took a gap year from medical school after passing the USMLE boards to try teaching in urban public schools. I attended a middle-class public high school and all of my STEM teachers were White and, as a female minority, I hoped to show these urban students that they could have a role model that looked like themselves.

RH: During graduate school, I needed to supplement my income and applied to be a long-term substitute teacher at a public school. When I got the position and first entered the building, I felt something I'd never felt at any job previous, like, this is the place for me to be in front of teenagers teaching math and science. I eventually stayed on as a full-time teacher, left graduate school, returned to get my M.Ed., and have been at my current school ever since. My mom was a chemist and I loved my high school chemistry teacher. He was funny, creative, questioning, though at the time I could never have imagined I'd be a chemistry too. I actually began as a physics and math teacher and didn't teach a chemistry class until 13 years into my teaching,

PK: After graduate school I began as a research scientist but my heart wasn't really into it. I'd always loved being with children and thought to teach chemistry given my background. Without experience, the first few years were difficult and looking back they were probably a disaster but a lot of learning along the way. Coming from another country I also had to learn the US system of education. Now I feel at home and I can say that I've truly found my calling.

EH: I've always been passionate about chemistry, and my training is in chemistry, not education, so I've had to learn a lot along the way about teaching as a profession. I love watching kids' learning spread out on their face and creating an environment for that learning to happen….I began a research job just after graduate school but didn't find it so exciting. I was shy in college and grad school, afraid to speak in my classes, but the few teaching experiences I had, I found I was able to come alive, and I think that being with kids, seeing their excitement in the classroom, and teaching them helped me with my confidence.

> **AM**: My father was a Ph.D. chemist and I always liked science as a student, hoping my interest would lead me to something to do with medicine. I became a practicing pharmacist for mom-and-pop drug stores for 13 years. As a working mom, I became involved in my own children's activities and came to really enjoy working with kids. As the big pharmacy chains took over, I began to explore alternatives which lead me to teaching, first as a long-term substitute, then full time, where I've been at the same school now for 20 years.

Even amongst this small sample, $N = 6$, there were a variety of pathways to lead these award-winning chemistry teachers to their classrooms. All of these teachers began their teaching coming from another career. All professed a love of chemistry and a joy to teach it.

How does your teaching demonstrate your beliefs about how your students learn best?

> **RH**: The student-teacher relationship is what it is all about. I see my beliefs as being able to support and maximize a student's potential to learn chemistry and to ultimately be able to observe, question, analyze, and view the world through a scientific lens.
>
> **SD**: It was eye-opening going from medical school where everyone knew science to an urban public-school setting where most students had no notion of science, coming from backgrounds where their parents might not have attended college, and they had no understanding about careers involving science. I learned early on that once I can establish a connection and relationship with a student [learning] the science becomes easy. I try to distance the chemistry at first and make it about the relationship.
>
> **DR**: I guess I'm somewhat of a traditionalist in that teachers must provide content and tools for understanding first to build a framework and structure for learning, then let students wrestle or even struggle with the material in small groups, allowing them to own their learning.
>
> **PK**: I believe that learning the fundamentals of concepts is most important to teach and for students to learn. Everyone learns differently and teachers must modify their instruction to each individual; for example, for the

> readers I give extensive notes, for the visual learners I use demonstrations, more hands-on activities, and animated presentations. I think most of us are visual learners. I believe that there's no best way of teaching but everyone must receive clear instruction and expectations. I try to relate what I'm teaching to real world examples and since chemistry is everywhere this is easy. I might lecture for the first few minutes then have the students work in groups on an activity or problem.
>
> **EH**: After the first few years of teaching, I realized that it was important to adjust my teaching to include more about *how* my students learn and to get them to explain their understanding more. It was also necessary to modify my lessons so that I could better relate to what kind of learners they were, for example, auditory, visual, or kinesthetic learners. What makes teaching so exciting is that no two students are alike so that you have to figure out who you're teaching to. At the beginning of the school year I learn what each student likes and dislikes and give them a set of test questions to inform me what kind of learner they are. Getting to know your students well and forming relationships is critical in being able to teach them well.
>
> **AM**: I believe teachers are responsible for showing *why* and *how* in chemistry, that is, modeling, then allowing them to work in pairs or groups to understand and visualize through inquiry, experimentation, and other creative activities. I use term projects that involve research and designing experiments that allow individualized exploration with peer evaluation and poster sessions at the end of the year.

These teachers varied in their beliefs but one commonality that shone through in each response is the importance of establishing strong relationships between teacher and students. How and why this was important amongst award-winning chemistry teachers is explored in Chapter Five.

How has your award-winning status affected the way you see yourself in the classroom? Has this changed in any way how your students perform?

> **PK**: I am grateful that there is external validation for my beliefs as an educator, not only as a result of the awards, but also from my students' performance on the Ashdown and Olympiad exams as well as on the AP exams. I guess I'm doing something right. An effect I think it has had on me in the classroom is to allow me to even more press the "Why?" with my students.

> **SD**: I actually found the award-winning status a disservice! It draws attention to me in a way that I don't care for. I'm just doing something that I really enjoy, not seeing some award. And has it changed how my students perform? No, not at all. They don't see me that way. At my current school, the awards gave me confidence to advocate for choosing my classes and advocating for my students. Yet at my current school I put in relatively *far less effort* because most are high achieving and I am more *enhancing* than *inspiring* their learning chemistry.

> **RH**: It's meaningful that my influence has had a strong effect on some of my students. The best teachers make each student feel like they are the only one being taught.

> **DR**: I'm honored that my work has been recognized but my teaching hasn't changed at all since receiving awards, nor do I think has my students' performance changed as a result of these awards.

> **EH**: My father always told me, "Don't look for recognition. If you work hard, it comes along on its own." I believe this. I also believe that when students trust you, you can teach them anything. The awards validate that I'm doing something right, but the real reward is the love each day of being in front of the students.

> **AM**: [My] award-winning status gives me a sense of accomplishment and appreciation from colleagues; it's definitely a confidence booster, but it hasn't changed me as a teacher and I'm not sure how it affects my students' performance. I will say that it has increased *my* opportunities as a teacher, and therefore my students' opportunities.

Though there is no consensus here, the general belief amongst the participants was that their teaching has not been much affected by the AWT status and that the award just confirmed what these teachers had been doing all along. None of the teachers here sought out awards and there seemed to be a general understanding that the awards validated their efforts at attempting to accomplish QT.

How and why do you think you have earned your status as an award-winning educator?

> **SD**: That's a good question! I don't know. One professor I had pushed me and told me I'm a female minority who is good at science and our urban students need teachers like you who they can be inspired by. You can be their role model. Working at my previous public school was *hard* work, and that alone might be how I've earned this status.
>
> **RH**: Being with adolescents and doing what I love to do, what could be better?! I strive to be a good role model, funny, and appropriate but know that many other teachers deserve this same status.
>
> **DR**: Teachers teach because they must have a passion for educating children. All of my colleagues and I share this passion working with our students. It's personally rewarding to push my students to do their best but, honestly, this is what I do as a teacher and I don't think I did anything special to receive these awards.
>
> **PK**: I work hard to prepare clear, structured lessons but can't take myself too seriously around the students, who know I love my job and I'm also not perfect, that I make mistakes, too. I'm surrounded by amazing teachers, anyone of whom could receive teaching awards.
>
> **AM**: That's easy: My passion and love for teaching! Someone, a colleague or supervisor, had the initiative to nominate me for these awards and in some cases as the NBCT [National Board Certified Teacher] I had to promote myself and that was a lot of work, but worth it.

I saw a kind of humility and "Why me?" in these responses, that awards could have just as well gone to other colleagues. I attributed this to the egalitarian nature of teaching and that teachers do not want to be thought of as any better than their colleagues even though the externally-awarded honors these teachers have received would seem to differentiate these teachers as more skilled.

What ways, if any, do you share your award-winning practices with others?

> **DR**: I'm also the Department Chair so I'm having conversations every day with colleagues whose classes I'm visiting regularly. I encourage fellow

teachers to learn from each other. It's good for the department when we engage with each other.

SD: We're very collaborative at our school, always bouncing ideas off of one another. Our doors are always open to colleagues. We've developed a few non-traditional chemistry courses together to attend to different student needs, some hybrid multi-level classes that cater to students with divers low abilities and courses that might bridge between the more traditional college prep and honors levels, but that still present advanced topics such as kinetics and equilibrium.

EH: My department is very collaborative. If any of us succeeds, it reflects well on the group. Even though I'm the sole AP Chemistry teacher, I also teach our freshman low-level physics class. Teaching these two classes on any given day makes me complete as a teacher, my life is whole. Shamefully, that low-level physics class has a disproportionate number of minority students compared to my AP class and I'm passionate about changing this as long as I'm a teacher.

RH: I run workshops and we all share work with each other in the department. In collaboration time meetings we share what works and what doesn't work in the classroom, and my classroom door is always open for visitors to come in and observe. It's an unsaid thing at my school to be able to see others' classes.

PK: I borrow from my colleagues and they borrow from me. We're truly collaborative. Though I am still more comfortable speaking in front of students than adults, I present at conferences and attend workshops. Teaching means you're always learning and sharing.

AM: We four chemistry teachers are sharing and collaborating all the time. We devise lessons and labs together, then share what works and what needs to be tweaked. Our doors are always open to one another which for me can be odd for me at times as I'm both fellow chemistry teacher and also head of department with an evaluative role, but I don't think this is strange for any of my colleagues. I also run workshops, attended and present at conferences, and have taught graduate level courses.

Collaboration was the thread through all of these responses. None of these teachers taught in a bubble, nor did any appear to share with others out of duty alone; all appeared to collaborate beyond normal sharing to learn from others and share with colleagues to improve others' practices and thereby that of their students' learning. It is a characteristic of QT that will be explored further in Chapter Five.

Is your teaching best described by "It," that elusive hard-to-define, innate quality sometimes referred to as the natural gift of teaching, or is it a set of practices learned from experience over time, or some mix of both? Define "It."

> **DR**: It must be a blend of the two. I reflect that the first 7–8 years you're trying to just master the content and in the next 7–8 years you're then thinking how you probably weren't doing things so well those first 7–8 years so it's time to modify and also to begin to focus more on the individual students, not just teaching to the whole class. No two teachers are alike in that each brings their own unique experiences and understanding of both the curriculum and the relationship to teaching. One thing I've learned in teaching is that there are *a lot of different* right ways of teaching.

> **SD**: (Long pause) Some are naturally gifted but may not be able to push or motivate; conversely, others, like me, are inhibited and not naturally public speakers, but can convey information easily. If anything, it's a skill-based practice like that phrase "95% perspiration, 5% inspiration." I know that at my present school with all of the resources and students with means and supports, teaching is relatively easy, whereas at my previous urban public school with few resources and students without the home support, I *had* to learn all of the teaching skills, the tricks to motivate and inspire, and the collaboration that my school had with area schools of education informed me that I wasn't isolated in my classroom but part of a larger connected system.

> **AM**: I would say mostly based on learned experiences, though that special spark has definitely gotten me through challenging lessons and days. Specifically, I know now looking back that I've made all the mistakes: misjudging where a student was coming from, discipline, grading, not making seating charts, but over time you learn tricks that make the art of teaching come through. I definitely felt the "It" that first time walking into school as a new teacher. I would define "It" as the desire and ability to convey knowledge to others.

> **PK**: I believe that my teaching is a blend of *three* things: some innate ability that involves a love of working with kids, some learned practices, and experience to define "It" is a combination of these three elements. I

> know that I'm patient, passionate, and empathetic but just having a passion for teaching is not enough. You do have to learn the skills as teaching is also an art. I've gained [these skills] from my mentors, colleagues, and from workshops over the years. I look back now and think that my first few years of teaching must have been disastrous! I also learn from my students who convey to me what works and what doesn't work in my classes. They might not know that they're teaching me but they always are. If something doesn't work in the classroom, you modify it until you get the result that you're looking for. In this, teaching is like experimenting, which I know from my research background. And every year you learn new things in the classroom. *If you're a teacher, you must also be teachable.* In that, being a teacher is about lifelong learning. Teachers must also understand *how* their students learn
>
> **RH**: If you love sharing knowledge, that's the inspiration to teach which you need to gain student trust, but you also need skills which come from experience. I was a chemistry major and never studied education, so I had to learn along the way. Relationships are important in establishing trust between teacher and students, and I believe you show trust by learning *who* your students are. "It" is the joy of teaching. Simple. Being passionate about chemistry and the eagerness to share it with others is what make my work a job I love!
>
> **EH**: My teaching definitely involves a combination of the art of teaching with learned practices; teaching is both an art and a science. You know who has "It" from the kids, in talking to them they share what teachers they really like and the sense of passion and respect other teachers convey, which teachers make it easy to learn, are patient, and offer that "I'm going to stick with you" sense that kids need to hear. Yes, you can learn these qualities but I think they're more innate. In education we're encouraged to continue to learn and build our skills. We all love to learn and I'm assuming that award-winning teachers do as well as also continually taking more coursework to improve. Defining "It"? Easy. It's the passion to teach. Kids can tell easily if you're having fun and if you want to be with them. In this sense, their passion for learning becomes your passion for continuing to teach in a kind of feedback loop. I'm asked by students why I left pharmacy which was good money to become a teacher which is less money and I always say that, money aside, teaching is just more fun and that is reward enough for me!

These comments highlight the "nature vs. nurture" question in teaching, that is, the art of teaching ('It') vs. learned skills. This question gave each of the participants the greatest pause, literally for SD, after having heard the question (even though they had the questions in advance), to formulate their answers. There was consensus that award-winning QT is a blend of the two and that learned skills outweighs the art of teaching, but that spark, or joy, or innate sense was present in all of these teachers' practices. Of all the interview questions, the responses to this question were the most expansive and detailed, ,supplemented with anecdotes and examples from their classrooms.

What do you still need to improve in your practice?

> **RH**: As much as I'm validated for teaching chemistry well, I will visit a colleague's class and be blown away by their instruction, leaving me feeling there's so much more for me to learn. I know I need work with the differentiated classroom, teaching ELLs, and digital curriculum. We teach in a constantly changing environment, especially now with COVID, and it demands that we constantly try to understand where the students are coming from and how to best meet their needs as learners.
>
> **SD**: I cut my chops for fifteen years at my previous urban public school with few resources and challenging students and worked to create an AP curriculum, then saw students score successfully on this exam. Now the question at my current school is how to take these already-prepared students to a higher level. Still in our lowest level chemistry classes that I teach, we see a majority of students of color and that is something we need to correct culturally responsive teaching, removing implicit bias from science education, finding ways to engage under-represented minorities in upper-level chemistry and science classes, and getting these students to consider chemistry and science careers.
>
> **DR**: Oh, probably everything! Really, not taking things so personally from students or parents, continuing to gain confidence as a teacher, not about knowing the science but about being the true person I am to my students, being able to joke about myself with my students. I'm not necessarily warm and nurturing like some other teachers, but that's OK, it's who I am as a teacher and certain students gravitate to me because of who I am to them. In that, schools need a diversity of [teacher] personalities.
>
> **PK**: For me, there's so much more to learn. I have always wondered how teaching work in countries known for their outstanding educational system, say, Finland or Denmark or Singapore. Perhaps I can go there

> sometime and learn their [teaching] practices. Here I see [high-achieving] students focus more on tests and grades instead of what I want which is more of a focus on enjoying learning and understanding why. I struggle with this as a teacher.
>
> **EH**: I can improve getting my students to think more alternatively about lab procedures, to lose the fear of speaking out more in class, create even more trusting environments in my classes, and structure more time for kids to work on open-ended problems, which they love.
>
> **AM**: Definitely during COVID, I need to improve remote learning and getting to know kids in this novel setting. Also, engaging kids now is very different than it was two and even one decade ago and we [teachers] must keep up with how best to engage our students as the technology drive a lot of this. Yet, it still comes down to relationships with our kids, and that's something that the technology can't replace.

None of these teachers were done with advancing their pedagogical knowledge or learning more chemistry. They were lifelong learners who strive to improve, and the importance of lifelong learning, though not expressed as an important belief by participants was, unquestionably, a value that all subjects held in high esteem. Why their AWT status might move them to this quality will be explored in Chapter Five.

Comments from Colleagues, Administrators, and Former Students

What follows are comments from participants' colleagues, administrators, and former students testifying to the QT these educators demonstrate. As a longtime member of the NESACS High School Awards Committee that receives annual teacher award nominations and letters of support from colleagues, supervisors, and past students, I was able to obtain these comments from past letters which were written or solicited over the past four years in support of three of the six participants.

> **From several past students of RH**: Ms. H is the most knowledgeable and helpful teacher I have ever had, and she showed her students an unrivaled

compassion. She gives lectures that rival those of college professors (it's obvious she spends countless hours perfecting the lectures). In class, when students have questions, she puts her insane breadth of chemistry knowledge to work, fielding questions about enthalpies of formation, aqueous solutions, renewable energy, and everything in between. On the rare occasion that she doesn't immediately know an answer, she does some research and sends us an email shortly after class with a detailed, comprehensive solution. On a Saturday afternoon, I emailed her a laundry list of questions about a potassium permanganate lab we were doing. That night, I received a thorough answering to every question I asked—her excellence doesn't stop, even out of school! No description of Ms. H would be complete without mentioning that she loves her students, how her face lights up as we enter class. She constantly encourages her students to ask questions and find mistakes or errors so that they occur again and, importantly, why they occurred. She makes us think like scientists. I look forward to class every day. Classes were fun with hilarious anecdotes and tidbits Ms. H would weave into her lectures helping to lighten up the mood. Ms. H puts an extreme amount of care toward her students. This fall I will matriculate to a combined physician-scientist degree program and I know I owe my success to Ms. H's encouragement and guidance.

From a teacher colleague of RH: I have known RH for 15 years. She is a master of content, meticulous in her organization, and is clear that each student can access and master content and goals. With her colleagues, she openly shares and encourages collaboration with others. She is empathetic and respectful to all. She is a trusted, respected colleague and a deeply connected to teacher to each of her students. She participates fully in the life of the school in ways few veteran teachers do.

From RH's Head of School: In addition to being a master teacher, she is a school leader, a mentor to other teachers, and avidly participates in school life beyond her department and is easily one of the most well-known and well-loved teachers in the school. The success of our AP Chemistry program is due entirely to her. Her classroom is a joyful learning experience. She is incredibly open with her students and fosters an environment of questioning and seeking to understand why. Great schools are made up of teachers like Ms. H.

Though from different stakeholders, common themes emerged regarding the QT of RH's practice. She is described by colleagues and supervisors and is identified by language in her awards as a master of content, caring, giving fully of herself to the educational mission both in and out of the classroom, inspirational. These themes will be reexamined in the final chapter.

Here are a similar set of comments from DR's past students, colleagues, and head of school:

> **From DR's past students**: I have learned so much from Mr. R's class. He makes sure that every student is attentive and engaged. We learn in a very unique way in which Mr. R has us debate a question we don't definitively know the answer to, then he encourages us to logically support our conclusions before revealing the answer. The debates can get quite heated as we're all passionate learners in Mr. R's classes. He has a compassion and care for all his students that has stood out for me. He ensures that every student has a comprehensive understanding before proceeding to new topics and he fosters a great classroom environment where students will openly discuss difficult topics and bring outstanding questions before the entire class.
>
> **From teacher colleagues of DR**: I've had the honor of working closely with DR for the last 11 years. What I most admire about his teaching philosophy is that the students' ability level dictates the course expectations. He's always thinking about how best to support and build student skills to raise the bar of *our* expectations over the year. His individual relationship with each student and ability to encourage each one to success to their full potential is inspiration to everyone in the department.
>
> **From DR's Head of School**: DR is one of the top chemistry teachers I have encountered in my 30 years of education. His content knowledge and teaching pedagogy are first rate. He is an innovator, recently leading his department in disciplinary literacy and rethinking how we assess students in our lower-level science courses. We need more teacher-leaders like DR in our schools.

Revealed in these comments were DR's strong content knowledge and his novel way of pushing his students by having them debate questions in front of class, and in small groups and his high expectations for all students.

Here are comments about AM.

> **From a supervisor of AM**: She is tireless and is passionate about getting *all* kids involved in science while guiding the creation of a culture at our school where science teachers are approachable and kids honor science as something exciting to learn. She has a welcoming and easygoing demeanor and develops excellent working relationships often times in leadership roles as a result of her knowledgeable, encouraging and dependable ways. Her wealth of knowledge and pedagogical beliefs allow her to make chemistry real for her *all* of her students.
>
> **From a colleague of AM**: She was responsible for writing the honors chemistry curriculum for our school, implemented a new teacher mentoring program, and as a NBCT, mentors all of the chemistry teachers in our department. Students who return from college share that they found college chemistry easy as a result of taking AM's AP Chemistry course.
>
> **From several past students of AM**: I saw from the first day in class Ms. M's genuine interest in getting to know each of us students. She demonstrates preparedness and professionalism that outmatches other teachers and her student-friendly explanations is something that her students appreciate and I always felt free to walk into her class between periods or after school knowing that she would happily answer my questions. I had to ask her write another separate letter of recommendation for a college and, where most teachers express irritation at having to write additional recommendation letters, Ms. M gladly wrote this additional letter for me, showing her superior generosity and compassion. She is passionate about not only chemistry but all arenas of science and her talents and qualities spurred me on to success throughout my time in high school. I ask lots of questions and Ms. M never seemed frustrated by my inquisitive bombardment; on the contrary she accepted every question I had and always did her best to answer it as fully as possible. Having Ms. M for two years of chemistry, I couldn't imagine a world where I didn't pursue chemistry further and it's because of her inspiration that I will major in chemistry in college.

What shone through in these anecdotes is AM's caring, compassion, zeal for teaching chemistry, and love of science that AM conveys to her students. She is a teacher leader in her school and with her NBCT status, a teachers' teacher.

Teaching Assignments

All but one of the participants in this study were currently teaching at least one section of Advanced Placement Chemistry, with other course assignments including "college prep," "honors," physics, or a general science course. Four of the six participants have doubled and one even tripled the number of students taking AP Chemistry in recent years with regular student success on the capstone AP Examination. Every participant has taught the range of secondary chemistry courses offered at their schools including chemistry-related courses such as biochemistry, organic chemistry, and environmental chemistry. All of these teachers had participated in some kind of subject specific, department wide, or external curriculum development at either the regional, state, or national level. Each of these teachers had served as a mentor for chemistry student teachers from area schools of education or teacher residency programs. Three of the six participants also served as the head of department, which gave them an evaluative role with their colleagues. All of these teachers have created ancillary chemistry and science related opportunities at their schools. These range from AP Chemistry Magic Show to Green Chemistry Initiative to ACS-sponsored Chemistry Clubs to Science and Art workshops.

The American Chemical Society Local Section and National Chemistry Exams

One benchmark of QT is the success students achieve on externally administered chemistry examinations. All of the participants in this study regularly register students to compete in the local section Avery Ashdown Examination Contest, the annual qualifying exam for the U.S. National Chemistry Olympiad (USNCO), a nationally administered exam by the American Chemical Society for approximately 1000 students across the U.S. The Ashdown Exam has been given in the greater Boston area since 1971 and is used as a qualifier for the USNCO since 1984. On average 100–125 students from over 30 schools public and private across the Northeastern Section of the American Chemical Society (NESACS) compete annually. All of the participants in this study regularly entered their students and every year these teachers' students place amongst the top scorers. Student success on the Ashdown Exam is recognized as a characteristic of QT throughout NESACS and is a noted quality in colleague and supervisor letters of support for these teachers' award nominations. Teachers have different methods for selecting students to take the Ashdown Exam, for which a maximum of five students per school are eligible. Most teachers take their current top five students based on class grade average, while others administer a qualifying test. Schools with several teachers sending students to the exam discuss who the best five are from different classes to represent the school. The limit of five students per school rule is to attempt to equalize schools' student test takers so that high achieving and less-achieving schools can send the same number of students.

For scoring, the top five Ashdown Exam scores receive cash awards, the next five scorers in both first-year and second-year categories receive Honorable Mention recognition. Of all of the Ashdown Exam test-takers, the top twenty-six are eligible to take the nationally administered USNCO (limit two per school, for the same reasons stated above to equalize participation amongst schools). Of the fewer than one thousand students who take this exam annually, the top twenty students attend a two-week study camp where Study Camp Mentors are selected by the ACS to tutor these top students. From this pool of 20 students, the top four are selected by end-of-camp examination to represent the U.S. at the annual International Chemistry Olympiad (IChO). A student making it all the way to IChO's Team USA is a truly remarkable feat. The ACS Office of K–12 Education has followed these Olympians since our country's participation in the IChO began in 1984. Many have gone on to become professors of chemistry or industry research chemists.

Results from the past 10 years of participants' students on the externally administered Ashdown Exam and USNCO (these data come from my serving for the past twenty years as NESACS Ashdown Exam co-administrator and USNCO Coordinator for NESACS) show a connection between award-winning teaching and these exams. The data presented show the teacher-participant and the number of students who qualified in each of the exam categories each year for the past decade. The exam categories are listed in ascending order from local section to international student qualification.

Table 4.

Results from Ashdown and USNCO Examinations 2011–2020

Year	Ashdown Cash Prize	Ashdown Honorable Mention	USNCO Qualifier	Study Camp	IChO
2011	1 DR, 1 PK	1 SD	1 SD, 1 PK, 2 DR, 1 AM		
2012		2 DR	2 DR, 1 PK		
2013		2 DR	2 DR, 1 PK, 1 AM		
2014	1 DR	2 PK	1 DR, 2 PK		
2015		2 PK	2 DR, 2 PK, 2 SD		
2016	1 DR, 1 PK, 1 SD	1 EH	1 DR, 1 PK, 1 SD, 1 AM		
2017	1 DR, 2 PK	1 AM	1 DR, 2 PK	1 PK	1 PK
2018	1 DR, 1 PK		1 DR,1 PK		
2019	2 DR,	2 DR, 2 EH, 1 PK, 1 RH			
2020	2 PK, 1 RH		1 PK	1PK	1 PK

An understanding of the importance of these data is explored in Chapter Five.

Classroom Observations

My original intent was to make live visits to make classroom observations but the pandemic in 2020–21 prevented such visits. Instead, I made remote and hybrid Zoom visits to observe teacher and students in classrooms. When schools adopted the hybrid model of combined remote and live teaching and learning in the Fall of 2020, schools were still preventing live visitors from entering school buildings. I visited classes using the Zoom IDs provided to me by participants. As stated in Chapter Three, my intent was to visit a class from the beginning for at least 20 minutes, if not the entire class period. Most often I was able to visit for the entire length of the class. During these visits, I remained muted with video off through each visit, then transcribed the classroom interactions for future coding. The original intent was to audio-visually record these visits focusing only on the teacher. On Zoom, this option was not possible due to video recording legal concerns.

What follows are reports of classroom visits recorded by hand then coded based on best practices themes taken both from the ACS Guidelines for Teaching Middle-and-High School Chemistry (Appendix A) and the Massachusetts Educator's Evaluation Rubric (Appendix B). Despite the online format, the class electronic visits were filled with energy, teacher presence, and student activity and revealed a class atmosphere that was still rich with teacher-student and student-student interactions.

The coding categories following were based on data collected by following Saphier's (2008) method (for evaluators) acting as a camera lens to observe how and what teachers do in the classroom. I have added several categories specific to science and chemistry pedagogy based on suggested best practices as described in the ACS Guidelines.

I chose to highlight certain lessons from my overall observations of each teacher that seemed representative of their practice as it is not feasible to portray all of the visits in this document. The observations for each participant were followed with a post-observation interview so that the observation and the interview were paired. The post-observation interviews were all conducted within 24 hours of the classroom observation.

Teaching a new topic. One observation of RH's AP Chemistry involved a lesson on the nature of chemical bonds. The introduction was a presentation of bond energy vs. intermolecular force and optimizing the distance between two atomic nuclei. The presentation was as much physics as chemistry using coulombic forces and distances to enrich this presentation. RH shared that even the class textbook made some assumptions about how bonds form that “were not entirely kosher.” One could sense RH speaking with great authority here as the students diligently took notes from her e-board drawings and definitions. At two points in the lesson, she held up pink sticky notes she pulled from her textbook and called these “Angry exceptions from last year!” and read them out loud to the class. This self-scolding elicited some smiles from students. The effect this had was both humorous and a transparent demonstration of the teacher making corrections in the curriculum for the benefit of the students’ learning, a great way to correct mis-conceptions, and a show of RH’s desire to improve her teaching before her students.

In another part of the lesson, RH drew an H-F molecule with an exaggerated electron density surrounding the fluorine atom. “Time to learn something not learned back in first-year chemistry, the physics behind the dipole moment.” Again, RH’s command of physics wove its way into her chemistry curriculum. She added the ∂+ and ∂- to the H and F respectively noting that the Greek letter delta here looked either like the Hebrew letter *lamed* or a sperm from biology class, then used the arrow to show the vector of electron density, saying that this was annoying because showing the vector was one way for physicists and the other way for chemists, a “raging unresolved debate.” As the dipole moment concept was presented, RH employed a self-created organization rubric called UDAVE (unit, definition, abbreviation, vector, and equation), something she used throughout the year in approaching a new equation or formula. By this time in the year, students knew exactly what she was referring to and chimed in with answers as she went carefully through the rubric. Class ended as she asked anyone to stick around with questions. The class was content-driven with regular hints that this or that will show up on the AP exam.

In another class visit, RH reviewed a FRQ (free response question found on the AP exam) assigned the day before. She presented the multi-part question involving determining the mass of zinc present in a 1.00 g of brass combined with an excess of 1.50*M* HCl. This was a short (25-minute) class and she used the first half to run through this question, explaining the hydrogen gas produced and collected by water displacement at a measured atmospheric pressure and temperature. Students were mostly copying her measurements and the PV = nRT formula to plug in numbers to find the moles, then the grams of Zn. After each step of the procedure, she paused to ask for questions (there were none for this problem). For the short second half of the period, she switched to the next chapter on chemical kinetics, asking students to recall what the class had already covered about chemical reactions (stoichiometry, energy changes, and entropy changes), but nothing so far about when and how fast a reaction occurs. She outlined on her shared electronic pad the three subtopics for this new unit: 1) rate laws, 2) reaction mechanisms, 3) models for chemical reactions, then posted the expression for rate: $\Delta[A]/\Delta t$ or dA/dt, emphasizing that those students taking calculus will be well familiar with expressions like this but those students who have not taken calculus would learn just what they need to know to be able to understand kinetics. This was a lot of dense content for a shortened period and RH admitted after class that she felt pressed for time and sped through the material. I sensed her eagerness to present and go through the new concepts while she acknowledged places where she could have touched the brakes on her pacing. She offered to ease more into this material next class and check in more for questions.

On October 23 (recognized as National Mole Day by the ACS), EH introduced the mole concept with a mention to the Italian scientist Amadeo Avogadro and his invention of the standard unit of measure for all elements, the mole. She briefly reverted to a short lesson in entering numbers in scientific notation into calculators. “Now the magic happens to be able to convert numbers of atoms to moles,” she said. Then she followed with a dimensional analysis example on the board, then put a problem up for students to work on. “OK, beautiful – you got it!” she exclaimed to a student after looking over her work. “OK, you’ll have eight questions like this for homework. The more you do for practice the better.” This particular class was a college-prep class as opposed to an honors-level class. EH moved at an even pace, anticipating math questions and corrections for the remainder of the class, with the goal of this new topic part of the lesson to set students up to be able to convert between numbers of atoms and moles.

PK’s AP class was being introduced to Lewis dot structures (LDS). In PK’s school, AP Chemistry is a first-year course, unusual for most high school chemistry classes. In introducing LDS, she based her presentation on students’ prior knowledge of valence electrons and electronegativity. There were no questions as she asked students to recall and apply these concepts in this lesson. Posting on slides, she first illustrated H-H and Cl-Cl showing the leftover unshared chlorine electrons and making the point that the pair of shared electrons between atoms represent a bond between the two atoms. “The goal is to give each atom eight electrons. When you draw a line between two atoms it represents a pair of shared electrons. The unshared electrons we'll call "lone pairs." Two shared pairs represent a double bond; three shared pairs are called a triple bond." She then asked the students to all follow her method of LDS drawing by providing two examples using PCl_3 and HCN, asking students to first place the least electronegative element in the middle as the central atom, then drawing bonds and counting electrons so that every atom has its eight electrons. Students then completed their own drawings using CH_4 and CO_2 as examples, and she asked them to hold their papers to the screen so that she could assess their drawings. Each correct drawing was individually praised with the student's name. A few students needed to adjust their bond drawing with not all electrons used. She then offered a few more examples to draw including NH_3 and H_2O, both examples that included lone pairs around the central atoms. The students all seemed to get this and PK said to the class, "Good job everyone—are we all having fun now? I could just do LDS drawings all day long! We can have a quiz on this stuff on Wednesday, but it looks like you're ready now." After two more examples, Cl-Br and SO_2, she asked "How's everyone feeling? OK, good then let's go into breakout rooms and practice some more." She ended the 50-minute class excitedly sharing what tomorrow's lesson is about (resonance structures, LDS exceptions, polarity), presenting this as an appetizing *hors d'oeuvre* to whet the students' appetite for the next day's lesson.

DR began class (24 chemistry honors students, all remote) by asking if anyone had questions about electron configuration before Friday's quiz, showing a slide with the orbital packing order vs. energy and a distance vs. energy for orbitals graph. The 25-minute lesson was to be an introduction to periodic trends beginning with atomic size and relative attractive vs. repulsive forces that yield periodic trends, and if time allowed, an introduction to ionization energy. What preceded were 12 minutes, nearly half the class time, of increasingly in-depth student questions about the nature of electron orbits. DR pulled up prepared slides that were not originally part of this lesson to illustrate orbital shapes. A student asked, “Is the electron always in its orbital?” to which DR wryly replied “Probably,” a wonderful double entendre perhaps lost on the student. DR then segued by praising the class for many great probing questions and showed a slide of atomic radii as a trend both down a group and across a row of elements on the Table and discussing how to interpret this graph of atom size vs. atomic number representing two trends for elements both vertically and horizontally. With class time up, DR left the students with an unanswered question, “As we go down a group, atomic radii increase, but as we go across a period the radii decrease. But *why*?” Class was dismissed. Similar to PK’s lesson, DR also employed these end-of-class invitations to join class the next day in an attempt to pick up with the curriculum’s story-like aspect and to provide a seamless, inviting, class-to-class rhythm that had the students continually engaged.

Teaching a review lesson. RH taught both 9^{th} grade physics and 12^{th} grade AP chemistry. In her interview, she said she felt at her best as a teacher when she taught these courses back-to-back, emphasizing the excitement of teaching students who differ in both age and level. In one physics class observation, RH was reviewing assigned determining velocity and acceleration questions using an organization rubric she created called PUCES (pronounced ‘pukes’ for the humor effect: picture, unknown, change, equation, and solve). RH used cold-calling to elicit responses, acknowledging correct answers always using the students name in her affirmations. When one student did not know the answer, she asked the class if a friend could help him out and when the friend provided the correct answer, another girl spoke out and said, “I was going to say that!” to which RH replied, “Good, I’m glad because it’s the right answer!” Part of the lesson was spent with some review of dividing by fractions with the using $\frac{1}{2} \div 2$ as an example and a drawn analogy to a half of a cookie that two people must share. ‘What part of the original cookie does each person get?’ The example spoke to the visual learners, of which RH proudly claimed to be one. Through the rest of the class, RH stuck to the lesson on determining velocity from the slope of a distance vs. time graph, while constantly checking in with her students understanding, regularly pausing for “Any questions? Are we clear?”

SD’s 27-student AP class was to complete a lab on molecular geometry. The class met for 90 minutes. It was really a review of molecular structures and a lab in the sense that students were presented with a problem and then asked in groups to solve the problem using applied data (given structures from a chart) and home-provided molecular model kits to build and draw the unknown structures. “For those of you wanting to work ahead of class, you’ll find everything posted on Schoology” (the school’s class posted platform). Previous to this class, students learned about bonding vs. non-bonding electrons, resonance structures, VSEPR theory, octet rule, and formal charge, so this lesson was built around confirming these concepts visually. The presented problem for students to solve individually was which two of the four molecules have similar molecular geometries based on VSEPR: SiF_4, SF_4, XeF_4 and SO_4^{2-}. As students were creating drawings and answering questions on ClassKick (another school platform used by the school's science department to present and submit student work) about each molecule such as identifying the numbers of bonding vs. un-bonding electrons, calculating formal charge, and so on, SD was able to view individual student drawings through the electronic platform. Roughly 40 minutes was used for students to do essentially a guided inquiry POGIL-like activity. A student asked, "Could XeF_4 also be square planar in addition to tetrahedral?" Another student asked, "What about an expanded octet?' SD replied, "Listen all, we're talking about molecular geometry, not VSEPR." Student: "I know. It's 'see-saw' shaped!" SD: "Yes, isn't that a crazy name?" (she held up a distorted tetrahedral sp^3d bonding molecule made from a kit to illustrate the see-saw shape). Students mostly worked quietly and quickly through this activity. When most were done, SD asked, "How about a thumbs-up if this activity has given you a better sense of creating molecular structures?" Most thumbs went up. To summarize, the class was steered back to the original question about which two shapes are similar. A student called out, "I know, it's numbers 1 and 4!" (tetrahedral SiF_4, octahedral SO_4^{-2}). Students were sent to virtual breakout rooms for the remaining 15 minutes of class to discuss and compare their answers. When called back, SD asked if there were any more questions, praising their work for today's lesson, and leaving them with "I hope you all have a wonderful Thanksgiving, and I am thankful for all of you for being such awesome students!" One student remained after class to ask why the octahedral-shaped molecule has only six sides to which SD replied that it is octahedral because it has six electron domains, not all bonding pairs. The student then wondered out loud why October is actually the 10^{th} month. It was a funny exchange and one that demonstrated the curious questioning and academic risk-taking environment that SD had created in her classroom.

Teaching about data collection and interpretation. In a variation of the classic emission spectra analysis using gas discharge tubes, EH placed several gas discharge envelopes around the room with the tubes already in their electrode holders and a hand-held spectroscopy clamped to a stand in front of the tube at an angle to maximize the line spectra observed inside the scopes. Students were instructed to take a photo using their cell phones, a novel use of student phones, and then upload the image to their Google Drive, where they were to then sketch the line spectra using color pens or markers. Students were to compare their sketches with known spectra to determine the unknown gases in each of the tubes. As a second part of this experiment, students worked in pairs to complete a PhET gas discharge tube simulation of the same unknowns to compare their live results to the simulations. In post-lab with the class, students claimed their results were *better* when performing the spectra observations live versus the simulations, a new understanding confirmed by EH again in her post-observation interview. EH shared after this experiment that nothing can replace the actual flame test procedure associated with this experiment in terms of producing and visualizing colors of light and how they relate to energy absorption and emission.

Teaching about discrepant events. AM performed a classic demonstration with a twist. The demonstration comes in different forms but typically involves two measured volumes, when mixed, that do not add to the sum of the two volumes. Her discrepant event involved mixing 500 mL of 1*M* HCl with 500 mL of 1*M* NaOH and seeing that the volume increases. Before answering “why,” she went directly into the mole concept with the intent that this would help students answer the “why” themselves. With the class agenda posted, the lesson began with, “We’re going to try some asynchronous learning today,” a transparent demonstration to try something new with her class.

Teaching a POGIL-Inquiry Activity-PearDeck-Jamboard, PhET Simulation. DR’s Chemistry I Honors course was using a PearDeck activity to review the mole concept for the next day’s quiz. PearDeck is an interactive application that allows students to share answers to questions with the entire class and has become popular while remote teaching. DR posted a question with a “Think/Group/Share” prompt for students working as small groups in breakout rooms. The question was about two sulfur-oxygen compounds being decomposed, given the masses of each of the two elements after decomposition keeping the mass of one of the elements a constant (here 1.00 g S for each and 1.00 g O and 1.50g O), and finding the ratios of S:O to then suggest formulas for these two compounds. The concept behind this is the Law of Multiple Proportions. Students were struggling with the mass ratios in making formulas that make sense. DR calmly suggested using ratios other than the masses as a gentle nudge in the right direction. One small group shared a collective “Aha!” moment and set out to then finding the moles of each element to then find the ratio for the formula. In another breakout room, one student was guiding the others in calculating moles from grams. The groups all seemed to get along and everyone was actively participating. It was clear that this cooperative tone had been established in the larger class with trust and high work standards.

In one of AM's classes, she began by asking each student to share something fun they did during the long weekend. Ten minutes in, she was going over dimensional analysis and converting units using a Jamboard to present the material. Jamboard is an interactive digital whiteboard presentation for classes, also popular in remote learning. Several examples were used to demonstrate the factor-label method of unit cancellations. A student asked, "What about when there's more than one unit in a question to convert?" AM, "Aha! I can see you're looking ahead. Great!" The last 10 minutes of class were used in small groups to work a conversion problem as an "exit ticket" (demonstration of understanding by the end of class). AM's final summary of the lesson to class was that she was teaching everyone a process for problem solving that would be necessary later in the year. The pacing and transition between the three segments of class were not rushed and seamless. The students were always on task with AM providing regular pauses and check-ins to affirm student understanding and answers to brief questions about how to round an answer or when to consider significant figures in conversion question. In another of AM's classes (10^{th} grade honors chemistry) she began by briefly going over the summative assessment students took the day before on dimensional analysis and mole conversions before moving to introduce atomic structure declaring "As we move on, don't forget the mole. It's a concept we'll circle back to in future units." She began the new unit introducing a prism and asking students how it works. It was a simple query, and the students mostly came up with plausible explanations using terms like "diffraction" and "separation' of light." This visual imagery led to a brief history lesson beginning with Democritus, then Aristotle, Galileo, Newton, and the development of practicing inquiry through the scientific method. Then AM led the class to the lesson's POGIL activity, an inquiry about light and waves, discharge tubes and spectra. The POGIL had 20 guided questions on these topics. The students were working together in small groups of three and it was clear from their discussion that they were applying some of their learning from their 9th grade Core Science Foundations course.

EH had students working on a PhET activity to build atoms. PhET is a high school teaching resource developed at the University of Colorado-Boulder that offers simulations in chemistry. This particular activity allowed students to add protons and neutrons to a nucleus, then to add corresponding electrons to either produce an electrically neutral atom or electrically imbalanced ion. She introduced the terms "cation" and "ion" referring to these as, "The fancy way to say positively and negatively charged ions." Near the end of this presentation, she added that being able to move electrons in and out of atoms is "What it's [chemistry] all about!" She explained using lithium atoms as an example of forming Li^+ cations, adding that lithium is important in both depression medicine and car batteries.

Post-Observation Interviews

The post-observation questions debriefing via a Zoom chat was held within 24 hours of each class observation, providing time for the participants to reflect on the lesson I observed (Appendix L). Participants' responses to these questions took approximately 15 minutes. Select responses are included here from these interviews and are paired with the classroom observations detailed in the previous section. The transcripts of these interviews were coded; the coded data table for the post-observation interviews may be found in the Coding section to follow.

Did you feel that your lesson was successful?

> **RH**: Hard to tell using Zoom, but I can regularly check-in with students for a thumbs-up and with a knowing nod. With the AP section it is harder to tell at times because I can see them diligently taking notes but they might not want to interrupt me, I can see smiles at my jokes and some good questions at the end of class, so overall successful. In another class reviewing a FRQ and introducing kinetics, I sped through the material feeling pressed for time, yet was conscious of the speed and made sure to pause briefly after each new idea introduced to ask for question, but the students all seemed fine with the material and know me well enough by now to stop me at any time if something is unclear. [After observing a two-day sequence introducing chemical kinetics:] Yes, the introduction to kinetics and rate laws worked because several students told me that it helped them understand the Ch. 12 concepts when they later looked at the example problems.

> **DR**: Sure, once I worked through the technical issues. I put together a question to have students not only differentiate between the Law of Definite Composition (LDC) and the Law of Multiple Proportions (LMP), but to be able to *justify* each to get them to use evidence to support a claim and how they might have a conversation with someone else about this. With time to discuss the question in smaller groups, I was able to visit each group and students mostly seemed to come to conclusions on their own, arriving at the type of thinking I was hoping to get them to. In my class on introducing periodic trends, timing was an issue. I made the decision to let students run with their questions on the nature of electron orbits because they were so thoughtful and I wanted to allow this freedom to question, maybe at the expense of the planned lesson but that's OK. I can pick up the pieces tomorrow.

> **EH**: Yes, for the most part. The students were able to answer my questions, especially understanding questions beyond those directly presented. The PhET activity assisted greatly here, especially for the visual learners in class.

> **AM**: Yes, because I was able to use student examples from the previous class that showed me their understanding (of dimensional analysis), and the students are beginning to feel more comfortable asking questions, and they did very well on the exit ticket! From another class visit observing a POGIL activity about light and spectra. Yes, mostly successful in that my intent was to activate kids' prior knowledge (from their previous Core

Foundations science class). I also had to correct several students' misunderstanding from yesterday's summative assessment about making a solution with a specific molarity. They misinterpreted the question by giving me calculations and conversation but I was looking more for the *process* involved to make the solution. Gosh, this would have been much easier if we were just in the laboratory together! Also, I happened to drop in to one group to see that they had decimal numbers for their mass numbers. This was a 'happy accident' as I then sent a blast to the entire class to remind that mass numbers must only be whole numbers as they represent the sum of the protons and neutrons and you can't have a fraction of a subatomic particle.

PK: Successful. Students weren't so vocal and they usually are when they don't understand something. I also affirm their understanding with an exit ticket.

SD: Yes, mostly based on the ClassKick (the school's online platform for receiving and submitting student work), the students were correctly drawing molecule shapes. I could have dropped in more to see their progress but when we came back together, there weren't any questions.

What evidence of student learning did you observe throughout and by the end of the lesson?

RH: I had a student at the end of class say, "Thank you, [that lesson] was so much clearer than the textbook, Zumdahl's 6^{th} edition!" Not much beyond pauses to see if there were any questions, and there were none for this lesson nor were there any looks of desperation, so I just continued on in another class on kinetics. I saw students engaging and smiling when it was funny and nodding when I explained a conclusion. If this class was live as opposed to remote, I'd also pause to do more examples and have them practice questions to affirm their learning.

DR: Most students were able to show that there were two different S:O compounds because of the LDC, but struggled somewhat to assert the LMP, and my open-ended question was designed to challenge their thinking here, even after they had heard the definition and seen an example from our previous class. Their struggle here provided good feedback about their understanding for me here. What I think is important as a teacher here is for students to be able to *apply* their understanding in ways they haven't necessarily thought of before. For me, that deeper understanding and application is where I am trying to get kids to. Though I don't think most of the students were quite there in this lesson, but was I hope instructive for them to experience this type of thinking. In the lesson on introducing periodic trends, the depth of the questions about electron orbits and making sense of the Schrödinger model was evidence enough for me here, though the online learning format presents a challenge so that I must 'dipstick' more often to check on the students' understanding, especially with the more abstract concepts that move me to constantly use more down-to-earth explanations and analogies.

EH: As I circulated around the room, I could see their math calculations, a few with crazy errors like getting 10^{46} when multiplying, so I knew to step back and review the math involved here.

AM: This has been tricky during remote and now hybrid learning. I can't do the routine "dip-sticking" with students to assess their learning, but try as best as possible online. In this particular lesson, I was at best only able to ask the entire class for any questions and you heard several kids unmute and ask their questions. Yes, most correctly shared what a prism does and during the POGIL activity I could see their correct answers as they worked together in small their groups.

PK: I feel that they were confident in grasping the material. There were no questions about how many valence electrons each atom could share. I see these students every day and I know when they don't understand things. In this lesson they're also applying prior knowledge [about electronegativity] and I could see from their drawing that they all looked good. I also know who the weaker students are and I can monitor them individually, but in this particular lesson they were all fine.

SD: If we were in-person they would be less inhibited and doing their work on a white board and holding up their drawings for everyone to see versus the online format.

Were there any elements of award-winning teaching that you exhibited in this lesson?

RH: I try to be myself in class, use humor, not take myself too seriously, I apologized to one class because of a mistake I made and then corrected myself with them, I use organizational rubrics (PUCES, UDAVE), and I make sure to try and call on every student at least once in a class period. Yes, one, that I had the confidence to bang out the answers to the multistep FRQ. This wasn't a masterful class, but yet I knew exactly what

I wanted to get through and I've done this before, nothing too creative here though.

DR: It is about showing students where you want to take their thinking skills that I'm trying to develop. Maybe this comes from being an experienced teacher. Part of my teacher responsibility is I have to have patience with this development as it's different for every kid and each can be pushed to some new level from where they start, and this differentiation is going to look differently for each student. I have a high level of confidence both my understanding of the curriculum and my ability to convey concepts to teenagers as well an ability to anticipate questions and some students' challenges in grappling with these concepts.

EH: Yes, the thinking questions, the more open-ended ones, give students greater confidence in taking educational risks, allowing themselves to be the source of questioning, not just me. This builds independent thinking which I know is important. This also allows me to do some 'research' with them, experimenting what works and what doesn't work. I have found from experience that students are excited to be able to ask knowledgeable questions in class. I need to know my students and how they best learn. When I talk one-on-one with each student, I evaluate how they best learn by one of three ways: by listening, by watching (visual), and by writing (note-taking), and I share this with them for their benefit. Many students return from other classes or back from college to share that learning how they learned in our class was important. With AP, on the first day I present to them that it's *us* vs. AP and I'm in it with them; *we* need to get that 5, and the motivation takes off from there.

AM: I'm not sure. I just kind of do it! I make sure that my format for each class is routine, beginning with an agenda, then incorporate a variety of styles in presentation such as using different colors, I've read some studies that use of different colors as a visual to help students break down problem solving. You become award-winning because you are studying pedagogy from experts, trying out things and seeing what works. Well, I would say that the main elements are experience, excitement, and passion. I love to emphasize science as a progression of knowledge that builds on itself.

PK: Ha! I don't even know what the definition of an award-winning teacher is. I pride myself in making strong connections with each student. I begin every year meeting one-on-one for 10–15 minutes to learn about who they are. The effect is this personal connection allows them to feel comfortable asking questions and taking risks in our classroom and the ease to stop me at any time in the lesson for clarification. This is especially important in AP where there may be a stigma to asking questions for fear of not appearing smart. My own children went here so I well know the stigmas and stresses students suffer in high level courses…. So, I teach a bit, show an example, then give them time to practice then check in with them for their understanding—this is just good teaching! I typically start with a Do Now activity and end with an exit ticket, so I'm constantly assessing understanding.

SD: (laughing) I don't know what that means! (recovering) I was just hoping to convey information with enthusiasm and show that drawing molecular structures can be fun and that you can challenge yourself to do these drawings and then justify them with your knowledge and understanding.

Was there any evidence of your beliefs as an educator on display in this lesson?

RH: That every kid can be an active participant in class, the course should be content centered vs. kid or teacher centered, that science is important, and that precision and accuracy of presentation are important. Making eye contact, constantly checking in for understanding knowing that it's my continual responsibility to clearly explain the work and interpret the textbook for them and to not just leave them to figure things out alone from the book. If this lesson were live I would have moved slower and given more time for students to do work in pairs or groups, and could have moved around the room to check in with their work. Yes, the reason I plowed ahead with the work was I believe the kids were all getting the materials and, especially with the higher-level math involved (calculus), I'd like to show them a bit more of a challenge.

DR: Yes, the *way* I asked the [S:O] question is evidence of my belief that students need to grapple with questions and their thinking instead of just providing a definition or asking a multiple-choice question. Don't get me wrong, I use those types of questions too. I want students to *evaluate* information to make conclusions based on data-based information. These are life skills that students can use beyond learning chemistry and science in general across many settings. Inviting questions at any time during the lesson, creating a safe environment to risk-take and allow students the space to say, "I don't know, can you help me understand?" Showing and knowing that I don't know everything is OK. I'm comfortable with this and I believe it's valuable for students to know that I still have things to learn. I have students in every class who are way smarter than me and will know far more than I do when they're my age, but my role here is to show them how to be their best selves and to give them the tools they need to be lifelong learners. In this sense I'm their encourager, their motivator, their coach.

EH: Yes, I understand students as learners directly informs me how I teach them. This year I have one group who are almost all visual learners, so I modify their lessons with more visuals. This is just good teaching!

AM: Yes, I suppose that every student should be able to be successful at learning to master the skill of dimensional analysis. Even though I said to them, "You have to do [dimensional analysis] *my* way," you embed in there using various methods such as different colors, cancelling units, identifying knowns, unknowns, and how to use the conversion factor. It's important to continually activate students' prior and outside knowledge and experience. I daily run through our class agenda so that they can see we're organized sequentially in our learning together. It's not about me just lecturing or running through a set of slides. Students should be able to succeed and develop concepts on their own.

PK: If students put forth the effort, they can achieve. It's my job to motivate them. I always say 'Keep trying, you can do this!' I put a lot of emphasis on practice problems, worksheets, using additional sources for reference, the Do Now and exit tickets, and encourage one-on-one after school meetings. I also believe formative assessment is very important in my teaching. I tend to introduce a topic slowly, carefully, then build in depth and pace as we move through a unit.

SD: Definitely. I always have inclusion on my mind as a teacher. I have several students of color in this class, some others with learning disabilities and I use my iPad to both give notes and to be able to then post notes for all students to see. I used to only do this for more important lessons but I now do it for every lesson so all students, present or absent, have equal access to the daily learning.

Is there anything you would change or modify from this lesson?

RH: I wish we had more instructional time! I should have worked the FRQ problem more carefully with them, showing them the step-by-step math when using the equation PV= nRT, but for lack of time I sped through this. They know by now that if they do have questions to stop me and no one did today.

> **DR**: Not really but if anything, more time. Knowing when to cut off questions and attend to the curriculum. It's always a balance between letting students run free with their naturally curious questions vs. sticking to the content. Obviously, bridging this gap is a constant balance that teachers seek.
>
> **EH**: Yes, more hands-on activities, especially with things that are more abstract like with organic chemistry and VSEPR and hybrid orbitals in bonding. Student feedback is so important. Being able to see students' faces and their reactions as you teach is difficult in remote learning vs. live.
>
> **AM**: Using the chat [in remote learning] more as another thread of conversation in class. Break up lessons more so that I can bring small groups back more to formatively assess their learning as a whole group discussion. I'm looking at this lesson's notes and see that I wrote in, "Next time give a break after question #14." It's important to reflect on how each lesson went for the next time you teach it.
>
> **PK**: Using more multimedia and innovative tools such as Pear Deck and other student interactive sites for the more visual learners.
>
> **SD**: Yes, I find that during the quiet down times (in this lesson) I am calling out for more responses….It's the remote learning format as in-person that would be lots of productive chatter and hand-raising. I miss this.

Common themes and assumptions from these classroom observations and the participants' reflections are discussed in Chapter Five.

Student Artifacts

These are items that participants selected and offer an insight to each teacher's core beliefs and practices. The works submitted here vary from a problem set with teacher corrections to responses to a molecular modeling activity and an inquiry-based challenge to figure out a way to determine the number of marbles in a jar, an example of indirection observation and measurement so important to emphasize in teaching high school chemistry. Several of these student responses were to design activities that feature the teacher's creativity and belief in establishing a forum that features a focus on student learning. The artifacts were shared with me over the Fall of 2020. I will summarize each of the pieces of work selected and each participant's beliefs about why that particular item was chosen.

From RH: The student work selected was a set of WebAssign problems from AP Chemistry involving molar concentration calculations for volatile and non-volatile solutions, part of a unit on colligative properties. The student had been struggling but clearly took the time and effort to write out each of the two problems with each step carefully labelled. Though parts of each problem were incorrect, RH spent as much ink as the student had making corrections and explaining how each of the step-by-step calculations were used to work the problem. RH told the student that once she received these corrections that they could follow up with an email or Zoom chat. Following this, RH shared:

> My teaching philosophy here is two-fold: First, that students learn best by writing out problems and not passively reading/hearing the material, and I insist on this when problems occur; and second, that I am pleased to give feedback to kids who need it (with frequent back-and-forth of problems ahead of the due date to make this happen). I don't accept or do this with late work, also a part of my beliefs as a teacher.

From EH: The student work submitted by EH included a laboratory experiment involving emission spectroscopy and electron behavior as a prelude to learning about electron configuration, and she also selected several different research paper assignments. The objectives of the spectra analysis involved observing emission spectra of heated gases using a hand-held spectroscope, sketching the spectra, then comparing the observed spectra with known spectra for specific gases to identify unknowns. The student work was to take a picture of the line spectra through the scopes using student cell phones, upload the photos to a Google Drive, and then highlight the sketch using colors from the line spectra observed to compare to known gas spectra. Then the students completed a PhET simulation of the same activity using three known elements: hydrogen, neon, and mercury to compare to the three unknowns from the hands-on activity. EH explained why this self-written experiment was useful and how it demonstrated some of her pedagogical beliefs through this activity:

> I have always found that it is difficult for students to grasp the idea of energy levels, the quantization of energy within the atom, and the fact that electrons can reach "excited states" through the absorption and transition to their ground states through emissions. Bohr's model is a great start to this concept because they can "see" that there are allowed pathways where the electron travels. Students come to this lab after the conclusion obtained from the photoelectric effect was understood. I transferred it assigning a set amount of energy to each energy level, and then I say to the students that once the electron absorbs extra energy, it could no longer stay in its original ground state and that it would move to the correct level for the new amount of energy it now had, now the excited state. I discovered that once this makes sense to them, I can safely explain what emission is by saying that the electron tends to lose the extra energy, hence it had to "come down" to levels, not in between. The evidence of this is if that transitions from higher to lower energy levels can be observed through instrumentation or even with our own eyes, visible spectra, then this is how this lab brings that concept home! This year I thought to use a PhET simulation lab to replace the flame test which I would normally do as part of using the gas discharge tubes but I must say that the simulation can't replace the real thing, and I wanted students to be aware of this fact. I had always used the discharge tubes and this year placed them around the room and clamped a hand-held spectroscope on a stand at the best angle to see the line spectrum for each element. I thought to have them take photos of the line spectra with their phones and upload to their drives to be able to analyze their observations more carefully. The students realized a big difference between what the simulation spectra looked like and what they observed live. The combination of the PhET simulation and the live lab minimized the guessing on how to interpret their data, and I'll probably add some post-lab questions based on these student observations next year.

EH's beliefs about student feedback to inform her as to how to improve upon a self-created assignment were on full display here. Her novel and creative way to have students obtain data by using their cell phones, definitely a "hook" for students who are typically told to hide their cell phone throughout the day, offered added student incentive for this activity as the use of electricity, colors of light emitted, and a challenge to identify unknows already provide plenty of "eye-candy" for this classic experiment. Finally, EH's look ahead to teaching electron configuration through students' understanding of energy levels was a part of her attempt to have students "see the bigger picture" in chemistry confirmed a stated mission of her classes.

The second set of student artifacts EH shared were research projects that she assigned in pairs each term beginning with the second marking period. The assignment for the second quarter was called "It's Elemental," with each student group choosing an element, researching it, completing a Power Point presentation, and teaching the class about their element. The assignment guidelines and rubrics were four pages long and were provided with a dozen suggested websites to help students with their research. Two of the shared slideshows clearly exhibited student interest, artistic license, relevance, and humor. One can only imagine the care the students placed in these assignments was a function of the thought and belief EH had shown her students in assigning it (EH shared that three of the four students in these two groups have declared an interest in majoring in chemistry at the college level). The third quarter assignment was another research project that focused on organic chemistry. Students were given possible topics but encouraged to discover a topic on their own, with prior approval before beginning their research. The final project in the fourth quarter was titled “Chemistry and the Environment.” The shared slides were full of embedded photos and links, graphically pleasing to the eye, and included chemistry that had been learned throughout the year. EH said that these final projects affirm her students’ ability to demonstrate their learning through creative, artistic, and novel ways, ways that taking written assessments cannot do, another of her core beliefs and a common feature of AWT.

From SD: The shared student artifacts from SD were from a four-week assignment called “Family Chemistry Project” (FCP) that she and several colleagues created over a decade ago and was used in all levels of chemistry at her school. Students identified a family member from a previous generation and a chemical, then used interview, library resources, molecular models and material from class to construct a poster that was then part of the FCP presentation week with a gallery walk where students visited each other’s posters and had a chance to learn more about their classmates’ family history and the chemical they chose. SD reported that there has been great excitement and interest during FCP presentation week, with many students relating that they got to know their selected family member in a way they had not known previously, and that it was great to learn about other students’ family members and histories. The student artifact was a FCP story and interview with the student’s grandfather and the chemical she selected was candlewax, a hydrocarbon. The submission was a beautifully constructed webpage with links to professional looking scenes from the grandfather’s childhood and a touching story of his growing up in France before coming to the U.S. as a refugee during WWII. It was truly impressive. SD believed strongly that this assignment

> is a chance for students to "be real" and show their authentic selves in chemistry by walking around [during FCP week] and sharing conversation in the same way that scientists share research. Every student has a story to tell and it suits so many learning styles: kinetic/tactile building molecular models; visual with posterboard or website; artistic and creative outlets—there are no restrictions for the style of presentation; audio for interviews and recordings; writing and research; and analytical for putting together a presentation in a cohesive format. It's wonderful to see students not necessarily engaged in science learning come alive by sharing their family story related to chemistry. We've had stories about how parents were married, grandparents who escaped Nazi Germany, a great-uncle who synthesized aspirin (acetylsalicylic acid), family members who have won Nobel prizes, and so many more. Although the focus of the project is researching the properties and molecular structure of chemicals, truly, what the students gain from their experience is connecting chemistry to their family history.

From DR: The student work shared were two responses to two activities (both from a chemistry honors class of mostly sophomores). The first activity was understanding inter- vs intramolecular forces through modeling with tiny marshmallows and toothpicks. I could see that students were able to visualize and articulate the differences between atoms vs molecules. He created this activity with the belief that chemistry teachers must make the microscopic world visually macroscopic for students, helping students to

> create accurate mental models for things they cannot see by using simple activities that are accessible to all students at all levels and supports mental modeling skills. Students often confuse intermolecular forces with intramolecular bonds, so this visual and manipulative is helpful for students to *see* the differences between the two.

The second activity was really two activities in one and the first time DR had used these, designed specifically for the shortened 30-minute once-a-week periods created during the changed hybrid learning school schedules. Students working in groups of three were given an empty jar and lid and another similar jar filled completely with marbles with the lid on, a single separate marble, and an electronic scale. The challenge was to determine the number of marbles in the jar without opening the lidded jar. The concepts here were several: To emphasize indirect observation and measurement, and to introduce the mole concept as a way of counting by weighing, and if there were the same relative masses, this directly relates to the same number of particles and vice versa. Student responses were generally on target in showing how to calculate the number of marbles in their jars. In the other activity, students were shown an image of two balloons, one filled with helium (He) and the other filled with argon (Ar), both at the same pressure and volume so that the number of gas particles in each balloon was also identical. A data table was presented with the mass of each balloon empty (0.010 g each), the mass of the filled He balloon (1.65 g) and the mass of the filled Ar balloon (16.51 g). The student challenge was to use the data to find the ratio of the mass of Ar to He in the balloons. Most student groups came up with the expected 10:1 ratio of Ar : He, which can be confirmed from comparing their atomic masses from the Periodic Table (40 : 4, respectively). It was clear that groups of three were helpful in talking through the problem together, each student contributing with making sense of the data collection and calculation.

> I would not have come up with these activities early on in my teaching career. Over time, I’ve gained a better understanding of student challenges around the mole concept. The idea of relative masses and the relationship between how many particles there are is one that students often struggle with, and I created this assignment as a way for students to *create* their own understanding instead of just learning the concept from a lecture or a textbook, a teaching belief that is crucial to thoroughly developing fundamental understandings before layering more complex concepts on those initially learned concepts.

From AM: The student work shared was a twist on the classic hydrate lab. This involved using a hydrated compound such as $CuSO_4 \cdot 5H_2O$, copper (II) sulfate pentahydrate, heating a measured mass sample of it until all of the water is evaporated, weighing the now-anhydrous sample to find the percentage of water evaporated to then determine the percentage of water present and, if the associated water molecule number is unknown, using the data to determine the unknown number of water molecules. It is a classic high school lab involving data collection using differences in masses, percentage composition and empirical formula, and pleasing color changes to produce the anhydrous sample and the rehydrate. The twist to this lab was AM's added student research for the two hydrates, copper (II) sulfate pentahydrate and magnesium sulfate heptahydrate, to also include safety data sheets (SDS) and LD_{50} information, synonyms (common names), and first aid information. These additions to the classic lab procedure came from AM's interest in toxicology and green chemistry. AM added:

> Students must create a flow chart, essentially a step-be-step procedure, prior to conducting the lab. I have always provided a complete flowchart after students wrote their observations during this activity. This is where the data are collected. I also purposely made an "error" in the data collection, only heating the hydrate once, so that students would have the opportunity to identify the error and realize the sample had to be heated multiple times until a consistent mass was reached. I feel that error analysis is a big part of any advanced chemistry course.

The student work that AM shared, in multi-colored ink, showed a clear flowchart with both observations and recorded masses on the side of each step in the chart. It followed the instructions laid out in the lab procedure.

Making sense of these submissions as they related to award-winning chemistry teaching are discussed in Chapter Five.

Focus Group Interview

The focus group interview was the capstone data collection element for this study. It provided an opportunity for the participants to finally meet one another and share their educational beliefs as they responded to several open-ended questions that allowed them to expand on one another's responses. The ideas for protocol development came from Boston College Student Affairs, chosen because their suggestions most matched the size, length of time, and qualitative data sought for this study (https://www.bc.edu/content/dam/files/offices/vpsa/pdf/assessment/focus.pdf). The focus group interview for this study was designed to be held following all of the survey, interview, classroom observations, and post-observations interview data collection so that the participants could reflect with one another on quality teaching and beliefs after information on them as individual teachers had been collected. Due to the pandemic, the focus group interview was held on Zoom over an hour on December 13, 2020, using the questions found in Appendix M.

After briefly hearing a description of the protocol, the participants were all able to see one another for the first time and introduced themselves. Several knew each other from Boston-area professional development and NESACS student awards meetings. One had served as a teacher-mentor for another when she was just beginning her teaching career, and another had taken a graduate class with yet another. There was a connectivity to the group that I had anticipated but could now clearly see. It felt almost like a reunion. The italics, all-cap lettering, and exclamation points are my own added here to convey the emphasis heard during the group conversation.

Can you discuss in what way your award-winning status as an educator has influenced your teaching?

AM: I don't think the award-winning teaching (AWT) status really has changed any of my philosophy or strategies as a teacher, but I do know that it has provided me with more confidence to try new things in the classroom, and has recognized me more as a leader among my colleagues.

RH: I would agree, I think the confidence boost is really important, especially when you mess up or forget something, which happens. The confidence carries you to say, "Hey, we've all been recognized by these external awards, we know what we're doing, we've been at this a while now, and it'll all be OK."

DR: I agree. You know, the interesting thing about teaching is there isn't a lot of external feedback, most days it's just you and your students and the majority of feedback is daily received from them. It's important to be recognized externally for the bigger picture of your teaching, but the daily reward is when you see a student figure something out or put the pieces of your lesson together by the end of class.

SD: I agree with everyone, especially AM that the AWT doesn't really play into your daily teaching, but it does give you recognition, for me as a female minority science teacher. It allows a platform, that I do have the credibility to share and act on my teaching beliefs. Yet I'm still as an individual somewhat uncomfortable with the award-winning recognition. For the students, it is positive for them to be able to acknowledge someone in this role that might look like them and realize they could possibly be like me.

EH: I don't think about [AWT], I just teach. Even though we're almost done with the semester, I still feel the energy from opening days in September. I continue to enjoy what I do and I want this to be contagious. I love seeing the kids' eyes light up around learning chemistry. This always makes my day. I share with my students that if you love what you do, the awards and recognition will follow. It's that simple. When I found out about winning these awards I said, "What, why me?!" That said, it is appreciated to be recognized, especially when you have a down teaching day.

PK: I agree, I hardly ever even think about AWT. I feel lucky to be able to do something I truly love to do, and the passion naturally flows from that love, and the students see this and it helps to form the relationships you build with them.

If you are observing an award-winning chemistry teacher in class, what would this teaching look like? What would you expect to see?

DR: Obviously a knowledge and content base, a level of organization and planning, and, importantly, an eye on where things have been and where things are going, while in the moment working to put pieces together while constantly setting up for students moments for them to tie parts of the curriculum together themselves, a level of engagement and expectation that they're interacting with the teacher, with them themselves, and with planned activities all to move students to engage with the curriculum.

AM: I totally agree with all that, and can add that it comes with experience. For example, you can anticipate student misunderstandings and can help them see where we've been and where we're going with the learning. Another piece is the "It," the necessary excitement and passion. Obviously, this will look different from classroom to classroom, but we all know it when we see it, one teacher might act like a goofball, another the masterful storyteller but in these is a passion and caring that are part of that intangible "It" that I'd expect to see.

RH: Both such great answers. It's hard to add to that!

SD: I so agree. I know if I enter the classroom where high level teaching is happening, that there's all of this support, organization, and structure throughout that goes into what I would be observing, yet what someone without a chemistry background or the students would see is the excitement and engagement, and the students are in these moments connecting with YOU! And what the teacher is seeing is, Wow, they're really connecting with the content, so cool that we're the intermediary between these two classroom observations, and to outside observers they would see that there's clearly something good happening here, that the kids are clicking.

RH: I would add that [the teacher] sets both a small and a large focus. I know entering any of your classrooms, that I would see the small focus, the day's lesson, but I could also see how these fit into the large focus of your whole year and you're also talking to them as though they also share your love of chemistry and science.

DR: To add, with the highest-level teaching, the amount of reflection is off the charts. I see a lot of this in my role as department chair, and when I debrief after a teacher observation, the content is a given but they're thinking how do I know if what I just taught was what they actually learned, that these teachers are constantly probing their students for evidence of learning. These are the things you'd likely see each of us doing on a consistent basis, and also making sure that we are attempting to reach every kid.

RH: Yes, also an attention to detail, modeling caring. We're not looking at the chemistry as that is a given. Instead, we're constantly checking in with the kids emotionally and seeing that everything is going well.

SD: An AWT is constantly looking for many ways for kids to access the information, not just what's on the board but it's at once auditory, visual, kinesthetic, using multiple modalities, especially for students who struggle grasping the concepts. I'm sure that all of us are in touch with the nuances of connecting students to the material.

RH: Our experience allows us, as was said earlier, to predict student misconceptions and address them as part of a lesson. Actually, we did this just yesterday in class while teaching electromotive potentials and why they don't scale up as you would in, say, Hess's Law. But a student wouldn't know this unless they've seen it before and that you've taught it enough times to know that this is where students might have misconceptions.

PK: I would expect to see strong student engagement through the teacher's passion in conveying the information and students receiving this passion with an enthusiasm for learning.

EH: Creating a space in the classroom that encourages a love for learning.

Does each of you have a theory of best practices? If so, can you discuss this briefly with us?

RH: One piece is that you really need to have solid organization and structure underlying everything, then you build on that with content and routine, but I'm not sure if this is AWT strategy, maybe just fundamentally good teaching.

AM: In our district we've gone from one best practice professional development to another over the past decade, so as a teacher you take it all in and do some mental calculus about what will work and what won't work for you individually as a teacher. Then you try out some new things and see if they work. I guess this becomes philosophical, maybe because we're all science-minded, we figure that if someone has already done the work and has the data to show that a strategy can work, then why not try it to see if it works for me.

RH: I agree, for example if you like to tell a story at a certain point in a lesson and it seems to work to break the pace and let students have a light moment to digest what they're learning, you make a note to try it again and after a certain amount of time this practice becomes engrained in your teaching. Your strategy began as a risk, it was tested, and proven effective. No question you have to plan ahead, but then you must learn from your trying new things and then weave them into your teaching.

DR: We develop a lot of tools and strategies over time. The key is which tool to use at which time in your teaching. I hesitate with the term "best practice." Some look at it and say. "Well, if I just do this because this is what the research says to do, then *should* work for my students, too," but the AWTs look at what their students most need and then meet the needs of their students. It's that simple. That said, each day is different and the best practice is to figure out what the right tool is for the students at the right time. There's an art to knowing this, and a lot comes from experience.

RH: And, you know, some of this can change over time. Different expectations, understanding kids' homelives, being attuned to learning differences.

SD: And we also mature individually as educators. I recall leaving medical school and as a beginning teacher teaching way over students' heads because I had so much to teach but that over time, I've come to know that I must first make a connection with each student in order to have them meet my expectations. AWTs are adaptable and have a keen sense of students' receptiveness. It takes time to incorporate this into your teaching all while conveying the chemistry and meeting students where they are is really having a sensitivity to the relationship you create with each student. Once there, you can really work wonders with kids!

PK: If students understand the relevance of what they're learning, it makes more sense to them. So, I always try to show how concepts relate to their daily lives, making the material relevant.

EH: I agree, that's a piece of it. I began the year talking about COVID and risk management and why we wear masks. Relevance matters because then kids will immediately engage. Another piece is understanding kids' family lives as sometimes challenges beyond the classroom limit how kids can learn with you in our classroom. I constantly keep an eye on kids in this regard, and I try to help in ways I can, or refer them to those who can better assist them.

What experiences in your education and/or your life's path brought you to focus on perfecting your practice as a teacher?

RH: I would say that raising children has given me a better perspective on working with kids. I knew I was an OK teacher before being a mom, but being able to see how kids think about things has been greatly enhanced by parenting.

AM: I have two daughters in their 30s and I can definitely agree with that. Both daughters went to my school, which is big enough that they didn't have to have me as their teacher, but it was a bit sad when the second one graduated as I had many of her friends in class and knew them in ways way beyond the classroom. I've always had good relationships with all of my students but none like the ones with my daughter's friends.

RH: My school is small, and I'm the only AP teacher and taught my own children. My second child was in my class my first-year teaching AP which, looking back now, was not quite a disaster but fraught with mistakes, still dinner table conversation pieces my son likes to bring up!

DR: I agree being a parent helps tremendously. To add, I'm a super competitive person and have competed athletically at various levels, and know that constant improvement and bettering your game daily is part of me as a person and a belief I bring to the classroom. I always want to be the best I can be. My coaching also carries over to my teaching.

RH: Also, talking to others not in the classroom about their experiences unlike ours inform me. We all found chemistry fun and probably easy, but not everyone has, and learning from others what their chemistry earning was like is a valuable perspective on what the experience might be like for some of our students.

SD: I have three kids and at one point, all three were taking chemistry: one in college, another in AP, and the third in honors chemistry. I was constantly informed by them about their experiences learning chemistry at different levels. And no, they didn't seek my help when offered! The other formative experience for me was teaching public school in the Bronx while I was in medical school. My students were 4^{th} to 6^{th} graders, mostly Black and Latino. I was tasked with getting them interested in science and I can say that this experience was far more exciting and engaging than what I was studying in med school. That, on top of teaching at an inner-city high school in Boston for 15 years and wondering how students got to my AP class without having *any* experience in the laboratory. Such inequities! I didn't see myself as privileged growing up, but I certainly had opportunities compared to those less fortunate. So, my underlying drive for the past 25 years has been one of giving back to students without a pathway to get into science. That remains my mission as an educator.

PK: I reflect on my time in high school and remember the subjects I liked. I had two great teachers, one for biology and the other for English. In my country, after high school you chose your path: you either do STEM or humanities. So, when I declared that I like science and English, my parents were confused and said I had to pick one. In college if I liked the professor or saw that they had a passion for what they were teaching it was easy to pay attention and do well in their course. So that's what I try to incorporate into my teaching: making the material relevant, showing a caring and passion allowing the students to learn, for them to show interest now and possibly later in college. We end every year with student evaluations of their classes and every year I hear that although AP Chemistry is difficult, they say they were always eager to come to class to see what's new and interesting. Student happiness, eagerness to learn, and interest translates to success in my classes.

EH: Knowing PK's school having taught there for a year, there was automatic student buy-in. At my school now, there is a greater range of incomes, and it's a bit more challenging as a teacher to create this eagerness and interest. For life's experiences, my father is driven and loves his work as a chemical engineer. When I was a kid, he took me to his plant and showed me around. This was my first exposure to science. My mother is an educator and I saw how much time she spent worrying about her students. When I declared chemistry as my college major, I vowed never to become a teacher after my mom constantly thinking about her students 24/7, even though my sisters became teachers because they liked what my mom did. I remember my mother telling me I'd eventually come around because she felt I was good working with younger kids and could explain things well. Later, my husband took a short-term job in another state. No chemical company would hire me short term, so I took a job teaching at a local college and instant fell in love with it. Here I was, coming around as my mother had predicted! Of course, what happened was once you taste what it's like to teach, you can't leave it. I told my mom then that she was absolutely right. Moms always know. So, I bring this love to my own students now, that you, too, can discover something you love to do and even get paid to do it!

In what ways do you see yourself growing and developing further as an award-winning teacher? Why did you choose these?

DR: In my role as department chair, I see a lot of teaching, and of those teachers who teach kids with a myriad of issues and challenges, this is an area I would like to improve, to acquire those tools and skills to better help that population of students. It's inspiring to watch an educator work well with a broad range of students each with individual needs.

AM: Having moved to be an administrator as well as continuing as a teacher, the role of working closely with fellow teachers to help improve their teaching has been really exciting. I continue to be involved teaching outside professional development and Green Chemistry coursework at UMass-Boston. Before I retire, I see myself continuing to work with improving the work with fellow teachers and developing curriculum.

RH: I continue to volunteer to be a teacher-mentor and for school-wide things like developing schedules and organizing science events.

SD: I'm pursuing an Ed.D. degree in educational leadership and hope to change some policy in the future!

PK: Every year I learn new things that I can incorporate into my teaching, for example the recent SEI (structured English immersion) coursework we all did to teach to student whose first language is not English. How different is must be to learn chemistry in English if it's not your first language! Chemistry itself is a language with its own vocabulary. I'm now constantly looking for better ways to reach these students.

EH: A few years ago, I had two really challenging groups of students, almost all with learning disabilities and many ELLs. Strategies from SEI were helpful. I can do more with modeling such as using M&Ms or marshmallows and toothpicks, that sort of thing. I learned visiting my son's back-to-school night and meeting his biology teacher who my son insisted I meet. This teacher was laid back, clearly worked to get all of his

> students to enjoy learning for learning's sake, and didn't take himself too seriously. That brief interaction changed me, and I now strive to be more flexible, to emphasize the joy of learning, and this has led me to incorporate more music and games into my curriculum.

An understanding of the focus group interviews will be explored in Chapter Five.

Student Surveys

Hard copies of the student survey were originally to have been completed in participants' classrooms live and hand-collected for compilation. This became impossible following the move to remote learning after March, 2020, and to the no-outside-visitor policy schools maintained since then. It was impractical to ask the study participants themselves to administer the survey to their students given the judgement and biases students might feel. I chose instead to conduct the survey with students at my own school, where I had access to my colleagues' first-year all 10th grade chemistry classes using the same questions and Likert-style scale (see Appendix K). I collected the student data through Zoom's electronic polling function. All students remained entirely anonymous. Each class survey took approximately 3–4 minutes to complete. Surveys were taken in four colleagues' classes during January 2021. The results are shown below. Responses are numbered on a scale of 1 – 5 (1 = least or worst, 5 = most or best).

Table 5.

Student Survey

	1	**2**	**3**	**4**	**5**
Explains concepts well			6 (7%)	31 (37%)	47 (56%)
Teaches with enthusiasm	1 (1%)	2 (2%)	8 (10%)	21 (25%)	52 (62%)
Challenges students academically		3 (6%)	17 (20%)	29 (35%)	35 (42%)
Displays a sense of humor		4 (5%)	14 (17%)	25 (30%)	41 (49%)
Exhibits a love of the subject		3 (4%)	9 (11%)	13 (15%)	59 (70%)
Exhibits a desire to teach	2 (2%)	1 (1%)	4 (5%)	15 (18%)	62 (74%)
Tries to teach to each individual student		2 (2%)	26 (31%)	26 (31%)	30 (36%)
Adapts their teaching to best convey concepts			12 (14%)	34 (41%)	38 (45%)

Total N = 84

I acknowledge that these data do not correspond with these participants' students as was initially planned. Using the survey with my colleague's students instead can serve as a general reflection of what students judge and most value educationally in their chemistry teacher. An analysis of these data is discussed in Chapter Five.

Teacher Interview Protocol (by Zoom, digitally recorded)

1	How did you find your way to teaching?
2	How does your teaching demonstrate your beliefs about how your students learn best?
3	How has your award-winning status affected the way you see yourself in the classroom? Has this changed in any way how your students perform?
4	Why do you think you have earned your status as an award-winning educator?
5	What ways, if any, do you share your award-winning practices with others?
6	Is your teaching best described by "It," that elusive hard-to-define innate quality sometimes referred to as the natural gift of teaching, or is it a set of practices learned from experience over time? How do you define "It"?
7	What do you still need to improve your practice?

Table 6.

Coded Data: Teacher Interviews

	1. Relationship(s)	2. Caring	3. Trust	4. Resources	5. Collaboration	6. Strong Voice/Clear Instruction	7. Confidence	8. Motivate/Motivation	9. Teachers as Learners	10. Passion(ate)/Love
PK	X	X	X	X	X	X	X	X	X	X
DR	X			X	X	X		X		X
SD	X	X	X	X	X	X	X	X	X	X
RH	X	X	X		X	X	X	X	X	X
EH	X	X	X		X	X	X	X	X	X
AM	X	X	X	X	X		X	X	X	X

For the interviews, post-observation debriefings, and the focus group, if a participant used one of the phrases more than once, it was coded in the tables.

Relationships (1) refer to the bond or rapport that a teacher establishes with students and colleagues; Caring (2) is a thoughtfulness and compassion demonstrated by the teacher toward his/her students and an open thoughtfulness toward teaching; Trust (3) is having faith in, counting on; (4) Resources refers to access to school supplies, and also financial, community, and professional support; (5) Collaboration refers to a group effort or sharing between teachers and also between students; Strong Voice/Clear Instruction (6) represents an articulate definitive power of speech and delivery of instructional expectations; Confidence (7) is a self-assurance and conviction of belief; Motivate/Motivation (8) refers to encouragement and inspiration; Teachers as Learners (9) is educators also taking classes, attending workshops and conferences; and Passion/Love (10) is a great enthusiasm.

An example of relationships can be found in interviews with EH "Relationships matter;" in SD's and AM's demonstration of caring toward their students emotional well-being; in DR's student's trust in being able to provide risk-taking answers while debating concepts; and in SD's access to school funding for AP workshops and collaboration with colleagues. Strong voice/clear expectations was heard in RH's agenda at the beginning of each class period and goals for each lesson. Confidence was displayed throughout each participant's interviews and observations. Motivate/Motivation was heard in DR's "I'm like a coach, an inspirer." All of these teachers as learners participated in professional development conducting workshops, and teaching and learning from colleagues. Passion/love was heard throughout the interviews, survey questions about beliefs, comments from colleague, supervisor, and former students, and responses from the teachers themselves.

Codes were selected based on commonly heard words and phrases from interviews and confirmed as valuable qualities found in various QT studies (Fenstermacher & Richardson 2005; Green 2013; Rockoff 2004; Yeigh 2008). An analysis of these data and how these codes are demonstrated from the classroom observations and compared to both the Educator's Rubric and the ACS Guidelines will be explored in the Answered Research Questions section of Chapter Five. I note again that presenting coded data in this manner does not provide *depth of analysis*, which might be captured with a frequency of codes, but instead show the *breadth or range* of codes used for each participant.

Teacher Post-Observation Protocol (via Zoom)

1	Did you feel that your lesson was successful?
2	What evidence of student learning did you observe throughout the lesson?
3	Were there any elements of award-winning teaching that you exhibited in this lesson?
4	Was there any evidence of your beliefs as an educator on display in this lesson?
5	Is there anything you would change of modify from this lesson?

Table 7.

Coded Data: Post-Observation Interviews

	1. Relationship(s)	2. Caring	3. Trust	4. Resources	5. Collaboration	6. Strong Voice/Clear Instruction	7. Confidence	8. Motivate/Motivation	9. Teachers as Learners	10. Passion(ate)/Love
PK	x	x	x		x	x		x	x	x
DR	x	x	x			x	x		x	x
SD	x	x	x		x		x	x		x
RH		x		x	x	x	x		x	x
EH	x	x	x	x		x	x	x		x
AM	x		x	x	x	x	x		x	x

Table 8.

Teacher Focus Group Protocol

1	Can you discuss ways in which your award-winning status as an educator has influenced your teaching?
2	If you are observing an award-winning chemistry teacher in class, what would this teaching look like? What you expect to see?
3	Does each of you have a theory of best practices? If so, can you discuss this briefly with us?
4	What experiences in your education and/or your life's path brought you to focus on perfecting your practice as a teacher?
5	What ways to you see yourself growing and developing further as an award-winning teacher? Why did you choose these?

Table 9.

Student Focus Group Questions

1	How would you define award-winning teaching? What informs your definition here?
2	If you are observing award-winning teacher in class, what would this teaching look like? What would you expect to see and what qualities identify this teaching as award-winning?
3	Some say that best practices can be taught, others argue that it's innate. Can you argue for one, or the other, or both? Define "It," the best teaching that you know it when you see it.
4	How would you define what makes a teacher award-winning?
5	External teacher awards reward best teaching practices. What incentives do you think award-winning teachers have to practice and maintain award-winning teaching?

Table 10.

Coded Data: Teacher Focus Group

	1. Relationship(s)	2. Caring	3. Trust	4. Resources	5. Collaboration	6. Strong Voice/Clear Instruction	7. Confidence	8. Motivate/Motivation	9. Teachers as Learners	10. Passion(ate)/Love
PK	X	X		X	X	X			X	
DR		X	X	X	X	X	X		X	X
SD	X		X	X	X		X	X		X
RH	X	X	X			X	X	X	X	X
EH	X		X	X		X	X	X	X	X
AM	X	X		X	X	X	X	X	X	

Table 11.

Coded Data: Student Focus Group

A	X	X	X		X	X	X	X		X
B	X		X			X	X		X	X
C	X	X			X	X		X		X
D	X	X	X				X	X	X	X
E	X	X	X		X	X	X	X		X

The Student Focus Group Coded Data Table uses the same codes found in the previous teacher coded data tables. The significance of this coding of participant interviews, post-observation debriefings, and focus group interviews are explored in Chapter Five.

Student Focus Group Interview

The student focus group was comprised of students not belonging to any of the teacher-participants in this study due to the impracticality of conducting such a group at their school during COVID or accessing them electronically without the teacher present, but instead with 11^{th} and 12^{th} grade students from my own school who were accessible to me and who had already taken chemistry. The student focus group questions were an amalgam of the Student Survey questions and the Teacher Focus Group questions, re-tooled to provide a student perspective (Appendix P). The audio for this meeting was recorded, transcribed, and coded using the same codes as the teacher interviews and focus group. Student responses have been summarized below. To anonymize the students, I labeled them A, B, C, D, & E. The italics and exclamation points to emphasize points made are my own.

How would you define award-winning teaching? What informs your definition here?

> **Student C**: My definition is teaching that stands out not only to students and their peers, but also to other teachers themselves. They're a caliber above what would be considered just average teaching, and teachers around them know this, too.
>
> **Student E**: This is kind of funny to me because I don't know what the criteria are to earn a teaching award. When I think about good teaching that really stood out for me as a student, I think of it as a love for what you do, a love that is very clear to students, and the student can build off of that energy. Also being a collaborator and a sharer with other teachers.

Student B: You have to have a passion for teaching and for the subject, and it's also important to be able to combine styles so that there is a bit of something for all students, not just, say, the visual learner or just the hands-on learners.

Student A: Being flexible, not having a rigid, set teaching style.

Student D: Making classes simple to learn in. I'm not saying to dumb down the material, but to make transparent and clear *how* to learn in each class. What is taught should be made easily accessible to all students.

Student C: I definitely agree with all of this, that great teachers have the ability to see where the class is going and to make the learning accessible, and the teacher should have a deep knowledge of the material, and a desire to share this with students, making it more interesting to learn.

Follow-Up Question: Do you think AWT translates to successful learning?

D: This depends on what successful learning means. Is it about tests and doing well on exams? If so, this is different than using knowledge to go on and be successful beyond school. Successful can mean many different things.

E: Beyond grades, this is more about how receptive a teacher is to students' feelings about learning and being adaptive, not just to the content, but also to creating a classroom community where everyone is made to feel supported in their mission to learn. Also, having good sense of humor and a good sign of creating a comfortable classroom learning environment. Being passionate is important. Teachers must be approachable, otherwise they can be isolated from the students and that doesn't encourage successful learning.

B: I do think that award-winning teaching can translate to good learning, or at least learning that is inspired to make students want to go deeper and ask more questions.

C: Good teachers don't just tell *how*, they move students to want to know *why.*

If you are observing an award-winning teacher in class, what would this teaching look like? What would you expect to see and what qualities identify this teaching as award-winning?

C: Not just like a lecture, but more like a discussion. The conversation is not just teacher to students but back and forth and also between students. There should be a lot of give and take.

A: The teachers aren't afraid of tangents and aren't uncomfortable straying from the topic within reason.

D: The ability to engage students. They can make the most boring topic interesting! It's all about the students, their eyes glued to what's happening in class. That's the difference between just good teaching and great teaching.

E: In class, it would be really clear that learning is happening, there's no busy work. The goal of what's to be learned is very clear.

Some say that best practices can be taught, others argue that it is innate. Can you argue for one, or the other? What is the basis of your argument?

A: A bit of both, I think.

C: I'm a deep believer in people's ability to evolve from their experiences they have. I don't think there's anything innate about teaching, but it comes down to personality shaped by personal experiences, how they were raised, and their set of values.

D: Yes, I don't think it's innate either, but instead a growing and constant changing to adapt to one's environment to produce great teaching.

Follow-Up Question: Can you define "It," that elusive quality of teacher charisma that award-winning teachers often possess?

E: It's definitely a combination of a bunch of different qualities. I'm thinking of teachers who are almost unanimously loved, not only as a person but also their classes. Being understanding, flexible, loving what they're teaching, like science teachers showing that they obviously love science, which I think is why all of my favorite teachers have been science teachers! Maybe this comes from life's experiences or maybe they had a powerful teacher in their past, or maybe they had a horrible teacher and thought to right this wrong, to do better.

B: It is a passion and a personality think, they are easy to connect with and relate to their students, especially in a larger group, being able to make individual relationships and connections that are necessary for learning to happen.

C: I think it's easier to define what is *not* "It" in comparison to defining "It," like teachers who just teach to a test, especially state-wide tests. That's a turn-off. Teaching to the love of learning is what's important and teachers must demonstrate this first in order to then get learning to be successful on assessments. If the focus is just the assessment, you can't get to the love of learning. But if teachers get to the love of learning initially, everything else in the classroom will follow. And that's special.

A: The teacher must have a deep depth of knowledge so that anyone can ask a question and there will be an answer. That depth of knowledge gets transferred to their students. This conveys a trust between students and their teacher that is so important with teaching and learning.

D: I think it is easy to find "It." As long as you have respect between the student and the teacher. Earning respect from the student to the teacher can produce "It" and award-winning teaching.

Teachers are offered opportunities to win external awards to reward best teaching practices. Do you think there are other incentives to reward teachers for best teaching practices? If so, can you make a case for these other incentives.

E: I don't think that awards are an incentive, or they shouldn't be. Once the motivation to teach becomes anything other than a love to teach and share with students, teaching becomes corrupted. But that said, AP classes are different in that they have to get through a set amount of material and it's the teacher's job to guide the students through the curriculum to be able to do well on the AP exam. This is perhaps at the expense of showing a love or passion for teaching, so that the student motivation is less about a love of learning and more about preparation for the exam.

> **C**: Yes, in AP it's teaching that gets to the benchmarks, the goal being that students learn the material from the teacher, but I wouldn't call this award-winning teaching. I don't like classes where I'm made to feel like a number or a machine to just get a grade. I need that interpersonal relationship to make me feel I want to be in the class and I want to learn with that teacher.
>
> **A**: Any incentive to create those relationships will produce good learning. Caring about students matters a lot here.

I again acknowledge that these data do not correspond with this study's award-winning participants' students as was initially planned as it was impractical to survey teachers' students remotely. Using these responses instead informed this study about what students see and value in high school chemistry teaching. Their responses are examined for common themes and will be discussed in Chapter Five.

CHAPTER FIVE

DISCUSSION

Introduction

In this concluding chapter, I present a summary of my findings organized around a conceptual framework. Then I will interpret and discuss the coded data from teacher interviews and surveys, classroom observations and post-observations interviews, and focus group interviews as I answer each of the research questions. Finally, I will deal with common themes and assumptions that transcend the answering of the questions, framing a discussion of the significance of this study.

References cited in the literature review showed me how to observe, how to get, and finally how to maintain QT (Berliner, 1987; Green, 2013; Saphier, 2008; Vanderkam, 2014). Hutner & Sampson (2015) offer five elements of exemplary science teaching, as seen in RH creating an environment where students want to learn, DR's making student thinking visible, PK's engagement of students in activities that highlight a lesson's content, EH's finding ways for students to practice science, and AM's leading students to understanding the meaning of important concepts in science.

Awards highlight teachers' attributes and pedagogy but do not provide specifics about their actions or depth in detail for understanding QT (Shulman, 2001). This study documented the QT found in award-winning teachers' practices and can contribute to an understanding of QT, beyond adequate or effective teaching, from these portrayals. How to get to and maintain award-winning chemistry teaching is suggested toward the end of this chapter.

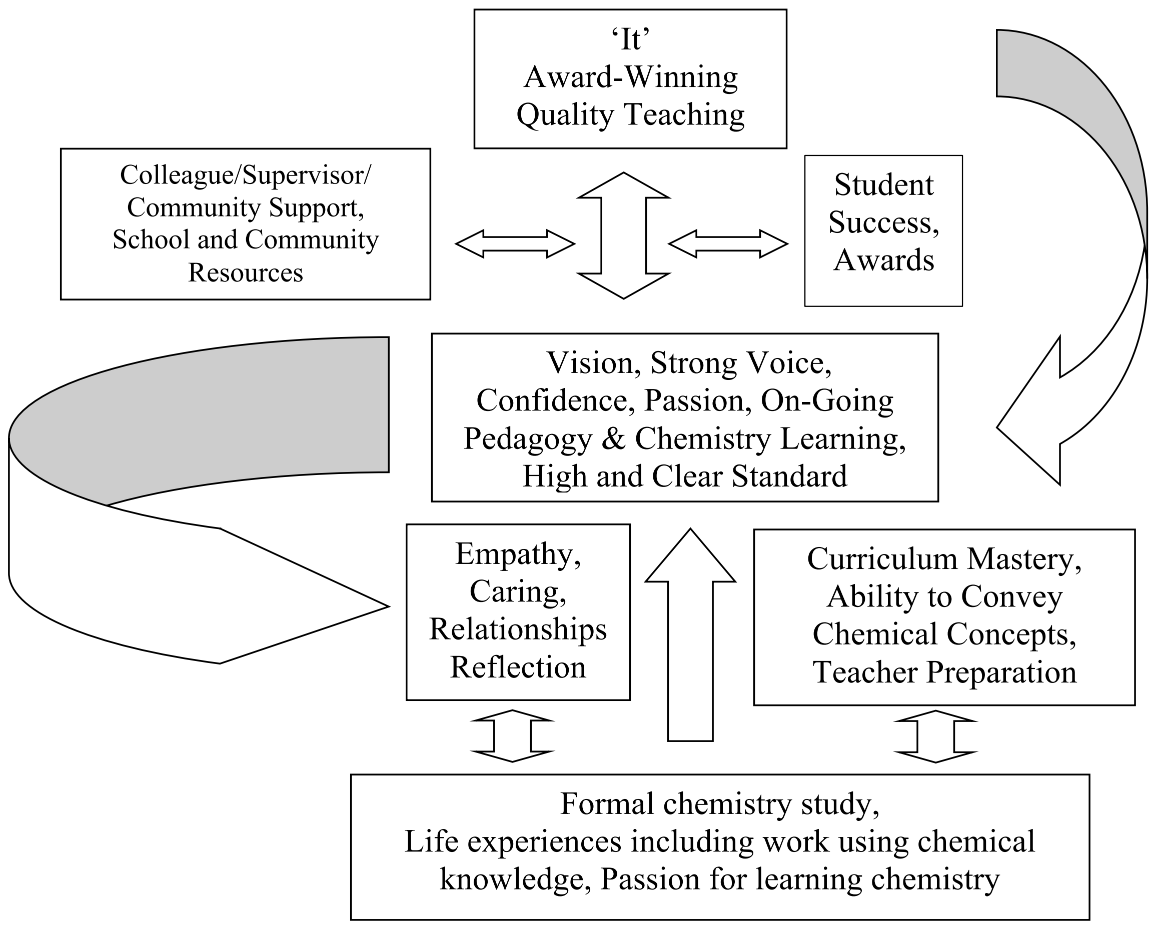
Conceptual Framework: Quality Chemistry Teaching in Context

Each of the participants achieved exemplary teaching status identified by their awards through a unique blend of personal and life experiences, educational backgrounds, and personalities. This is consistent with Stone's (2004, 2015) attempts to understand how QT is reached. Specifically, the participants here spoke of "always liking chemistry," "being surrounded by a family of teachers," "passion for understanding and teaching why," "A love of working with children." All taught at Boston-area public high schools. Two of the schools were regional high schools fed by several working-/middle-class communities, and two were in solidly suburban middle-class communities, and two were located in sparsely populated wealthy communities. Two participants were from the Midwest, two were from the East Coast, and two were foreign born (South America, South Asia). Two taught at the same school as their spouses, two were department chairs, and two were beginning Ed.D. degrees in educational leadership. Their educational backgrounds varied, from learning high school chemistry in different settings that included small parochial, suburban public, laboratory-university affiliated, and foreign British-system schools. Their universities ranged from small liberal arts colleges to large public and private to advanced technical institutes. They came into teaching through different paths. Their personalities and teaching personas were different. One described herself as "not the warm and fuzzy type, but caring and motherly," while another described himself as "like a coach in class, with clear and high expectations," and another as "not good at public speaking but at home speaking with teenagers."

Even though there were clear differences among these teachers, they shared characteristics that they believed helped them become exemplary teachers. One commonality that was striking was that all of the participants knew in their first year of teaching chemistry that they had found their profession. How they knew they had found their calling can be found in the teacher interview question #1, with the number of codes for "passion," "love," and "relationships." Vanderkam (2014) demonstrates that award-winning teachers possess a blend of intelligence, passion, skill, and dedication. The participants all demonstrated these qualities in this study, as revealed through interview, observation, and comments from colleagues, former students, and administrators. Given *N* = 6, and a range of background and life experiences, a greater sample size would have likely revealed an even greater range of these attributes, yet I believe it would also have confirmed a fairly consistent sets of common beliefs and practices that demonstrate and define award-winning chemistry teaching.

Common themes emerged that can enhance understanding about QT. These award-winning teachers shared a common language as heard in the focus group interviews about what their beliefs about teaching and learning were, what they identified as QT in their classrooms, and what influence their practices had on their students' learning. The factors that help explain QT are represented in Illustration 1.

Illustration 1: Conceptual Framework of Quality Teaching



There is a significant feedback in this framework required to get to AWT and QT. The basis of QT is a passion for learning and prior experiences in chemistry, including both formal education in chemistry and work experiences in the field such as in research, pharmacy, or the chemical industry. It is important to note that their preparation was not primarily in traditional schools of education, but through one-the-job learning, leading to an experimental teaching style that fit well with becoming a quality chemistry teacher. All agreed that their on-the-job learning, especially early in their teaching careers, far surpassed their education school training in providing insight to curriculum presentation, pedagogy around chemical concepts, and experience devising and running laboratory experiments for students.

Two factors feed a teacher's vision, voice, and confidence: a personality that expresses empathy, caring, and compassion alongside a mastery of curriculum, and the ability to clearly and authoritatively convey chemical concepts. The two pillars that support AWT/QT in the Conceptual Framework are the socioemotional qualities found in SD's empathy and caring toward her students, in AM's daily pre-class check-ins, in EH's addressing a student's sad face after class, alongside a deep content and pedagogical knowledge through mastery of subject matter with a relentless desire and action to improve and add to this base of knowledge and practice.

Beyond these individual qualities are external factors that included on one side colleague/supervisor/community support and school and community resources for both teachers and students. All participants in this study felt strongly that they were able to be award-winning teachers at least partially because of these supports and school/community resources. These supports included encouragement from department chairs to collaborate with colleagues around curriculum development and to innovate in the classroom and to maintain an autonomy that belies a professional trust between the school and the educator in the classroom. Several participants reported that their department chairs regularly secured grants for teachers to attend workshops and professional development. The community in each school district maintained a non-profit educational foundation that offered individual and collaboration grants to support teacher innovation. All of the study participants have received both individual and collaboration grant awards from their districts.

In addition, student success in chemistry competitions, student selection to competitive colleges and courses of study, and teacher awards all provide clear feedback that quality teaching is occurring. Recognition of success by these external factors feeds teachers' confidence, voice, and passion; confirms their visions of QT; and empower on-going self-improvement. These qualities, in turn, reinforce empathy, caring, and compassion. Though teachers in this study were not unanimous about the influence, if any, their awards had on their own teaching, a conclusion can be drawn from the shared comments from colleagues, supervisors, and former students that these teaching awards represented a positive reinforcement of best practices including innovation in the classroom, novel and effective pedagogy, strong, confident voice, and the further desire to share and collaborate with colleagues.

At the top of the framework is "It," the self-actualization of award-winning QT, which will be discussed in more detail later. Though I would not say that this framework represents a definitive roadmap to award-winning chemistry teaching or to "It," the data from this study suggested that this pathway with its on-ramps and feedback loops could be useful in conceptualizing the development of award-winning QT.

This study demonstrated that, though their personal experiences and backgrounds varied, the award-winning teachers shared many common qualities. These common themes will be presented in two way. First, the research questions will be answered, focusing on the ten codes from the data analysis. Second, a broader discussion of the implications will be presented with the goal of illuminating the significance of the findings.

Research Questions Answered

The sub-headings in this section come from the codes used throughout this study and are supported by evidence from the classroom observations, survey, and interview data.

Research Question 1: How does the award nomination process and language found in these nominations match the language found in the "Exemplary" standards of the Massachusetts Educator's Evaluation Rubric?

Teacher awards are one criterion used to promote and recognize quality teaching. Rarely are recognized teachers directly observed and their pedagogy critiqued by the members of the committees charged with selecting award-winning teachers. Awards are typically given based on a nomination letter and letters of recommendation from colleagues or supervisors/principals to a committee outside of the school. These letters support the nominated teacher with anecdotal observations, lists of school-based accomplishments, and student, colleague, or supervisor observations of the teacher's classroom practices. An external committee of educators then selects awardees among other nominees based primarily on these letters of support and, typically, a telephone, email, or in-person confirmation of the teacher nominee's worthiness of the award. Members of award committees are usually comprised of fellow secondary educators, administrators, and university professors. Having been the recipient of several of these awards, and also having served on award committees to select dozens of fellow secondary chemistry teachers to receive awards over many years, I have come to think that paying attention to the nominee's letters of recommendation actually prevents award committee members from observing these teachers in action, experiencing their quality teaching in their classrooms, and understanding from first-hand observation what award-winning might look like.

Teaching to all students. I heard from all participants that teaching to all students, from the least competent to the highest achieving, was a core belief in their teaching and belief mentioned in award nominations and award criteria. This cohered with the Massachusetts Educators Evaluation, Part III: Guide to Rubrics, Standard II: Teach to All Students (2018) which describes educators who

> Consistently define and set high expectations. Creates a safe learning and collaborative environment using rituals, routines, and maintains a safe physical and intellectual environment where students take academic risks. Establishes an environment in which students respect and affirm their own and others' differences and similarities related to background, identity, language, language, strengths, and challenges.

DR demonstrated establishing high expectations and a safe environment for student risk-taking in situations where his students debated questions and answers. Descriptions of his teaching from the Richards Award stated, DR "demonstrates the special effort and dedication that characterizes his or her interaction with students, both academic and extra-curricular." RH captured best her willingness to teach to all students as she taught the lowest level freshman physics course, with most students lacking resources to be successful, and the senior level Chemistry AP course back-to-back, stating that when she taught both of these classes she felt like a "whole teacher." SD's declared mission to get more students of color into the higher-level chemistry classes at her school showed her commitment to all students. AM's Richards Award revealed "results of a particular skill in communicating, especially to students not intending to become chemists, the role chemistry plays in their lives and in society." Also from the Richards Award was the notice of PK's "students who placed high in the Chemistry Olympiad and the Ashdown High School Examination Contest. These achievements might very well be more significant than the basic abilities of the student would suggest." EH's command of chemical knowledge and ability to share effectively with others was summarized in the USNCO Study Camp Mentor appointment: "Mentors are selected based on their solid chemistry background and their proven ability to work well with high achieving students." These teachers were not asked to adopt these qualities, but instead educators went beyond teaching classes and made teaching to all students a part of their QT.

Collaboration. Also found in the Educator's Evaluation Rubric, this was a common theme expressed as a belief and as a practice by all participants, who acknowledged in different ways that no one teaches in a bubble and that sharing with colleagues improves everyone's teaching. This quality was noted in participants' award nomination letters from colleagues and supervisors. All appeared to collaborate beyond the normal call to learn from others aligns with the Massachusetts Rubric (2014):

> Standard IV
> Consistently seeks out professional development and learning opportunities that improve practice and build expertise of self and other educator in instruction and leadership. Supports colleagues to collaborate. Examines student work, student performance, and planning appropriate intervention.

Collaboration among the teachers was exemplified by RH's numerous workshop presentations and publications, EH's overhaul of the entire chemistry curriculum with three colleagues who all joined the department simultaneously, AM's decade-long Green Chemistry Institute involvement bringing back curriculum to the department, PK's service for years as her school's Professional Learning Community Coordinator, and SD's annual receipt of grant awards to constantly improve her school's AP Chemistry curriculum.

Passion/love. Neither passion nor love are explicitly stated as qualities in the Educator's Rubric or the ACS Guidelines, yet as a code from this study were repeatedly referenced in the teachers' surveys regarding beliefs, in the interviews, and in both the teacher and student focus groups and in the literature. Question #6 from the participant interviews asked about the age-old "nature vs. nurture" in teaching: Is QT innate with "It" being the spark of personality, the inherent passion and personality, or is it a learned set of practices, or some blend of the two? A conclusion from participants' responses to interview question #6 about describing their practices as "It" vs. learned practices was that one informs the other. RH reported that she "made a lot of mistakes as a rookie teacher but through observing and learning from colleagues is why I'm where I am now. There are so many pedagogical tricks so that on challenging lessons or days, the 'It' emerges." All participants agreed that the passion and love for chemistry teaching alongside a deep knowledge of content and rich experience was what worked best to combine over time to achieve award-winning QT. In addition, their shared belief about the value of continually improving and striving for bettering teaching was tied to their passion and love for teaching. The data from student survey and focus group interview also demonstrated the importance of teachers' passion for the subject and love of sharing through teaching.

Teachers as learners. None of these award-winning teachers were done with their learning about chemistry teaching or their pedagogy in presenting curriculum. They were lifelong learners who were striving to improve and convey the results of this improvement to their students. They reported that their lessons were constantly being tweaked and improved based on a combination of student feedback, realizations about teaching concepts in a different or better way, and a relentless effort to constantly improve. Inherent in this quality was reflection both alone and in collaboration with colleagues, to be explored below.

Content knowledge. The solid background knowledge of each teacher came from their undergraduate majors in chemistry, graduate work in a specialized area of chemistry, work in a laboratory or company setting, and years of experience learning in the classroom how best to present a challenging curriculum. This strong background cohered both with the ACS Guidelines and the Educator's Rubric, Part III: Subject Knowledge: "Demonstrates expertise in subject matter and the pedagogy it requires by engaging all students in learning experiences that enable them to synthesize complex knowledge and skills in the subject."

Research Question 2: What beliefs about learning drive the work of these award-winning educators?

Motivation. Through this study, I have coined the term "relentless expectations," a drive that each of these teachers expressed and modeled for all of their students. It was found in RH's constant prodding to have her students question the curriculum, in DR's coach-like pushing of his students to adopt and practice analytical thinking, in EH's nurturing student relationships to move them to work for her academically, and in PK's beliefs that determination, hard work, and creating a genuine interest were motivators for student success. Each of these award-winning teachers went beyond the standard forms of assessment such as paper and pencil quizzes and tests, showing their interest in finding many ways for students to show success. Inquiry abounded in each of their classrooms. Their students knew that open-ended questions forced their learning through applying concepts to solving worthwhile problems. Teachers factored in both extrinsic and intrinsic motivation, although not in the same combination for all teachers. This was seen in DR's classes when students were encouraged to debate a particular formula or concept, when EH used discovery to help students identify unknowns in the laboratory, and when RH cold-called on students to consider where a formula or equation might have been headed during part of a lecture. In these and other examples, the AWTs moved the onus of learning squarely onto the student, with the teacher serving as a guide and inspirer to the process of learning. As DR said, "My role here is to show them how to be their best selves and to give them the tools they need to be lifelong learners. In this sense, I'm their encourager, their motivator, their coach."

Relationships, trust, caring. All of the participants created a respectful, trusting learning environment. Strong teacher-student relationships were fundamental to these teachers' practices. This trait is not explicitly stated in either the Educator's Rubric nor in the ACS Guidelines, but I think it falls on the "It" side of the spectrum of what contributes to QT. Experts on teaching agree that this "soft" side of teaching is crucial in QT. Palmer (1998) and Green (2005) argue that building strong classroom relationships based on such factors as trust, "going the extra mile for a student," clear expectations, and passion enable these teachers to get the most from their students. A recurrent theme throughout the interviews, classroom observations, post-observation debriefing, and the focus group interviews was that building and maintaining trusting, caring relationships was critical to promoting successful student learning. The strong relationships each participant created in their classrooms was a subtext of every lesson observed. The importance of relationships is further explored below.

Research Question 3: What aspects of their teaching do these teachers say are more likely to lead to good learning for their students?

Some responses from the survey questions inspired by the STEBI were conclusive, others not, but the small sample size limited making broad conclusions about QT here. All agreed on continually finding better ways to teach chemistry, demonstrating a need for constant improvement, never being satisfied with one set method and, as DR put it, paraphrasing David Tyack (1974), "There's no best way [to teach], but many right ways." This kind of statement aligns with Hammerness (2006), who portrays a function of QT as constantly clarifying a vision of teaching along with an element of constant improvement. Kenney-Kennicutt (2008) probes the aspirations of an award-winning high school science teacher and finds that his students' success is built on his constant improvement. This follows the old adage, "If the teacher is not [continually] learning, the students aren't learning."

Strong voice/clear instruction. Good teaching translates to good student understanding. This is captured by Brophy (1986) and Fenstermacher and Richardson (2005) who draw connections among many qualities, including force of personality, clear instruction, and active student learning, that contribute to increased student achievement. The consistent results of the participants' students scoring so well on the ACS examinations over the last decade speaks to this. DR's direct instruction to debate an equation, RH's calm yet declarative voice about the debate between physicists and chemists about certain definitions, and AM's authoritative "Do this my way!" declarations in problem solving all demonstrate strong voices and clear instruction.

Confidence. Hutner & Sampson (2015) put forward five necessary elements to exemplary science teaching including creating the need to learn, making student thinking visible, engaging in activities before delving into content, practicing science, and negotiating meaning. Participants' confidence that their efforts continually cause student learning, I would argue, are a result of practicing each of these five elements as seen in classroom observations and heard in interviews. Each of these teachers exuded a confidence and conviction about themselves as educators. Each emanated an awareness, comfort, and ease with who they are to their students, and a deep sense of self in their classroom. The ability to face one's self and bare one's soul to students through strength of voice, direct and clear explanation, relentless expectation, caring, and humor is what Palmer (1998) meant in his phrase "a courage to teach," in his book of the same name.

These participants all agreed that they know what to do to increase student interest in learning chemistry. These teachers created an encouraging, safe, trusting environment that encouraged students to take academic risks and conveyed a passion for learning science, chemistry in particular. This was seen throughout the interview responses, peer, administrator, and colleague anecdotes, and classroom observations.

Some disagreement arose as to whether the teacher is generally responsible for the achievement of students in learning chemistry (4 agreed, 2 were unsure). A possible explanation for this disagreement came from their discussions about students achieving top scores on the externally administered Ashdown and Olympiad exams. For sure, they said, an award-winning teaching was one contributor to the potential success of their students, but the schools, the households, and community resources available to these high-achieving students were all factors that might lead teachers to question that they could take full credit. All of these teachers believed in strong and active student effort in learning, and therefore they may attribute student success to the students, while taking less credit themselves than they rightly deserve.

The greatest disagreement was in response to AWT translating to high student achievement with two agreeing, two disagreeing, and two unsure. I related these answers to the teacher interview responses to Question #2 about how award-winning teaching demonstrated beliefs about best student learning. All of the participants responded here that building relationships was key to achieving student success in learning chemistry, though there was some unease in the interviews about making a direct connection between award-winning teaching and high student achievement. Some of this might derive from the humility these teachers expressed around winning these awards; four teachers claimed that "any of my colleagues could also have won these awards."

Research Question 4: What personal and career experiences contribute to becoming an award-winning teacher?

Similar personal and career experiences were shared in the initial teacher surveys and again in the focus group. These experiences included a solid chemistry background and a love of sharing this knowledge with students. All came to teaching from previous careers and knew within their first year as educators that teaching was their calling.

Parenting was important to each of the participants as it informed them about creating a trusting, caring environment while maintaining clear, strong expectations, and also about how to relate to teenagers and their parents. Being able to empathize with students and to form strong relationships based on trust while demanding high expectations be met were features that these teachers reported were rooted in their individual experiences as parents. Parenting also has helped these teachers communicate with their students' parents, a skill that all have said is important in making transparent their educational beliefs and highlighting parent and community support.

All expressed a shared understanding that as veteran award-winning teachers, they reach beyond just working to build their content knowledge to be able to focus as much on the lives of their students, attend to their socioemotional needs in class, and build and maintain relationships to motivate and push them academically. Many of these relationships extended into the school community with parents/guardians, as the participants here were longtime members of their schools and had, over time, come to know well families of many of their students.

All of these educators were humble, which complicated my efforts in finding out more about AWT from interviewing them. In describing their AWT status, they echoed each other saying, “Why me?” or “Anyone else in my department could have won these same awards,” as if winning teaching awards seemed to them a stroke of luck. This was unsubstantiated by the overwhelming evidence from colleagues, supervisors, students, and observations from this study that luck was not a factor in these teachers achieving AWT status.

Research Question 5: Do these teachers feel supported by their colleagues, administrators, and community?

There is ample evidence that the school culture and *milieu* contributed to growing the award-winning status of each of these teachers. Certainly, the school resources (or lack of resources in SD’s former urban school, forcing her to have to create, innovate, and collaborate), culture of high achievement, presences of supportive, collaborative colleagues, and freedom to create and develop curriculum aided in fostering their QT. Given that all of the participants admitted that the innate “It” quality was important in their own teaching, and each of these teachers demonstrated this inherent passion and personality, the coding and interview responses suggested that these teachers probably would have arrived at their current award-winning status regardless of the *milieu*. It is also likely that the resources available to these teachers both in the school and in the community and the consistent positive feedback from the success of their students served to further enhance their award-winning teaching. Praise and support, both from within the school building and from the community beyond the school house, affirmed these teachers as award-winning educators.

Research Question 6: Which attributes from these award-winning chemistry teachers might be distinctive to chemistry or science teaching in general?

All of the participants demonstrated various forms of unusually effective methods of presentation and pedagogy including use of POGIL (Process Oriented Guided Inquiry Learning) activities, flipped classes, inquiry and open-ended based problem-solving laboratory experiments, and the use of creative platforms for engaging students including PhET and Collisions simulations, Kami, Jamboard, and Peardeck. These methods of presentation cohered with the best practices ACS Guidelines for Teaching Middle-and-High School Chemistry (2018). These are pedagogical tools that all of the participants agreed were important to use as varied and effective instructional tools. Each reported experimenting with these methods, tweaking and modifying them to fit their instructional goals. None were completely satisfied with any one form, and all demonstrated continued learning about their uses. This experimentation was highlighted during pandemic learning as teachers sought more creative and varied methods of presentation while teaching online. When asked where these methods were acquired, all responded that they learned these practices from attending workshops or presentations as part of their on-going professional development. All attempted to engage student learning and place importance on students developing understanding around learned concepts, not just the teacher providing information for students to absorb. I myself learned of many of these best practices as two-time Coordinator for the ACS National Meeting *High School Day* (2002, 2007), where nationally recognized chemistry teachers held workshops and presentations to share these cutting-edge effective forms of pedagogy with attendees.

Participants used discrepant event demonstrations, data analysis, and inquiry with open-ended questions and problems that forced students to think and make connections with the curriculum, not just memorize or reply to rote learning, another best practice noted in the ACS Guidelines. Focusing on student understanding resulted in classrooms where students were able to take academic risks and question the teacher and the curriculum, hallmarks of award-winning chemistry and science teaching. This was seen in DR's inquiry challenge to find the number of marbles in a jar without opening the jar, EH's activity connecting spectral lines with identifying elements, and SD's predicting and drawing molecular geometries by applying VSEPR rules. Many of these qualities and methods can be extended to other teaching other scientific disciplines. All were on constant display among these award-winning chemistry teachers' practices.

Beyond the Research Questions: Topics Worth Further Discussion

What Was Not Heard or Seen

Lack of diversity among schools. Though the six participants in this study came from different nationalities, educational settings, socioeconomic backgrounds, and unique work experiences leading to their current professional positions, their schools were predominantly White and Asian middle/upper-middle socio-demographically and all were active in ACS. It was clear that using ACS awards as selection criteria had resulted in excluding participants from schools with mostly poor and minority students. It is unlikely that there were no quality chemistry teachers in those schools. Concerned about the exclusive nature of the ACS awards, I conducted an additional investigation of this issue after the original data had been collected and analyzed. I reviewed the procedures of the ACS for announcing the awards and choosing the awardees. I contacted the six participants again and asked them about their and their colleagues' involvement in ACS. I looked at the winners of the Richards Award for the past ten years in terms of their involvement in ACS and the type of school in which they taught.

Calls for nominations are sent electronically to science department heads throughout the Northeast. Nominations provided by department chairs came from school colleagues, department chairs, and NESACS members familiar with the participants' work. The awards committees, made up of a chairperson and other past awardees, then reviewed these documents and decided each year who is to receive these awards. Some attention has been paid to the diversity of the candidates and potential awardees, but perhaps not to the diversity of schools/communities. ACS has not actively recruited teachers from schools with students of lesser means and from minority communities for membership or award nominations, although the secondary school award committees work to increase visibility and access to nominations by reaching out directly to fellow chemistry teachers in schools not represented by award winners. To increase overall participation, ACS has recently eliminated annual local section (NESACS) membership fees with the hope that this would further encourage greater participation and involvement from teachers and districts with lesser means.

In the six cases in this study, school colleagues and department chairs were less familiar with the ACS than the participants but had responded to annual mailings and online announcements to consider nominations for these awards. An analysis of the Richards Awards from 2011 to 2021 revealed that all of the winners were active members of ACS. Almost all winners taught in elite schools with well-to-do students and plentiful resources. Only one of the 11 schools was outside Massachusetts. One school was in an urban area serving working-class and middle-class families from a dwindling White majority. One was an elite urban examination school with a diverse student body. One was in a White, middle-class suburb. Six were in White, well-to-do suburbs. One was an elite private school with mostly White students. These results are shown below

Table 12.

Richards Award Winners, Active ACS Members, School Demographics

Year	Awardee Active in ACS?	School Type, Community Demographics
2021	Yes*	Public, Suburban, mostly White, well-to-do
2020	Yes*	Public, Suburban, mostly White, well-to-do
2019	Yes	Public, Suburban, mostly White, well-to-do
2018	Yes	Public, Suburban, mostly White, well-to-do
2017	Yes	Public, Suburban, mostly White, well-to-do
2016	Yes*	Public, Urban, White majority, middle-class
2015	Yes*	Private, Suburban, mostly White
2014	Yes	Public, Suburban, mostly White, well-to-do
2013	Yes	Public, Suburban, mostly White, middle-class
2012	Yes	Public, Urban Exam, diverse
2011	Yes*	Public, Suburban, mostly White, well-to-do

* Indicates first year nominated – all others were nominated one or more previous years

The results of this mini-study suggest that the ACS awards programs do select awardees who are active in ACS and teach in schools where there is strong support and students that are likely to win awards, too. ACS can do more to recruit and award quality teachers from less supportive settings. More important, ACS needs to redefine quality teaching to include accomplishing good things in tough teaching situations. These findings also call into question the value of using teacher awards as criteria for selecting quality teachers as participants in research. While there is little doubt that this procedure did provide quality teachers to study, the lack of diversity of their school settings damages the applicability of the findings to teachers in the schools that need the most help.

Perhaps more important, QT chemistry teaching might look different in high-needs schools than in advantaged schools. This study's six participants come from mostly advantaged school districts and several criteria in assessing these AWTs involved competitive high-level student chemistry examinations. Teachers, challenged to push their students and provide deep, rich curricular experiences, were able to rely on student buy-in, language fluency, strong school habits, and support from well-educated parents. In more socio-economically diverse and higher needs settings, teachers face different challenges, including English language acquisition, weaker mathematical preparation, and mediocre metacognitive skills with respect to school habits. Whereas QTs in advantaged schools might be judged according to student success on national examination competitions, QTs in disadvantaged schools might instead have different criteria, such as college acceptance rate or student interest to pursue further study in chemistry or science in general. QT may look differently in high-needs classrooms and may need to be measured differently.

No slowing down. All of these teachers were veterans, all having taught at least 15 years, most more than 20. Not once throughout this study was the topic of retirement mentioned (the average age of the participants was 48.5 years; teachers typically retire in their late 50s or early 60s). Clearly, these teachers were looking ahead toward continued teaching and learning to improve their practices. Two began doctoral programs in educational leadership, while two others balanced their award-winning teaching with duties as department chairs. Even though they had been recognized numerous times as award-winning teachers, they certainly did not rest on their laurels.

No cynicism, pessimism, blaming. Given a profession built with institutional structures that might impede a teacher's creativity, autonomy, and community support, it was refreshing to see that there was no cynicism expressed in any of the interviews or in the focus group. Nor was there a belief that maintaining high standards was the effort of the teacher alone or that teachers' doors were closed literally and figuratively to collaboration and feedback from colleagues and supervisors. Schools' institutional politics and bureaucracy can breed feelings of defeat, yet pessimism, lack of faith in students' ability to succeed, criticism of parent and community support, faltering expectations, interference with family life, or excessive grading were nowhere heard from participants throughout this study. It is likely that the strong support of their particular school and community settings protected them from the worst effects of an uncaring system, but in any case, they were able to teach with a pragmatic optimism and high expectation for themselves and for their students.

Relationships. The important AWT quality of forming strong relationships is not found in either the ACS Guidelines or Massachusetts Evaluation Standards. Perhaps this is because exemplary teaching presumes that best teaching practices are built on forming strong student-teacher relationships. Caring, trusting classroom expectations that create strong relationships promote active student learning. Exemplary chemistry teaching should encourage active student learning (ACS Guidelines, 2018; Gallagher-Bolos, 2004; Spencer, 1999). Unlike traditional lecturing and note-taking, which make up the core of an ordinary chemistry teacher's practice, active student learning puts students to task around a particular problem or concept. Teaching and learning this way is risky, so good personal relationships and the trust it engenders may be seen as a prerequisite for active learning. There is a deeper discussion of the importance of developing and maintaining good relationships below.

The Value of Reflection

Though I did not create questions here to further explore the reflectiveness of these teachers, I found that all of the participants were reflective about their practice by virtue of their willingness to participate in this study and share their beliefs and aspirations as educators. The surveys and post-observation interviews offered ample opportunity for these teachers to reflect on one aspect of their practice. This was seen in DR's creation and delivery of the activity to have students estimate the number of beans in a jar without actually counting them, a model for predicted numbers of atoms in a mole of a substance. DR reflected on when in the curriculum to introduce this and how to get more out of this activity. What appeared as a fine exercise still demanded tweaking from DR's perspective. Reflection was seen in RH's constant self-correcting and verbalizing to her class's points in the lesson, or from the textbook, that she would do this differently the next time it was taught, visibly adding sticky notes to the pages in the textbook as self-reminders. Often, reflection was seen in interactions with colleagues as with SD's Chemistry in Family projects, created initially with fellow chemistry teachers and modified and improved upon every year with reflection from others after the projects had been completed.

Reflection in teaching allows educators the opportunity to improve. It is, some argue, a necessary teaching practice (Kenney-Kennicutt, 2008; Schön, 1990). The AWTs constantly reflected on student responses to a lesson, how a particular concept was presented, and the success of incorporating new methods in presenting a concept. The relentless expectations for students applied as well to each of these teachers themselves. They constantly reworked their lessons, aiming but never succeeding, according to them, in perfecting lessons, but nonetheless, over time, constantly reworking and tinkering with their presentations. From DR's rewriting and adding to activities or thinking through a lab activity on a jog home, to RH's sticky notes from last year as reminders what to add to particular lessons, SD mulling a lesson on the car ride to school, EH tweaking a presentation of light and atomic structure, the participants here were reflectively self-correcting and constantly using student feedback to augment and improve upon their pedagogy. In this, these teachers were their own hardest critics, so that what I saw as an outside observer was always works in progress, thoughtful attempts to build more perfect educational experiences. Reflection was the engine of their constant betterment. To paraphrase Edmund Burke, teaching without reflection is like eating without digestion.

The Indispensable Synergy of Content Knowledge and Relationships

Importance of deep content knowledge and practical experience in science.

All six of the participants majored in chemistry as undergraduates, four earned graduate degrees in chemistry, one of whom had a Ph.D. All participants had experience doing chemistry laboratory research, four of whom engaged in related work beyond college. One practiced pharmacy for 13 years prior to teaching. All of these prior experiences fed their knowledge base and laid a foundation for demonstrating their chemical expertise in the classroom.

The importance of strong content knowledge cannot be overstated. It is a standard for both the Educator's Rubric and the Guidelines, and is a quality mentioned in every one of the participants award nomination letters and supervisor comments. Demonstrating deep content knowledge forms the basis for trust and motivation for strong student learning. Data from this study showed that solid content knowledge allowed participants to construct more open-ended inquiry-based assignments, focus more on individual student learning, and practice a more creative, inventive pedagogy, the kind of instruction that the Guidelines promote as best chemistry teaching practices. This can be extended to teaching any other science disciplines. Just as Picasso was trained classically before creating a completely new form of artistic expression, AWTs must have the formal knowledge base in order to express their individual QT.

Importance of caring for the craft and for students. "Caring" had a special meaning for the AWTs in this investigation. Common to each of these teachers' classroom observations was the care and sculpted crafting of each lesson. There was clear direction in the trajectories and goals. Every student was held to a high standard, but no student was left behind. Although seemingly effortless, the thought, planning, care, and reflection involved was evident in every observation, down to the pre-lesson chat and check-in to ease students into class. I liken these teachers to master chefs, daily preparing artful, appetizing, eye-pleasing dishes for their hungry diners. Each meal is prepared from experience with personal seasonings and garnishes and is presented lovingly at the diners' tables daily. The expectation is to completely finish the meal and arrive back for more the next day. To extend the cooking metaphor, all of these teachers made their craft look like Asian-style cooking: 90% preparation, 10% execution. These teachers modeled daily for their students what caring for their jobs should look like.

Even though the participants claimed to be caring for their craft, data from colleagues and from observations indicated that they cared for their students as well. Indeed, I had to add a category for "relationships" to hold the clear evidence that their caring relationships were part of the foundation of their QT. Although prior research about science teaching and the standards of the profession and the state did not emphasize relationships, I found that they were an indispensable and integral element in their teaching. It is possible that these strong and caring relationships were simply a means to an end for these teachers, but the evidence showed that the relationships were warm and real.

How content knowledge and relationships work together in QT. As represented in the Conceptual Framework, both content knowledge and relationships encouraged trust and risk-taking for students. Deep, foundational content knowledge was the driving force of each lesson. Mastery of presentation was bolstered by regular encouragement to ask questions and to question the teacher and the curriculum itself. Students believed that their teachers knew what they were doing, both in terms of content knowledge and instruction, and so they developed confidence to try to learn something that at first might have appeared difficult. Though the teachers themselves talked more about love of teaching chemistry, comments from others showed that they were equally demonstrative about their loving relationships with students. The qualities of caring and empathy demonstrated by each of the participants added to students' buy-in, trust, and motivation to learn. The crafted relationships, both with individual students and with the class as a whole, were the product of the participants' demonstration of their passion to share with the students. The participants cared so much about their students' learning that they made sure their knowledge was current and accurate. Their lessons were designed to benefit all of their students. Students parlayed their teachers' passion for chemistry and for themselves toward their self-motivation to learn.

Participants created near-perfect classroom environments for learning. High expectations were obvious, but challenge was balanced by understanding that it was acceptable to take intellectual risks, to try out new ways of thinking, and to fail. The caring relationships, between the teachers and the students and among students, buttressed the feeling that these classrooms were safe places to take chances and to work very hard. Designing and maintaining classrooms for maximum learning can take a whole career to master; in fact, the participants were sure that they would never truly meet this goal.

Both the "soft" (uniquely personal socioemotional qualities which are the basis for developing strong student-teacher relationships) and "hard" (formal education, curriculum mastery, and professional experiences and training) sides of teaching worked together allow the participants to achieve QT and AWT status. Both sides are necessary. When these two sides of teaching come together seamlessly, they reveal the gold standard for teaching. The participants' educational backgrounds underpinned their mastery of the curriculum; their individual personal life experiences allowed them to made their practices suited to develop and maintain strong interpersonal relationships with their students. So it was as much who they were as what they did that made them QTs.

Getting to "It"

That mystical, elusive characteristic inherent in AWT that defies definition but all know when it is present, was evident throughout my time spent with the six participants. I observed deft presentations, seamless segues between topics, reliable wit and humor, constant charisma, rich student-teacher and student-student discussions, and student questions both grounded and in orbit that were all answered with authority, clarity, and enthusiasm. And behind the facetime with students was daily planning, constant revision, mulling, improvement, and continual reflection. The sum of these characteristics is wrapped up in "It," an AWT quality representing the highest form of QT without clear definition but ever on display throughout this study. In *The Snow Leopard,* Peter

Mathiessen (1973) described how he spent months tracking yet never finding the elusive Himalayan great cat about which little then was known. Though he never actually spotted one, evidence of the snow leopard's presence throughout his quest was everywhere to be seen. The author found this to be a metaphorical journey in seeking a higher spiritual state of mind just beyond his grasp. The elusive "It" in QT can be thought of similarly, hard to settle on a definition, but evident everywhere in award-winning teaching portraits.

All of the participants agreed that their own award-winning teaching has been some alchemy of innate qualities of passion, love of subject, and empathy versus learned techniques (almost entirely on the job). When pressed to define "It," most replied that it was a "passion," "love," or "joy" to teach that is conveyed to their students. As noted in Chapter Two, the literature supports studies from either side of this question, from the innate qualities of personality described by (Green, 2010; Palmer, 1998) to a formulaic analysis of QT that can then be taught and maintained to would-be teachers (Lemov, 2009; Saphier, 2008). Palmer (1998), in particular, argues that to get to the highest level of teaching through reflection, one must ultimately know one's self:

> Teaching, like any truly human activity, emerges from one's inwardness and [one] must project the conditions of [one's] soul onto their students. Viewed from this angle, teaching holds a mirror to the soul. If one is willing to look into that mirror and not run from what is seen, a teacher has a chance to gain self-knowledge – and knowing one's self is as crucial to good teaching as knowing [one's] students and the subject. (p. 102)

Others conclude that QT in general must have teachers know the subject well, engage students in high level learning, be reflective, stay active in the profession and collaborate with colleagues, and demonstrate an eagerness to go beyond the job description and take educational risks (Stone, 2004). These five practices referred to previously were clearly demonstrated by all six of this study's participants as noted by colleagues, administrators, and student anecdotes, as well as through classroom observation, interview, and focus group. The findings of this dissertation study suggest that the importance of relationships and reflection in getting to and maintaining AWT cannot be overstated. Each of these award-winning teachers crafted a learning *milieu* for students in their own, unique, personalized way based on individual preferences, experiences, and resources. But all relied greatly on developing strong interpersonal relationships with students to be able to carry out their "relentless expectations" evidenced from the attentive, responsive engagement of each of these teachers' students. The reflection heard throughout this study's data collection, in the interviews, observations, post-observations, student artifact explanation, and focus group, spoke to these teachers' relentless reflection and constant check-in, both with their students and themselves. Teaching, by definition, is a reflective practice.

I wonder if the qualities and supports from the Conceptual Framework shown at the beginning of this chapter could be provided and encouraged for a teacher, AWT and "It" could necessarily be achieved. Though this question might be the focus of another related study, what is clearly shown here is that these factors in varying degrees have collectively contributed to the award-winning teaching portrayed from this study's participants.

> At its deepest level, teaching is about bringing people in communion with each other, with yourself as the teacher, and with the subject you are teaching. Good teaching cannot be reduced to technique; (it) comes from the identity and integrity of the teacher (Palmer, 1998, p. 104).

For "It" to be purposely developed, I argue that when most if not all of the internal and external attributes as shown in the Conceptual Framework are present, then the highest standard for teaching becomes possible for any reasonably qualified teacher.

Conclusions

These teachers did match well with what the literature says QT is. My data support all of what the literature described as great chemistry and science teaching, portrayed here through classroom observations and heard from in interviews and focus groups. These teachers exhibited a great majority of the selected codes drawn from the literature on QT and from the Massachusetts Educators Evaluation Rubric and the ACS Guidelines for Middle-and-High School Chemistry Teaching and more than met my expectations from these sources. These two sources cover both general teaching practices considered exemplary by the Massachusetts Department of Education and the best practices for the teaching high school chemistry nationally by the American Chemical Society. The ACS Guidelines, written in a more generalized style, was somewhat less supportive than the Educator's Rubric. Varied data sources allowed me to visualize and experience participants award-winning practices that ticked many boxes in the Educator's Rubric. Interview and classroom observation data demonstrated the qualities leading to and maintaining AWT as shown in the Conceptual Framework.

The awards earned by the participants in this study did, in fact, reveal all of the attributes of AWT and "It," as attempted definitions of the highest order of QT defined both by participants and in the literature. The award process to validate AWT also matched the Educator's Rubric and ACS Guidelines sources, although the teachers' humility and my several visits per participant to classes, all online, prevented me from learning much more about becoming and being an AWT.

These teachers worked in unusually supportive work environments. There was strong community support both from the parent community and in the form of grants and awards for professional development. Students came to these teachers, as PK noted, "with wind already in their sails." The implication is that all teachers might be more likely to develop AWT/QT with broad and deep support from the school and from the community.

These teachers were unusual in that their career paths, although similar to each other's paths, were very different from the typical experience and education that leads most people to teaching. The implications might be that a unique blend of strong interest in chemistry early on, a strong educational background providing a deep knowledge base, work experience in the field, a school with a supportive community and access to resources might lead to award-winning teaching. Add to that an individual confidence, passion, empathy, and love of teaching and sharing with students to possibly achieve "It." Unlike citations in the literature that claim to provide formulas for achieving AWT, I am suggesting that the route that led these participants to achieve the gold standard for teaching carried all of these external and internal attributes, and might do so for others. This means that in order to improve the profession of teaching, more thought and resources should be spent on making sure candidates have solid education and experience in their field before they begin their training as teachers. Presently there are only a few people, like the participants in this study, who match these qualifications, and they were attracted to work in elite schools serving mostly students from well-to-do families.

I was struck by the ease with which these AWTs shared an immediate common language in the focus group interviews. Teaching in general, and science teaching in particular, lacks a common language similar to the ones found in medicine or law. Yet once these teachers were in the same Zoom room together, they displayed a shared understanding of QT by using unknowingly most of the codes in their shared responses to the interview questions. Convening the final interview focus group with the six participants was like a homecoming reunion. Everyone had at least one connection to another through ACS-related activities and events, and one participant had served as a mentor to another at the start of her teaching career. None of these teachers had attended a school of education before beginning to teach, so they could not have been immersed in educational jargon during early socialization into the profession. However, as they gained experience, all of them had searched for and found high-quality in-service education, some of it sponsored by ACS, where they were exposed to new ideas from higher education. In addition, they "talked teaching" with their colleagues, always looking for useful ideas. As good consumers, they chose to spend time learning theories and strategies that they deemed were most likely to lead to good learning for their students. It might seem that these choices would lead to professional expertise that was idiosyncratic. However, these QTs gravitated toward many of the same good ideas, providing a common knowledge base. The common language generated by the common knowledge base would normally be heard only when experienced teachers in an isolated school would share teaching ideas, but bringing top teachers together in one place allowed them to articulate their deepest ideas about teaching. They recognized that the others were also QTs, so they could speak freely and quickly, using the language they were pleased to find the others had also mastered. I assumed that I was witnessing something very special, but there must be some ways to encourage deeper thinking about the practice of teaching by having less experienced teachers participate in conversations where language common to QTs is verbalized.

One of the major unexpected findings of this investigation was the importance of relationships in QT. This socioemotional side of teaching includes qualities of caring and empathy. Though each teacher had her or his own way of dealing with students and others, it was clear that relationships mattered to each of these AWTs. Relationships seemed to be built on teachers' need to pass on their passion for chemistry, confidence about their teaching, and investment in their students' successes. In a sense, one could describe "It" as a synergistic combination of unique personal background experiences (including parenting), love of learning, and caring for their craft and for students. Instilling trust and confidence resulted in in safe spaces for risk-taking, environments with high academic expectations and successful learning. This means that in studying and evaluating best teaching practices, equal weight should be given to documenting and encouraging the "soft" side as well as the "hard" side.

The importance of portraying award-winning teaching as an insight to identifying and maintaining QT cannot be understated. Shulman, Cohen, Lemov, and recently the Gates Foundation, have all placed great stock in QT as the root to improved student achievement and school improvement. Following many of the cited authors' conclusions that producing exemplary teaching is at the core of raising the overall quality of schools in general, and student achievement in particular, then probing the underpinnings of what makes and sustains award-winning teaching is critical. "Good teachers develop in the dark. We need to develop them with others around a common language and understanding" (Tate, 2016). And as Collins (2005) notes in *Good to Great*, "Adequate is not enough." By understanding commonalities in QT, supervisors, school systems, and schools of education can promote these qualities in an effort to achieve and sustain outstanding chemistry and science teaching practices to best promote student achievement, the broader goal of our primary mission as educators.

Suggestions for Policy and Practice

One of the findings was how the support provided to these teachers allowed them to grow into QTs. States and communities should develop cost-effective ways to provide such resources for all teachers. This could be a non-profit, community-funded initiative to support teachers who request monetary grants and to recognize those teachers who make obvious efforts to improve and enrich their classrooms.

States and schools of education should encourage the development of a teacher candidate pool with more people with practical experience in fields of study like chemistry. This endeavor could include recognizing and supporting new paths to teaching. As was seen in this study, AWTs often find teaching after another career, and their previous career served as a foundation for their teaching acumen.

Preservice teacher education could be improved by encouraging, or even requiring, candidates to practice teaching students from different ethnicities and social classes. Placing beginners in diverse districts and classroom settings would challenge them to acquire classroom skills and values that might help them to approach AWT status later in their careers. This suggestion came from the participants themselves.

Educators should find ways to nurture the development and spread of a common language about the craft of teaching. A common language would assist teachers in talking about their trade productively, particularly in specific fields like chemistry teaching, and would support the development of worthy professional beliefs and values. Perhaps beginning and experienced teachers could discuss cases of teaching and learning with QTs while paying attention to the language of teaching. This process could confirm the importance of deep knowledge and experience in the content areas along with the effects of positive relationships on trust and learning content.

The ACS, and perhaps other groups that give awards for teaching, should make concerted efforts to recruit and recognize candidates for awards from school districts with lesser means. In chemistry education, this could be achieved by working with local and regional coordinators to identify those school districts that do not have active ACS members and to reach them through live "road shows" at department meetings and by holding informational meetings (live or online) much like the ones ACS has begun recently with their webinar series for secondary school educators.

Suggestions for Further Research

Using a pre-research survey to become acquainted with was participants was valuable in understanding more of what was observed once the research began. Knowing teachers' backgrounds and their beliefs in advance made the classroom observations richer and more meaningful.

Limitations of this study could be overcome if future researchers could observe teachers and students live in their classrooms. The original interviews and observations for this study were to be conducted live. COVID made most of these impossible and were completed virtually. Yet, it was possible to carry out all of the research online and, though lacking the interpersonal cues and nuances present in a live classroom, data from interviews, observations, focus group interviews, and surveys was successfully collected electronically. This is good news for researchers who may be limited to electronic classroom visits and interviews.

The two general well-known sources used to cohere this study's data, the Massachusetts Educator's Evaluation Rubric and the ACS Guidelines for Teaching Middle-and-High School Chemistry, were adequate in selecting codes used to match award-winning teaching practices with these sources. Future research might also include several more sources from which to cohere data from either end the achieving QT spectrum. From the inherent, art-like qualities of QT including works by Green (2014), Palmer (1998), or Vanderkam (2014) to the prescriptive, defined learned practices to get to QT by Lemov (2009), and middle-of-the spectrum *The Chemistry Classroom: Formulas for Successful Teaching* (Herron, 1996), using additional sources such as these would serve to enrich and further highlight those qualities and practices identified to get to and maintain award-winning QT.

Originally, participants' students were to be surveyed live. This became impossible during the pandemic and, though I was able to survey my own students, surveying these teacher's students would provide yet another data source from which to portray AWT. With more time, a greater number and range of survey questions and individual interviews with their students would yield a richer student perspective on AWT. The same could be said for interviews with colleagues and supervisors. Though I had anecdotal evidence of AWT from award nomination and supporting letters, live or online interviews would have added significantly to these AWT portraits. Greater time spent observing and talking with teachers would yield a greater breadth and depth of data.

This was a small study with only $N = 6$. The small sample size was based on the narrow criteria for teacher selection: potential participants in the greater-Boston area who received two or more ACS-sponsored awards within the past 10 years. Increasing the number of participants would likely yield richer data. Spending more time with classroom observations and widening the types of schools visited to include private, parochial, and charter schools would increase the diversity of responses as well. Though there was a socioeconomic range of communities from regional working class to suburban to wealthy, more teachers from a greater number of schools would again likely produce an even stronger set of data.

Finally, the diversity lacking in this study's schools was due to the narrow criteria of the participant selection (two or more ACS-sponsored awards won in the last ten years). This led to participants in the greater-Boston area who taught in socio-economically advantaged communities. Either expanded criteria for AWTs to include a greater diversity of schools or encouragement by the award committees at the local level and the ACS at the national level to seek AWT nominations from more varied schools should be made for further research. Another corrective measure would be for someone to study award-winning teachers who only teach in schools where the students come from disadvantaged and working-class families. Hopefully, future studies like this one may encourage others to pursue results bringing to life award-winning secondary school chemistry teaching.

Final Thoughts

It was difficult to not be able to reveal the identity of these teachers portrayed in this study. I have lived with them as they bared their souls to me in our interviews and in their classroom, sharing in their practices as a fellow teacher and being part of their success, aspirations, and passions as award-winning educations. I have come to so greatly admire these teachers who, at the top of their practice, were not yet ready to fully acknowledge their excellence themselves. They inspired me as they continually strived to perfect a particular lesson, work on a certain student’s trust, or share with colleagues what might work better pedagogically, revealing so many qualities of their award-winning teaching.

Throughout this study, I was obviously witnessing something most impressive and special that remained hard to describe accurately but yet was so evident from all of my data sources. My hope has been to leave readers with a strong sense of the talent, dedication, passion, and love on display from this select group of educators.

APPENDICES

Appendix A: AMERICAN CHEMICAL SOCIETY GUIDELINES FOR TEACHING MIDDLE AND HIGH SCHOOL CHEMISTRY (2018). Source: American Chemical Society website, www.acs.org

This document is comprehensive in every aspect of secondary chemistry teaching.

The relevant parts of the Guidelines as they directly relate to best classroom practices

can be found on pp. 2, 5–7:

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In the fall of 2010, the American Chemical Society (ACS) Education Division, under the auspices of the Society Committee on Education (SOCED), established and charged a task force to update a guidance document, titled "ACS High School Chemistry Guidelines and Recommendations," which was last revised in 1984. The purpose of this document is to provide guidance to the high school chemistry education community focusing on the nature of the instruction, including the physical and instructional environment, the big ideas in chemistry, and the professional responsibilities of chemistry teachers. This document is not a course outline or syllabus, a detailed description of instructional methodologies and best practices, or a program outline for teacher preparation and professional development. The intent is to capture the importance and value of teaching chemistry at the high school level and to emphasize the essential components of the high school chemistry learning environment. The primary audience for this document is high school chemistry teachers, their supervisors and principals, and school administrators. This document should also serve as a resource for pre- and in-service teacher preparation programs. The focus of this document is to describe the broad requirements necessary to teach chemistry to all high school students from diverse populations. These guidelines recognize the professional integrity of high school chemistry teachers who may want to share with their school or district administrators' information about best practices and the physical environment, including the tools of educational technology and laboratory facilities. These guidelines are presented in order to support the work of classroom chemistry teachers.

Pathways to Learning: Expected Outcomes in a High School Chemistry Course:

Since at least 2001, states have been developing and validating specific science standards to be learned. In nearly every case, these state science standards were influenced by two national-level publications, the National Research Council's (NRC) National Science Education Standards (NSES) (NRC, 1996) and the American Association for the Advancement of Science's Benchmarks for Scientific Literacy (AAAS, 1993).

The NSES defines scientific literacy as the ability to:

1. Ask, find, or determine answers to questions derived from curiosity about everyday experiences;

2. Describe, explain, and predict natural phenomena;

3. Read and understand articles in the popular press and engage in social conversation about the validity of the conclusions;

4. Identify scientific issues underlying national and local decisions and express ideas that are scientifically and technically informed;

5. Evaluate the quality of scientific information on the basis of its sources and methods; and

6. Pose and evaluate arguments based on evidence and apply conclusions appropriately (NRC, 1996).

Effective Strategies for Teaching Chemistry

Advance planning is crucial for active student engagement in learning. Chemistry teachers should first decide on the conceptual learning goals for their students, focusing on broad concepts within the big ideas in chemistry. Spiraling the curriculum, building on and making connections to what students already know, will encourage student participation and understanding. Identifying the essential or guiding question at the beginning of each lesson focuses the attention of teachers and students on key learning objectives.

Several lesson formats, such as guided inquiry and investigations in the laboratory, promote a deeper understanding. In the 5E Learning Cycle Model (Bybee, 1997), teachers engage students, then allow them to explore through experimentation, explain or summarize their new learning, elaborate through application, and finally evaluate their claims. Other effective lesson formats appropriate for some topics in chemistry include role playing, simulations, and direct instruction. For more than 20 years, cognitive science has discouraged "teaching as telling" (Bransford et al, 2000). Therefore, careful planning is needed to avoid this pitfall. When lectures are used, pre- viewing the information and providing advance organizers (Ausubel, 2000) helps maximize student participation and promote understanding.

Regardless of the lesson format that is chosen, teachers must prepare appropriate questions in advance to assess student understanding during each phase of the lesson. These questions include an engaging question at the beginning of a lesson to determine what students already know, probing questions during the lesson to guide student learning, and end with closing questions to gauge what students learned at the end of the lesson.

The opening questions should be answered by students with the understanding that the purpose of answering the questions is to confront students' initial ideas, not for students to have the "right" answer. For example, a lesson about intermolecular forces could begin with a question about how pollutants (and other substances) dissolve in water. Often these questions uncover naive ideas or misconceptions which will be addressed later in the lesson. During the lesson, effective questioning techniques help students develop their critical thinking skills, as well as their ability to solve problems. The questions should help students make connections to other learning. To determine what students truly understand, open-ended questions are much more effective than questions that have only one answer.

Student engagement may begin with a provocative question related to students' lives, or a puzzling discrepant event to challenge prior conceptions. Many chemistry teachers enjoy beginning a lesson with a demonstration or video clip that makes students think about the topic in a different way. Sometimes even a simple demonstration paired with a good question is sufficient to spark student learning.

For example, asking "What are the bubbles made of?" while pouring water from a pitcher into a beaker will encourage students to think more deeply about everyday experiences. This can be followed by heating the beaker of water on a hot plate and discussing the difference between the small bubbles viewed initially and the large bubbles produced when the water boils. Asking students how they can test their ideas about the composition of the bubbles lead to a much deeper understanding than providing them with a step-by-step lab procedure, or telling them the answer.

Chemistry students must be good problem solvers. Solving problems is an active, messy process, which is often frustrating, but the process can be rewarding. Thomas Edison didn't invent the light bulb by following a recipe. He developed more than 1,000 faulty light bulbs during the process. Students must learn to explore problems and understand that taking a "wrong" step is often as valuable as following the correct path. Students should be observant during the problem-solving process to evaluate whether they are getting closer to, or farther from, the desired solution.

When modeling problem solving, teachers should model their own thinking to help students see how experts think through a problem, starting with the given information and ending by determining if the answer is reasonable. Cooperative learning strategies could be employed to help students solve meaningful real-life problems. To avoid cries of "Why do we have to know this?" from students, teachers should develop a context for learning. For example, students could work in teams to investigate local air quality, learn the nutritional value of their favorite foods, or discover the effects of fertilizer on water quality.

Much of chemistry deals with atomic and molecular phenomena that cannot be observed in the high school classroom. To help students understand these abstract concepts, carefully prepared analogies and models should be used. Lewis dot structures and molecular models are commonly used in chemistry, as are mathematical equations such as the gas laws. All models have limitations, so teachers should plan classroom discussions with good questions to prevent student misconceptions later on.

Vocabulary can be problematic in the chemistry classroom. Students often use vocabulary to hide their misconceptions. For instance, students may be able to define density mathematically, as well as state that an object will float in water if its density is less than 1 g/cm^3, but when asked to think more deeply about buoyancy, students may be unable to explain floating in terms of particles. As a general rule, vocabulary should be introduced near the end of the lesson to give names to the concepts the students have come to comprehend more thoroughly (Le Tellier, 2007.)

Finally, providing students with time to reflect on their new learning through journaling or searching for real-world examples will help ensure their understanding endures past the closing bell. One popular strategy is to ask students to complete exit cards with prompts, such as “Today I learned. . .,” “I would still like to know more about. . .,” or “I still don’t understand. . . .” Another idea for student reflection is to ask them to write a letter to a relative or a friend explaining in nontechnical terms what they learned in chemistry that week. In chemistry, well-planned lessons include effective questions, student interaction with new ideas, and student reflection—all focused on the conceptual learning goal. Chemistry teachers should capitalize on the importance of chemistry in everyday life to engage their students, and then follow through with opportunities for them to actively explore newly introduced concepts. Advance planning will reap big payoffs in student motivation and deepen their understanding of topics in chemistry.

Appendix B: MASSACHUSETTS MODEL SYSTEM FOR EDUCATOR'S EVALUATION, PART III: GUIDE TO RUBRICS (2018). Source: DESE website, www.doe.mass.edu

The "Exemplary" standard for each indicator is listed below.

Standard I: Curriculum, Planning, and Assessment

Elements: Subject Matter Knowledge, Child and Adolescent Development
Demonstrates expertise in subject matter and the pedagogy it requires by engaging all students in learning experiences that enable them to synthesize complex knowledge and skills in the subject. Is able to model this element.

Rigorous Standards-Based Unit Design, Well-Structured Lesson
Designs integrated units of instruction with measurable, accessible outcomes and challenging tasks requiring higher-order thinking skills that enable students to learn and apply the knowledge and skills defined in state standards/local curricula. Is able to model this element

Develops well-structured and highly engaging lessons with challenging, measurable objectives and appropriate student engagement strategies, pacing, sequence, activities, materials, resources, technologies, and grouping to attend to every student's needs. Is able to model this element.

Variety of Assessment Methods, Adjustment to Practice
Uses an integrated, comprehensive system of informal and formal assessments, including common interim assessments, to measure student learning, growth, and progress toward achieving state/local standards. Is able to model this element.
Organizes and analyzes results from a comprehensive system of assessments to determine progress toward intended outcomes and frequently uses these findings to adjust practice and identify and/or implement appropriate differentiated interventions and enhancements for individuals and groups of students and appropriate modifications of lessons and units. Is able to model this element.

Analysis and Conclusions, Sharing Conclusions with Colleagues, Sharing Conclusions With Students; Individually and with colleagues, draws appropriate, actionable conclusions from a thorough analysis of a wide range of assessment data

that improve short- and long-term instructional decisions. Is able to model this element.
Establishes and implements a schedule and plan for regularly sharing with all appropriate colleagues' conclusions and insights about student progress. Seeks and applies feedback from them about practices that will support improved student learning. Is able to model this element.
Establishes early, constructive feedback loops with students and families that create a dialogue about performance, progress, and improvement. Is able to model this element.

Standard II: Teaching All Students

Quality of Effort and Work, Student Engagement, Meeting Diverse Needs
Consistently defines high expectations for quality work and effort and effectively supports students to set high expectations for each other to persevere and produce high-quality work. Is able to model this element.
Consistently uses instructional practices that typically motivate and engage most students both during the lesson and during independent work and home work. Is able to model this element.
Uses a varied repertoire of practices to create structured opportunities for each student to meet or exceed state standards/local curriculum and behavioral expectations. Is able to model this element.

Safe Learning Environment, Collaborative Learning Environment, Student Motivation
Uses rituals, routines, and proactive responses that create and maintain a safe physical and intellectual environment where students take academic risks and play an active role—individually and collectively—in preventing behaviors that interfere with learning. Is able to model this element.
Teaches and reinforces interpersonal, group, and communication skills so that students seek out their peers as resources. Is able to model this practice.
Consistently supports students to identify strengths, interests, and needs; ask for support; take risks; challenge themselves; set learning goals; and monitor their own progress. Models these skills for colleagues.

Respects Differences, Maintains A Respectful Environment
Establishes an environment in which students respect and affirm their own and others' differences and are supported to share and explore differences and similarities related

to background, identity, language, strengths, and challenges. Is able to model this practice.
Anticipates and responds appropriately to conflicts or misunderstandings arising from differences in backgrounds, languages, and identities in ways that lead students to be able to do the same independently. Is able to model this practice.

Clear Expectations, High Expectations, Access to Knowledge
Clearly communicates and consistently enforces specific standards for student work, effort, and behavior so that most students are able to describe them and take ownership of meeting them. Is able to model this element.
Effectively models and reinforces ways that students can consistently master challenging material through effective effort. Successfully challenges students' misconceptions about innate ability. Is able to model this element.
Individually and with colleagues, consistently adapts instruction, materials, and assessments to make challenging material accessible to all students, including English learners and students with disabilities. Is able to model this element.

Standard III: Family, Community Engagement is omitted in my study as this did not seem relevant to the focus of my study.

Standard IV: Professional Culture

Reflective Practice, Goal Setting
Regularly reflects on the effectiveness of lessons, units, and interactions with students, both individually and with colleagues; and uses and shares with colleagues, insights gained to improve practice and student learning. Is able to model this element.
Individually and with colleagues builds capacity to propose and monitor challenging, measurable goals based on thorough self-assessment and analysis of student learning data. Is able to model this element.

Professional Growth and Learning, Professional Collaboration
Consistently seeks out professional development and learning opportunities that improve practice and build expertise of self and other educators in instruction and leadership. Is able to model this element.
Supports colleagues to collaborate in areas such as developing standards-based units, examining student work, analyzing student performance, and planning appropriate intervention. Is able to model this element.

Decision-Making, Shared Responsibility
In planning and decision-making at the school, department, and/or grade level, consistently contributes ideas and expertise that are critical to school improvement efforts. Is able to model this element.
Individually and with colleagues develops strategies and actions that contribute to the learning and productive behavior of all students at the school. Is able to model this element.

Judgment, Reliability and Responsibility
Demonstrates sound judgment and acts appropriately to protect student confidentiality, rights and safety. Is able to model this element.
Consistently fulfills all professional responsibilities to high standards. Is able to model this element.

Appendix C: CODING. Used to identify common themes found in participant interviews.

Code	**Description**
1. Relationship(s)	The bond or rapport that a teacher establishes with students and colleagues
2. Caring	A thoughtfulness and compassion demonstrated by the teacher toward his/her students
3. Trust	Have faith in, can count on.
4. Resources	Supplies and also Means
5. Collaboration	A group effort, sharing
6. Strong Voice/Clear Instruction	An articulate definitive power of speech and delivery of expectation
7. Confidence	Self-assurance and conviction
8. Motivate/Motivation	To encourage and inspire
9. Teachers as Learners	Educators also taking classes, attending workshops and conferences
10. Passion(ate)/Love	A great enthusiasm

Appendix D: ACS AWARDS

Descriptions of local of local and regional secondary chemistry teaching awards found on the Northeastern Section American Chemical Society and Northeastern Regional Meeting websites, www.nesacs and www.acsnerm.org

ACS AWARDS

1. ***Aula Laudis Society* Award**: For outstanding contributions to the teaching of chemistry within the Northeastern Section of the American Chemical Society (NESACS). Selected teachers receive a plaque and letter of recognition to their building supervisor/principal. The committee is comprised of 2-3 previously awarded teachers who read over the nominations each year, or make nominations themselves, and judge the awardees based on the years taught, strength of the nomination letters, and contributions to chemical education within the Northeastern Section.

2. **Theodore Richards Award for Excellence in High School Chemistry Teaching**: Honors a teacher in the Northeastern Section who, through innovation and dedication, has inspired potential chemists, has communicated chemistry to non-chemists, or has influenced other teachers of chemistry. The selected teacher is officially honored with both a $1,500 prize and a Certificate of Recognition. The criteria for excellence correspond broadly to the effectiveness with which the teacher conveys the principles of chemistry to students and to the influence that the teacher has had on students and on other teachers. The teacher's effectiveness could be a direct result of innovative and exciting techniques used to help students comprehend and remember chemical concepts and descriptive material. It could be a result of the special effort and dedication that characterizes his or her interaction with students, both academic and extra-curricular. It could also be a result of a particular skill in communicating, especially to students not intending to become chemists, the role chemistry plays in their lives and in society. The influence of the teacher could be reflected in the way he or she inspires the students or promotes the better teaching of chemistry among other teachers. The influence might have led to students choosing chemistry as a career or might have prompted students to choose an appropriate scientific specialty. It might also have led to other teachers learning to use, through workshops or written material, successful new approaches taken by the nominee to demonstrate laboratory experiments or to solve chemical problems. The measure of such effectiveness and influence could be reflected in the achievements of his or her students or of students of other teachers who have learned from him or her. It is assumed that many students fortunate enough to have learned chemistry from this teacher could win awards of their own and would go on to become chemists. Such students might have placed high in the Chemistry Olympiad, the Westinghouse Science Talent Search, the Avery Ashdown High School Examination, science fairs, etc. These achievements might very well be more significant than the basic abilities of the student would suggest.

The Richards Award Committee is comprised of 2–3 previous Richards Award recipients who use a nominating letter from a colleague or supervisor and at least one other letter of support from a colleague of supervisor. Past letters from students are also received.

3. **NERM Northeastern Regional Meeting Award**: ACS Division of Chemical Education Northeast Region Award for Excellence in High School Teaching: To recognize, encourage, and stimulate outstanding teachers of high school chemistry in the Northeast Region (New York, Pennsylvania, New Jersey, New England). The nominee must be actively engaged in the teaching of chemistry or a chemical science in a high school (grades 9-12) on at least a half-time basis and is recommend by an official from a local section within the Northeastern Region based on his/her contributions to local section education-related activities.

The NERM Award Committee is comprised of 3-4 members of the Northeastern Regional Meeting Committee representing a mix of secondary educators and professors. The committee evaluates the nominees based on a nomination latter from a supervisor and two letters of support from colleagues.

4. **Henry Hill Award for Outstanding Service to the Northeastern Section** is awarded annually to a member, to a former member, or in memory of a deceased member or former member of the Section who has made outstanding contributions to the Section's programs and activities. The award is comprised of a plaque and a scroll suitably engraved with an appropriate citation. It is awarded annually at a regular meeting of the Northeastern Section unless otherwise specified by the Board of Directors.

The Hill Award Committee is comprised of 3-4 members of the NESACS Board who have previously served or currently serve on education committees.

5. **USNCO Study Camp Mentor** is selected by the ACS USNCO Office to train and tutor the top 20 students selected for the USNCO Study Camp, then accompany the top 4 students selected for Team USA to the International Chemistry Olympiad (IChO). The Mentor's responsibilities at the Camp include writing and grading challenging exams, reviewing study problems, setting up lengthy laboratory experiments, and grading lab work. For those Mentor's accompanying students to the IChO, this involves working through translations from the host country, supervising students while at the IChO, and grading their work to be reviewed by the host country. There are typically three Mentors per year, selected based on their solid chemistry background and their proven ability to work well with high achieving students.

Appendix E: PARTICIPANTS AND THEIR AWARDS

The participants names here are fictionalized. The ACS-related awards are real with years awarded omitted to keep the teachers anonymous.

Selected Teachers	Awards
1. Dean Rosenburg (DR)	*Aula Laudis* Society Theodore Richards Excellence in Secondary Chemistry Teaching
2. Stella Danes (SD)	*Aula Laudis* Society NERM Excellence in High School Chemistry Teaching
3. Roxane Hobbes (RH)	*Aula Laudis* Society Theodore Richards Excellence in Secondary Chemistry Teaching
4. Patricia Kearns (PK)	*Aula Laudis* Society Theodore Richards Excellence in Secondary Chemistry Teaching
5. Elena Hernandez (EH)	*Aula Laudis* Society USNCO Study Camp Mentor
6. Amy Morris (AM)	*Aula Laudis* Society Theodore Richards Excellence in Secondary Chemistry Teaching

Appendix F: SCHOOL DISTRICT PERMISSION LETTER TO CONDUCT RESEARCH

To Whom It May Concern:

I am a doctoral candidate at the Boston University School of Education and I propose to write a dissertation that will portray quality teaching (QT) as identified through externally determined awards for award-winning secondary chemistry teachers in the greater Boston area. Definitions of QT, often also referred to as exemplary teaching, range greatly in the literature. Throughout my study, I will equate QT to best practices or exemplary teaching. By understanding QT, it is hoped that educators can hold it as a standard of achievement and excellence that teachers are evaluated by and teachers-to-be can strive for. The broad question to be addressed by this research is: What QT characteristics do award-winning high school chemistry teachers exhibit and share?

Classroom observations and interviews will be used to portray teachers as case studies in the context of their award-winning practices. I hope to collect data to write a narrative of the award-winning QT practices I observe. My role is to be the camera or lens to teaching already identified as quality teaching. I will solicit anecdotal evidence of these teachers' QT from students as well as colleagues and supervisors, who will likely speak of students' improved achievement as a result of their experiences from the teachers in this study.

This study will consist of observations and interviews using six teachers from greater Boston-area high schools. Each teacher has been selected based on his or her receipt in the past ten years of at least two state, regional, or national level awards in the area of secondary high school chemistry instruction. All of the awards here are recognized and selected by the American Chemical Society, the professional organization of academic and applied chemistry educators nationwide. The teachers in this study will be either mid-career (defined by many districts as with 4-10 years of experience) or veteran status (beyond ten years of experience).

I plan to obtain consent from each of the teachers to be used in this study by contacting them initially by email to inform them of my hope to have them participate in this study. I will present teachers with my criteria used to identify them each as participants. To protect the confidentiality of the teachers I will not use their actual names in any publication, including my dissertation, nor will I use the actual names of the school or district. No students will be directly identified in this study. Permission from the schools/school districts to conduct this study involving online interviews, in-class or online observations and digital audiovisual recordings will be requested by email from the building principal and/or superintendent following the Boston University IRB approval.

The risky nature of classroom observation and reflection can leave teachers feeling vulnerable. It is hope that trust is established between the researcher and this study's subjects to limit any feelings of vulnerability. Benefits for both teachers and students include the positive reflection following successfully taught lessons.

The methods for data collection in this proposed study will include surveys conducted through electronic mail with the subjects, face-to-face interviews with the teachers, classroom observation and recording, collecting teacher-selected student work, and leading a focus group interview with these teachers.

The recorded audio classroom will be transcribed and coded for common themes. Codes will be determined based on the "Exemplary" indicator criteria used in the Massachusetts Educator's Evaluation System rubric as well as on criteria for excellence in the American Chemical Society Guidelines document. Once these codes have been developed initially, I will likely modify them after reading and rereading transcriptions to produce a draft of the findings.

Compiled analyzed data and conclusions from this study will become my completed dissertation. Copies of this dissertation will be sent to the library of Boston University. An abstract will be sent to the K-12 Education Offices of the American Chemical Society in Washington DC where, it is hoped, findings can be used to update the ACS Guidelines for Teaching High School Chemistry, and also to the Nucleus publication of the Northeastern Section American Chemical Society. The findings of this study may be re-worked as a conference paper at an ACS National Meeting or an article for publication in the Journal of Chemical Education. I will provide each award-winning teacher and district involved in the study with a summary of my research.

I am including the consent forms for participants.

Thank you for taking time to consider allowing me to conduct research with an award-winning teacher in your school.

Acknowledgement of this letter can be considered permission to work with your award-winning educator. My thanks,

Sincerely,

Steve Lantos
41 Harvard St 1R
Brookline MA 02445
617 320-7510
steve_lantos@psbma.org lantos@bu.edu
Dissertation Advisor:
Philip M. Tate

Boston University, School of Education
2 Silber Way
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617 721-5509
ptate@bu.edu

Appendix G: RECRUITMENT LETTER AND FOLLOW-UP EMAIL FOR AWARD-WINNING TEACHERS

Recruitment Letter

Dear:

I am requesting your participation in a study of award-winning secondary chemistry teachers. This research study involves observing teachers in their classroom and scripting aspects of their practices. The objective of this research project is to portray quality teaching (QT) practices.

The procedure for this study involves one-on-one interviews with eight teachers prior to classroom observations. The interview protocol follows this consent form. This research study also involves observing teachers in their classroom and recording their practices audio-visually and by written scripts, participating in face-to-face interviews, post-observation interviews by telephone or email, a focus group interview, collection of student work, and a one-time survey of your students. Once the data are collected (by digital recording and note-taking), the researcher will transcribe these interviews and then code these observations based on common themes and similarities. The actual names of teachers and their schools will be not be used. It is hoped that the final study might be shared with other teachers and schools so that they might benefit from portraits of excellence in teaching.

Your participation in this study is voluntary, and you may end your participation at any time. If you have questions about the research, or would like to receive a summary of the results when they become available, please contact Steve Lantos (primary researcher) at lantos@bu.edu or 617 320-7510; or Dr. Phil Tate (research study supervisor) at ptate@bu.edu or 617 721-5509.

Subject's signature:

The nature and purpose of this research have been satisfactorily explained to me and I agree to become a participant in the study as described above. I understand that I can discontinue participation at any time if I so choose.

______________________________________ date ________________

Follow-Up Email

Dear:

Thank you for your consideration to participate in a study of award-winning teachers for my research at Boston University. I will follow-up with scheduling times and dates for interview and classroom visits. I look forward to working with you.

Sincerely,

Steve Lantos

Appendix H: FOLLOW-UP EMAIL TO SUPERVISOR/PRINCIPAL TO NOTIFY OF INTENT TO HAVE TEACHERS PARTICIPATE IN STUDY

Participation Notification to Supervisor/Principal

This email is to notify you that Mr/Mrs _______________________ , a chemistry teacher on your faculty, has agreed to participate in a study I am conducting on practices of award-winning high school chemistry teachers. Their participation will involve completing an electronic survey, participating in a face-to-face interview to be digitally audio-recorded, to be audio-visually recorded while conducting a lesson (students will not be included in this recording), and will participate in a face-to-face focus-group with the other teacher-participants from other schools.

Mr/Mrs _______________________ 's participation is voluntary and this participation my be ended at any time. If you have questions about the research, or would like to receive a summary of the results when they become available, please contact Steve Lantos (primary researcher) at lantos@bu.edu or 617 320-7510; or Dr. Phil Tate (research study supervisor) at ptate@bu.edu or 617 721-5509.

Appendix I: INFORMED CONSENT FOR COLLEAGUES AND ADMINISTRATORS

Informed Consent Form

You are being asked to participate in a study of award-winning secondary chemistry teachers. Subjects have been selected based on receiving at least two state, regional, or national teaching awards. The objective of this research project is to portray quality teaching (QT) practices.

Your participation as the subject's colleague or administrator is to participate in a face-to-face, telephone, or email interview. Once the data are collected (by digital recording or note-taking), the researcher will transcribe these interviews and then code these observations based on common themes an similarities. The actual names of the teacher and their schools will not be used. It is hoped that the final study might be shared with other teachers and schools so that they might benefit form portraits of excellence in teaching.

Your participation in this study is voluntary, and you may end your participation at any time. If you have questions about the research, or would like to receive a summary of the results when they become available, please contact Steve Lantos (primary researcher) at lantos@bu.edu or 617 320-7510; or Dr. Phil Tate (research study supervisor) at ptate@bu.edu or 617 721-5509.

Subject's signature:

The nature and purpose of this research have been satisfactorily explained to me and I agree to become a participant in the study as described above. I understand that I can discontinue participation at any time if I so choose.

____ date _________________

Appendix J: TEACHER SURVEY

Participant Surveys (electronic mail)

1. Name
2. School
3. Years of Teaching
4. Education, College Major
5. Extracurricular Activities at Your School
6. Collaboration Activities with Colleagues (both at and beyond your school)
7. Teaching Awards
8. Personal Qualities/Professional Behaviors Cited When These Awards Were Given
9. Professional Associations and Involvement
10. Workshops, Publications, Presentations

Survey STEBI-like Questions

Please indicate the degree to which you agree or disagree with each statement below using:

SA = Strongly Agree, A = Agree, UN = Uncertain, D = Disagree, SD = Strongly Disagree

11. I am continually finding better ways to teach chemistry. SA A UN D SD
12. The inadequacy of a student's understanding can be. SA A UN D SD
overcome by good teaching.
13. The teacher is generally responsible for the achievement SA A UN D SD
of students in chemistry learning.

14. I know what to do to increase students' interest in learning chemistry. SA A UN D SD

15. Award-winning teaching translates to high student achievement. SA A UN D SD

Appendix K: STUDENT SURVEY

Dear Student:

Thank you for participating in this research study of award-winning teaching. Your responses to these questions will help in portraying best practices in your teacher's classroom. Please answer candidly without using your name. No teachers will see your responses to these questions. By filling out and turning in this survey, you are assenting that the information from the survey may be used in this study.

On a scale of 1 – 5 (1 = least or worst, 5 = most or best).

Your teacher:

1. Explains concepts well ____
2. Teaches with enthusiasm ____
3. Challenges students academically ____
4. Displays a sense of humor ____
5. Exhibits a love of the subject ____
6. Exhibits a desire to teach ____
7. Tries to teach to each individual student ____
8. Adapts their teaching to best convey concepts ____

Thank you for your time and candor.

Appendix L: TEACHER POST-OBSERVATION PROTOCOL

Teacher Post-Observation Protocol (via email)

1. Did you feel that your lesson was successful?
2. What evidence of student learning did you observe throughout the lesson
3. Were there any elements of award-winning teaching that you exhibited in this lesson?
4. Was there any evidence of your beliefs as an educator on display in this lesson?
5. Is there anything you would change or modify from this lesson?

Thank you for your time and candor.

Appendix M: TEACHER FOCUS GROUP PROTOCOL

Focus Group Protocol (audio-visually recorded)

Moderator: Thank you all for attending this focus group session. I would like to begin by asking each of you when you respond speak to first identify yourself by first name for the audio recording as I will be transcribing and coding this entire session. A reminder that when the final study is written up, you will remain anonymous. Thank you.

1. Can you discuss ways in which your award-winning status as an educator has influenced your teaching?
2. If you are observing an award-winning chemistry teacher in class, what would this teaching look like? What would you expect to see?
3. Does each of you have a theory of best practices? If so, can you discuss this briefly with us?
4. What experiences in your education and/or your life's path brought you to focus on perfecting your practice as a teacher?
5. What ways do you see yourself growing and developing further as an award-winning teacher? Why did you choose these?

Appendix N: TEACHER INTERVIEW PROTOCOL

Teacher Interview Protocol (face-to-face, digitally recorded)

1. How did you find your way to teaching (chemistry)?

2. How does your teaching demonstrate your beliefs about how your students learn best?

3. How has your award-winning status affected the way you see yourself in the classroom? Has this changed in any way how your students perform?

4. Why do you think you have earned your status as an award-winning educator?

5. What ways, if any, do you share your award-winning practices with others?

6. Is your teaching is best described by “It,” that elusive hard-to-define innate quality sometimes referred to as the natural gift of teaching, or is it a set of practices learned from experience over time? How do *you* define “It”?

7. What do you still need to improve in your practice?

Appendix O: EXAMPLE SCHOOL PERMISSION TO CONDUCT STUDY (SCHOOL NAME REDACTED)

This is an example of the permission approval after requesting permission from the school district to conduct this study.

Peter Garik. See attached for confidentiality and freedom from harm
Procedures for providing translations: NA
Process for publication and dissemination of results: Submitting final dissertation to the Mugar Libraries, Boston University Charles River Campus.

Start Date: Oct. 28, 2020
Expected End Date: Dec. 21, 2020

Additional Comments: Given hybrid teaching and learning status, I hope only to visit classes remotely on Zoom with both video and audio muted, and plan to remain silent throughout my observations.

~~~~~~

Request for more information:

Approved:

Denied:

Assistant Superintendent Superintendent

[redacted]Request for Research Access Form page 2
~~~~~~

Request for Research Access

Please complete and attach this form to the letter formally requesting permission to conduct research with the [redacted] and send to the Assistant Superintendent for Teaching and Learning.

Boxes will expand as you type.

Date: October 19, 2020
Title of Project or Study: Quality Teaching Practices: Portraits of Award-Winning Secondary School Chemistry Teachers

Name and Title of Person Making Request: Steve Lantos, Doctoral Candidate
Affiliated Institution Name and Address: Boston University School of Education
Office Phone Number: (617) 713-5365
Cell Phone Number: (617) 320-7510
Email Address: steve_lantos@psbma.org

Name of Supervising Professor (if applicable): Dr Phil Tate, Dr Peter Garik, both BU SED *If the study is the basis for a dissertation, include a letter of approval and commitment to supervision from the faculty advisor(s), along with the college/university Internal Review Board (IRB) approval notice (or evidence that IRB is not required).*

Institutional Review Board Contact Information (name, title, email, and phone number): Boston University Charles River Campus IRB, 25 Buick Street, Rm 157, Boston MA 02215, (617) 358-6115, www.bu.edu/irb

School/Grade/Ages Involved in Study: [redacted]
[redacted]

Purpose, Statement of Problem, and Research Questions: Observing Award-Winning Chemistry Teaching in [redacted]
Research Design and Procedures (Please attach a copy of all data collection instruments.):
Procedures for ensuring confidentiality and freedom from harm (including storage of information): Storage on a Google Drive with password known only to me and my Advisor

Appendix P: STUDENT FOCUS GROUP QUESTIONS

Thank you all for participating in this voluntary student focus group over Zoom. I will ask a set of general question as it relates to my study on best practices of award-winning teaching. Please listen to each other's responses and feel free to agree or disagree, or add to each other's answers. All of you will remain anonymous. I will record our session's audio for the purpose of transcribing and coding your responses. Thank you.

1. How would you define award-winning teaching? What informs your definition here?
2. If you are observing award-winning teacher in class, what would this teaching look like? What would you expect to see and what qualities identify this teaching as award-winning?
3. Some say that best practices can be taught, others argue that it's innate. Can you argue for one, or the other, or both? Define "It," the best teaching that you know it when you see it.
4. How would you define what makes a teacher award-winning?
5. External teacher awards reward best teaching practices. What incentives do you think award-winning teachers have to practice and maintain award-winning teaching?

APPENDIX Q: PORTRAITS OF SIX AWARD-WINNING TEACHERS

Patricia Kearns. In PK's school district, six grade schools have fed into two middle schools which has sent students to either one public high school grades 9–12 or a regional vocation technical high school. The public high school was established in the mid-1850s and at the time of this study had a population of approximately 2300, with an Asian population of 40%, highest in the state. The school continually ranked in the top 1% in the state, based on math and English proficiency test scores. Many of the families have been affiliated with Boston area high-tech and academic institutions. Patricia knew that students arrived to her class with "a lot of wind already in their sails" and she acted at times more as the helmsperson guiding them through the curriculum. Students regularly participated and were top scorers on the ACS sponsored local section and national chemistry exams, which Patricia actively promoted to her students annually. In the past four years, two of her students reached the International Chemistry Olympiad (IChO) as part of the four-person Team USA. Of these two, in 2020 one was *the top scorer* from nearly 100 national teams, that is, the top in the world. Patricia was as much a coach as a teacher, guiding her students through the curriculum in preparation for the final match, the AP exam and for some, the ACS-sponsored chemistry exam competitions.

For all of the outstanding success that occurred in Patricia's classroom, the physical space was surprisingly spare. There were a several wall posters but few charts and tables found in typical chemistry classroom. One, titled Science and Engineering Practices, listed encouraging ways of thinking about science and engineering. Another, drawn by a student features "HI (hydrogen iodide) Welcome to Room 402" with hand-drawn laboratory equipment and chemical formulas. The door to her classroom had a GLBT Safe Space sticker and a hand-colored sign "Science Rocks! Dr. K" to greet entering students. PK's lecture table was in front of rows of desks and there were tables lined up in the back of the classroom for laboratory work. The classroom overlooked the school's courtyard off of which are low-slung one-story classroom wings.

Patricia's mastery of chemistry knowledge and pedagogy were instantly on display in conversation and in the classroom. To watch her teach, one sensed a master craftsperson weaving an intricate tapestry of chemical concepts. Like an experienced raconteur, she paused at crucial moments to heighten her audience's anticipation or to emphasize a key point in her presentation. In turn, her students were rapt as she moved in a lesson from introduction to showing examples and offering problem-solving tips and pitfalls to look out for in working questions. The students seemed to demonstrate an almost reverence for her teaching through their captivation, display of work habits, and knowing that she is a demanding yet caring teacher. She was pensive in sharing her beliefs about chemical education, using measured words to offer that there are many possible pathways to award-winning education but that foremost, a teacher must know the chemistry. Though her undergraduate, masters, and doctoral work in chemistry were in a traditional system of learning in her native country, Patricia employed many non-traditional practices that challenge her students and her as a teacher-learner, methods she has learned from workshops, collaboration, and creation. She claims to be a traditionalist in that "teachers must provide content and tools for understanding first, to build a framework and structure for learning, to then let students wrestle or even struggle with the material in small groups, allowing them to *own* their learning." Here is an example of her teaching style from my observation notes.

> PK's AP class is being introduced to Lewis dot structures (LDS). Posting on slides, she first illustrates H-H and Cl-Cl showing the leftover unshared chlorine electrons and making the point that the pair of shared electrons between atoms represent a bond between the two atoms. "The goal is to give each atom eight electrons. When you draw a line between two atoms it represents a pair of shared electrons. The unshared electrons we'll call 'lone pairs'. Two shared pairs represent a double bond; three shared pairs is called a triple bond." She then asks the students to all follow her method of LDS drawing providing two examples using PCl_3 and HCN, asking students to first place the least electronegative element in the middle as the central atom, then drawing bonds and counting electrons so that every atom has its eight electrons. A few students needed to adjust their bond drawing with not all electrons used. She then offers a few more examples to draw including NH_3 and H_2O, both examples than include lone pairs around the central atoms. The students all get this and PK says to the class, "Good job everyone. Are we all having fun now? I could just do LDS drawings all day long!"

Dean Rosenberg. Dean, in his mid-40s, lived in the same community several miles from where he taught. Dean met his wife at this school where she also taught science. He often jogs to and from school. He was easy-going and immediately at ease in conversation, lacing his interview responses with anecdotes about student interactions. Dean had a ready smile and there was at times a playfulness in his voice, as though he was participating as a fellow student in these classroom recollections; other times he was clearly the teacher at the center of the business of teaching. In the classroom he was matter-of-fact, clear, and concise with his instruction. Dean coached soccer fulltime before coming to teach, and he has served as the varsity soccer coach at his school. He said that coaching transfers naturally to his role as a teacher. He was plain-spoken and exuded a measured calm confidence. His ready smile drew in others. He was someone upon first meeting you knew you could trust. Dean admitted that he has grown greatly in his profession in his time teaching and that the awards he has earned along the way have only been markers in his career as a lifelong teacher-learner. To watch Dean teaching was like watching a master storyteller, using measured and practiced direction and explanation. The tone and inflection of his instruction was at once calming and authoritative. It was clear that a high level of planning, organization, and reflection had gone into preparing his lessons. In turn, students were at the edge of the class discussion, adding to points others made and calling out when a point Dean made needed clarification. Students in his classes were active and engaged to the point of deliberating and debated when he moved toward discussion time within a lesson. Dean was proud of the *milieu* he created that allows students to productively argue over such things as the relevance of a chemical equation or the significance of experimental error from a lab. Dean readily agreed that his teaching is like Chinese cooking: 90% preparation, 10% in the wok.

Dean recognized that students develop required thinking skills at different times and his calmness and patience over time in class was another theme seen in AWT teachers, “Every kid can be pushed to a new level from where they started and that’s going to look differently for each student.” He was very much attuned to each of his students’ academic and socioemotional needs alongside being a teacher with demanding expectations.

> The student-teacher relationship is what it is all about. I see my beliefs as being able to support and maximize a student’s potential to learn chemistry and to ultimately be able to observe, question, analyze and view the world through a scientific lens.

Dean's school could be described as rural-suburban. His classroom was modern with the front half for lecture with desks and the back half with tables for lab work. Wall-mounted cabinets lined the room above the lab countertops on two sides with a long whiteboard and the teacher's desk and a worn swivel armchair toward the front of the classroom. Like PK's classroom, for all of the great teaching and learning here, the room was remarkably absent eye-catching posters, charts, or other science/chemistry promotion. The school building, a two-story campus built in 1973 in a brick and concrete was reminiscent of that cookie-cutter style of school architecture. The school has served two communities, both forested with lots of land between homes and with typical New England town centers around a common, original 18th century churches and Federalist style town offices building. The school served grades approximately 1900 students, grades 9–12, with a graduation rate of 98.2% (DESE). The mean SAT scores were 1258 with 99% taking the SAT or ACT, and the average household income placed this school in the top 6.9% compared to other Massachusetts schools. Students from Dean's classes regularly competed in annual science and chemistry competitions, and many years they received top scores.

Stella Danes. Stella has lived in a middle-class community several towns away from where she was teaching. Her three children attending the public school in the town where she lived. She said that the lessons she has been preparing to teach and her students were constantly on her mind, including as she has been driving to and from work. Her husband has also worked as a science teacher at the same school.

Stella's classroom was a safe space in many ways, and she has worked each year to create this space by earning and demonstrating trust, showing a deep interest in getting to know her students, and fostering a culture of taking academic risks. Here is what I saw in one class visit.

> The AP class meets for 90 minutes and will do a 'lab' really an activity on molecular geometry. It is really a review of molecular structures and a lab in the sense that students are presented with a problem and then asked in groups to solve the problem using applied data (given structures from a chart) and home-provided molecular model kits to build and draw the unknown structures. "For those of you wanting to work ahead of class, you'll find everything posted on Schoology" (the school's class posted platform)." SD is able to view individual student drawings through their class electronic platform. Roughly 40 minutes is used for students to do essentially a guided inquiry POGIL-like activity, a student asks, "Could XeF_4 also be square planar in addition to tetrahedral?" Another student, "What about an expanded octet?" SD, "Listen all, we're talking about molecular geometry, not VSEPR." Student, 'know – it's 'see-saw' shaped!" SD, "Yes, isn't that a crazy name?!" (holds up a distorted tetrahedral sp^3d bonding molecule made from a kit to illustrate the see-saw shape). When most are done, SD asks, "How about a thumbs-up if this activity has given you a better sense of creating molecular structures?" Most thumbs go up. To summarize, the class is steered back to the original question about which two shapes are similar. Student, "I know, it's numbers 1 and 4!" (tetrahedral SiF_4 and octahedral SO_4^{2-}). Students are sent to breakout rooms for the remaining 15 minutes of class to discuss and compare their answers. When called back, SD asks if there are any more questions, praising their work for today's lesson, and leaving them with "I hope you all have a wonderful Thanksgiving, and I am thankful for all of you for being such awesome students!" One student remains after class to ask why the octahedral-shaped molecule has only six sides to which SD replies that it's octahedral because it has six electron domains, not all bonding pairs. The student then wonders out loud why October is actually the 10th month. It's a funny exchange and one that demonstrates the curious questioning, trusting, and academic risk-taking environment that SD has created in class.

Stella's take on innate versus learned as the genesis of award-winning teaching was, from the teacher's point of view, "5% 'it' which involves passion, wonder curiosity, drive, caring, and affection versus 95% pedagogy, that is, teaching skills, ability to understand and respond to student learning and convey complex information with ease and confidence." She continued, "But from the student point of view, it's flipped: 95% 'it' and the relationship they form with you, without which *no good learning will happen;* and 5% pedagogy as students don't see "all the behind-the-scenes work involved and don't even realize if good teaching is happening, it just is because they're so engaged in learning, and at this point my job is to step aside and the students take the lead."

Roxanne Hobbs. Roxanne's district had one K–3, one middle school, and a single high school serving 700 students grades 9–12, which is relatively small for greater-Boston area public high schools. The spread-out single-story high school campus was built in 1961 with different departments added on or modernized since then. The school has continually ranked in the top 1% in the state, based on math and English proficiency test scores. Amongst the students there has been a sense of high expectations, especially within STEAM subjects. Many students have entered external competitions for science, math, and art, and have exceled. The typical stress that is found in high-achieving schools was felt here as well.

Roxanne was plain-spoken and down-to-earth, belying her three advanced degrees from prestigious technical institutes. She exuded a passion for her profession and was described by fellow colleagues and students alike as "funny," "creative," "empathetic," and "smart." She had a knowing, reassuring tone in conversation and there was excitement and charisma in her voice as she explained her beliefs about science education, teaching in general, and working with teenagers

Moving through the curriculum was at the forefront of each lesson with Roxanne constantly checking for student questions and pausing to ask for overall class understanding. “How’s everyone doing with the work so far today?” was a constant rejoinder in the pace of her lectures and discussions. She is nurturing in tone and encouraging with regular, “Good job,” “Well done,” “Nice!” peppered throughout class discussions. Roxanne reported that she firmly believes that every kid can and should be an active participant in class and that her classes be primarily content centered versus kid or teacher centered. Roxanne’s room until COVID was arranged with 24 desks cramped together all facing a front board with lab benches and sinks toward the back of the room, allowing her classes to hold lecture and perform lab work all in the same space. Her desk was at the front corner of the classroom, next to a dark wood bookshelf crammed with texts. A few charts adorned the walls and a rectangular poster in the form of an element block with the symbol “Aha! the element of surprise!” hung above the front board. Since COVID, the desks, all distanced apart, were all turned to face the rear and a well had been formed from several tables for the teacher. Less inviting and more formal looking, it was a necessity given the pandemic conditions. Visiting any of her classes, one immediately sensed the three players present: teacher, kids, and curriculum. If you had to draw a triangle about these three players its longer base would be the content. The precision and accuracy of Roxanne’s presentation undergirded her careful planning and explicit expectations for each class, initially stated and often restated throughout the class period. Her teaching and reflection were transparent with her students. Often, she caught herself in class mid-sentence to share that she taught this concept a bit differently last year, but learned how to improve its presentation for this year, or to share with students that she left a sticky note to herself in the teacher's textbook labelled "Angry exceptions from last year!" which she read aloud, eliciting some smiles from students. In all of this, the students heard and saw a teacher constantly wanting to improve her pedagogy and curriculum presentation with humor and transparency. In other class moments, she debated the curriculum in front of the class in a Talmudic-like conversation with the effect of encouraging students to likewise debate and question the material to benefit their understanding:

> In another part of the lesson, RH draws an H-F molecule with an exaggerated electron density surrounding the fluorine atom. "Time to learn something not learned back in first-year chemistry, the physics behind the dipole moment." Again, RH's command of physics weaves its way into her chemistry curriculum. She adds the ∂+ and ∂- to the H and F respectively noting that the Greek letter delta here looks either like the Hebrew letter *lamed* or a sperm from biology class, then uses the arrow to show the vector of electron density, saying that this is annoying because showing the vector is one way for physicists and the other way for chemists, a raging unresolved debate.

The effect this modeling seemed to have is a classful of students engaging in a similar transparent reflection toward their own learning and attention to perfecting their understanding. The students seemed particularly engaged when these mid-class debates were presented, knowing it was a feature of RH's modeling to have students similarly question the curriculum. "It's my continual responsibility to clearly explain the work and interpret the textbook for them, not to just leave them to figure things out on their own," she stated. Here are my notes about another exchange.

> In AP Chemistry, part of class involved a discussion on the nature of chemical bonds. The introduction to this was a presentation of bond energy vs. intermolecular force and optimizing the distance between two atomic nuclei. The presentation was as much physics as chemistry using coulombic forces and distances to enrich this presentation. RH shared that

> even the class textbook made some assumptions about how bonds form that, in her opinion, "were not entirely kosher." Students smiled at this informed yet off-hand remark.

In this sense, Roxanne was a curriculum interpreter and cheerleader for her students to conquer the content. From Day One of her AP class, Roxanne has let students know that they are in this together versus the AP exam, treating her class more like a team with Roxanne as the captain calling the plays.

Elena Hernandez. Elena's classroom was modern, with a long white board and in-focus ceiling mounted projector. Classrooms along the science corridor look out over the celebrated football and soccer fields. Her desk sat in front of the school's back view with a forest extending beyond the campus. On one wall hung an enormous periodic table updated to include the most recently named element, no. 118. Several yellow and red molecular orbital models sat atop one of the wall-mounted cabinets. The day's agenda for each class was written neatly using different colors at one end of the white board. The classroom was a large, open space where students could move around and work in small groups, something Elena encouraged for many planned activities. Like several of the previous participants' classroom, the walls mostly devoid of wall charts, posters, and chemistry tables typically found in many classrooms.

Like all others in this study, Elena came to teaching from another career path, in her case it was research at a laboratory bench. Finding this impersonal and too rote, Elena exhibited personal pride and exaltation in finding her way to a career in teaching. She was plainspoken, engaging in conversation and was ready to break a smile or offer a funny anecdote when sharing some examples of student interactions in her classroom.

Her love of teaching and passion for relaying chemical knowledge to her students was evident in her retelling of past student interactions, both good and not-so-good. As she related, Elena's epiphany in her early years of teaching was the importance student-teacher relationships have motivating students to be successful. Years later, she was integrating get-to-know-you activities and exercises into her chemistry teaching not just at the beginning of the year, knowing that if her "students see their teacher cares, then they will care." Relationships born from trust and caring in Elena's classroom were pillars of her pedagogy. Her joy each day, in addition to telling the story of chemistry to her classes, appeared to be sharing with teenagers for who they are and strengthening the relationships she maintains with each student.

As Elena shared, one day a student left class with a frown on her face. Elena wasn't sure if this had to do with the class, her reaction to something Elena had said, or something else, but made a mental note to address this with the student the next day. When she pulled the student aside to ask her about her grimace at the end of class, the student through tears related that she was having a difficult time at home lately and was glad that she (EH) had noticed. To watch Elena work with her students was to watch a loving mother tend to her flock. Her maternal sense was on display as she leaned in to students with questions or moving them with care toward group work in class. She said that early in the year she has made time for each student to have a get to know you one-on-one, from which she could more completely understand each student's likes, dislikes, hopes, and dreams. It was this forged bond she created with each of her students that, she claimed, allowed the buy-in her students have for learning chemistry with her. She, in turn, has openly shared in class that she is a fellow learner and that her students had much to teach her about teaching and learning. “Yes, I understand students as learners directly informs me how I teach them. For example, this year I have one class who are almost all visual learners, so I must modify their lessons with more visuals. But then again, this is just good teaching!” Here is a statement from her beliefs about what motivates her as an educator.

> The student-teacher relationship is what it is all about…. I see my beliefs as being able to support and maximize a student’s potential to learn chemistry and to ultimately be able to observe, question, analyze and view the world through a scientific lens.

Amy Morris. Amy has taught for the past nearly 20 years at a regional high school located about 40 miles south of Boston. The district drew students from several small adjacent bedroom communities. These towns were a mix of working class and professional households, mostly suburban middle class. The regional high school was established in the late 1950s and had an enrollment of about 1300 students grades 9–12. Since the current new building and athletic fields were built around 12 years ago, student enrollment has steadily grown. Music, business and marketing, and STEM all have had strong, well-attended programs. Students here had a high expectation for achievement and students have expressed some stress around taking high-level courses and getting into good colleges, though not nearly so as DR’s or PK’s schools. The school has continually ranked in the top 5% in the state, based on math and English proficiency test scores. Sports has been very popular here, and the students have taken great pride in their athletic teams. Athletic events, especially with rival schools, have been well-attended by both students and parents.

Amy's school had a science sequence that began with 9th grade Core Foundations, a combination of introductory chemistry, physics, biology, and earth science, a curriculum that Amy had a big part in developing. Following was biology, chemistry, physics sequence for 10th–12th grade, with the option to double up junior and/or senior year for AP courses.

In her teaching, Amy constantly attempted to keep the chemistry relevant, connecting it with students' prior and background knowledge with a hope to make the learning part of their daily lives.

> She begins the new unit introducing a prism and asking students how it works. It's a simple query, and the students mostly come up with a plausible explanation using terms like 'diffraction' and 'separation' of light. This visual leads to a brief history lesson beginning with Democritus, then Aristotle, Galileo, Newton, and the development of practicing inquiry through the scientific method. This leads to the lesson's POGIL activity, an inquiry about light and waves, discharge tubes and spectra. The POGIL has 20 guided questions around these topics. The students are working together in small groups of three and it's clear from their discussion that they are applying some of their learning from their 9th grade Core Science Foundations course.

In recent years, Amy had been teaching first year honors chemistry with the one section of AP taught by a newer teacher who Amy trained to teach the course so that she could devote time to her role as department chair. Her other teaching assignment was to co-teach an AP Research course, a capstone senior seminar for students to learn research methodologies and presentations accompanied by a final 5000-word paper. Colleagues and students described Amy as a teacher "who doesn't quit any of her students," who is "passionate about chemistry teaching," and is a "teacher's teacher." She was declarative and excited in sharing her love of teaching and there was an obvious pride in her voice, with a subtle Midwestern twang, in having found her calling as a mid-career move. Amy was a master at using chemical demonstrations as a hook to emphasize a concept, initiate wonder, or provide a discrepant event to leave students questioning their assumptions. In one class she performed a classic discrepant demonstration almost telling it like a story for which the students must provide the punchline.

> The demo comes in different forms but typically involves two measured volumes, when mixed, that do not add to the sum of the two volumes. Her discrepant event involved mixing 500 mL of 1*M* HCl with 500 mL of 1*M* NaOH, and seeing that the volume increases. Before answering 'Why', she went right into the mole concept with the intent that this would help students answer the 'Why' themselves. With the class agenda posted, the lesson began with "We're going to try some asynchronous learning today", a transparent demonstration to try something new with her class.

She was known as a creative curriculum innovator and lesson planner, at ease using different methods for presenting material in novel ways. Her adaptability and constant adjustments of curriculum for her students' needs and abilities came from a belief that all students learn differently and teachers must adjust their instruction accordingly.

> "For the readers I give extensive notes, for the visual learners I use demonstrations, more hands-on activities, and animated presentations. I think most of us are visual learners. I believe that there's no best way of teaching but everyone must receive clear instruction and expectations…I try to relate what I'm teaching to real world examples and since chemistry is everywhere this is easy…I might lecture for the first few minutes then have the students work in groups on an activity or problem. It's important to continually activate students' prior and outside knowledge and experience."

REFERENCES

Acheson, K., & Gall, M. D. (1997). *Techniques in the clinical supervision of teachers: Preservice and inservice applications*. New York, NY: Addison Wesley Longman.

Amback, G. (1996). Standards for teachers: Potential for improving practice. *Phi Delta Kappan*, *78*(3), 201-207.

Barton, L. (2001, March). To drill or not to drill: Some fresh ideas for teaching high school chemistry. *Canadian Chemical News*, 23-24.

Berliner, D. C. (1987). Simple views of effective teaching and a simple theory of classroom instruction. In D. C. Berliner & B. Rosenshine (Eds.), *Talks to teachers* (pp. 93-110). New York, NY: Random House. (Original work published 1987)

Berliner, D. C. (2005, May/June). The near impossibility of testing for teacher quality. *Journal of Teacher Education*, *56*(3), 205-213.

Berra, Y. (2008). *You can observe a lot by watching*. Hoboken, NJ: John Wiley & Sons.

Brophy, J. (2006). Generic aspects of teaching. In P. Alexander & P. Winne (Eds.), *Handbook of research of educational psychology* (2nd ed., pp. 755-780). Mahwah, NJ: Erlbaum.

Brophy, J., & Good, T. (1986). Teacher behavior and student achievement. In M. Wittrock (Ed.), *Handbook of research on teaching* (3rd ed., pp. 328-375). New York, NY: Macmillan.

Campbell, J., Kyriakides, L., & Muijis, D. (2004). *Teacher effectiveness: Developing a differentiated model*. New York, NY: Routledge-Falmer.

Cohen, D. B. (2010, April 28). No value added: The mismeasurement of teaching quality. Retrieved June 10, 2013, from Education Week website: http://www.edweek.org/tm/articles/2010/04/28/tln_cohen_teachquality.html

Coleman, H. (2010). An exemplar of effective practice. *Journal of Education, Boston University School of Education*, *190*(1/2).

Collins, J. (2005). *Good to great*. New York, NY: Harper & Collins.

Coppola, B. P. (1996). Progress in practice: The scholarship of teaching. In *The chemical educator* (pp. 43-50). New York: Springer-Verlag. (Reprinted from *The Chemical Educator*, *1*(3), 1996, October).

Corbin, J., & Strauss, A. (2008). *Basics of qualitative research* (3rd ed.). Los Angeles, CA: Sage.

Corcoran, S. P. (2010). Can teachers be evaluated by their students' test scores? Should they be? The use of value-added measures of teacher effectiveness in policy and practice. In Annenberg Institute (Comp.), *Annenberg Institute for School Reform at Brown University*. Retrieved from http://www.annenberginstitute.org/pdf/valueAddedReport

Darling-Hammond, L., & Youngs, P. (2002). Defining "highly qualified teachers": What does "scientifically-based research" actually tell us? *Educational Researcher*, *31*(9), 13-25.

Datnow, A., & Castellano, M. (2000). Teacher's responses to success for all: How beliefs, experiences, and adaptations shape implementation. *American Educational Researcher*, *37*(3).

Deters, K. (2004, December). Inquiry in the chemistry classroom. *The Science Teacher*, 42-45.

Engel, S. (2009, November 1). Teach your teachers well. *New York Times*, Opinion Editorial, p. 21.

Ericsson, K., & Charles, N. (1994). Expert performance: Its structure and acquisition. *American Psychologist*, *49*, 725-747.

Fenstermacher, G. D., & Richardson, V. (2005). On making determinations of quality in teaching. *Teachers College Record*, (107), 186-213.

The five ingredients of outstanding teaching. (2013, May 2). *Secondary Education UK*. Retrieved from http://www.sec-ed.co.uk/best-practic/the-five-ingredients-of-outstanding-teaching. Accessed July 5, 2016

Fosnot, C. (2006). Learning to teach, teaching to learn. In *Teaching Education* (Vol. 5, pp. 69-78). New York, NY: Center for Constructivist Teaching/Teacher Preparation Project. (Original work published 1993)

Gage, L. (1978). *The scientific basis of the art of teaching*. New York, NY: Teachers College Press.

Gallagher-Bolos, J. (2004). *Teaching inquiry-based chemistry*. Portsmouth, NH: Heinemann.

Garnett, P., & Tobin, K. (1989). Teaching for understanding: Exemplary practice in high school chemistry teaching. *Journal of Research in Science Teaching*, *26*(1), 1-14. http://dx.doi.org/10.1102/tea.3660260102

Geertz, C. (1973). *The interpretation of cultures: Selected essays*. New York, NY: Basic Books.

Good, T., & Brophy, J. (2000). *Looking in classrooms* (8th ed.). New York, NY: Addison Wesley Longman.

Gordon, L.M. (2001, March). *High teacher efficacy as a marker of teacher effectiveness in the domain of classroom management*. Unpublished working paper, University of California, San Diego, CA.

Green, E. (2010, March 7). Can good teaching be learned? Retrieved June 8, 2013, from *New York Times Magazine* website: http://www.nytimes.com/2010/03/07/magazine/07Teachers-t.html?_r=0

Green, E. (2014). *Building a better teacher: How teaching works*. New York, NY: W.W. Norton.

Hammerness, K. (2006). *Seeing through teacher's eyes: Professional ideals and classroom practices*. New York, NY: Teachers College Press.

Harrison, A., & Treagust, D. (2001). Conceptual change using multiple interpretive perspectives: Two case studies in secondary school chemistry. *Instructional Science*, *29*, 45-85.

Herron, J. D. (1996). *The chemistry classroom: Formulas for successful teaching*. Washington, D.C.: American Chemical Society.

How to make a good teacher. (2016, June 11). *The Economist*. Retrieved from http://www.economist.com/node/21700383/print

Hutner, T., & Sampson, V. (2015, May). New ways of teaching and observing science class. *Phi Delta Kappan*, *96*(8), 52-56.

Kenney-Kennicutt, W. (2008). An award winning high school science teacher shares his classroom insights. *International Journal for the Scholarship of Teaching and Learning*, *2*(1).

Ladson-Billings, G. (2012). Teacher quality: Conversations on quality. Retrieved August 8, 2015, from http://www.rethinkingschools.org/special-reports/quality_teachers/peer.shtml

Lampert, M. (1999). How do teachers manage to teach? Perspectives on problems in practice. In E. Mintz & J.T. Yun (Eds.), *The complex world of teaching: Perspectives from theory to practice* (pp. 255-271). Cambridge, MA: Harvard University Review. (Original work published 1999)

Lantos, S. (2005). Letter from the classroom. *The Nucleus*. Northeastern Section of the American Chemical Society. *84*(3).

Lantos, S. (2009). *Identifying "It."* Unpublished working paper, CT735, Boston University, Boston, MA. Sept. 29.

Lantos, S. (2010). *Getting good: Evaluating quality teaching and its implications for policy*. Unpublished working paper, AP702, Boston University, Boston, MA. March 13.

Lantos, S., & Meshoulam, D. (2012). Reflections on learning and teaching. *Boston University Journal of Education, 192*(1), 1-4.

Lantos, S. (2012). *Doctoral comprehensive examination*. Unpublished working paper, Boston University, Boston, MA. March 22.

Lantos, S. (2018). Going for the gold. *The Nucleus.* Northeastern Section of the American Chemical Society. *96*(6).

Lawrence-Lightfoot, S. (1983). *The good high school: Portraits of character and culture*. New York, NY: Basic Books.

Lemov, D. (2010). *Teach like a champion: 49 techniques that put students on the path to college*. San Francisco, CA: Jossey-Bass.

Mark, M., & Osbourne, J. (2000). *Good practices in science teaching*. Philadelphia, PA: Open University Press.

Mason, D. (2010). A new decade in chemical education. *21st Biennial Conference on Chemical Education in Journal of Chemical Education*, *87*(6), 575-577.

Massachusetts model system for educator evaluation: Part III: Appendix C: Teacher rubric. (2012, April). Retrieved August 11, 2016, from Massachusetts Department of Elementary & Secondary Education website: http://www.doe.mass.edu/edeval/resources/rubrics/

Merseth, K. (1996). Cases and case methods in teacher education. In J. Sikula (Ed.), *Handbooks of Research in Teacher Education* (pp. 722-744). New York, NY: McMillan.

Mortimer, E. F., & Scott, P. (2003). *Making meaning in secondary science classrooms*. Philadelphia, PA: Open University Press.

Napso, J. (2005). *The definition of teacher quality: What state policy makers say in three states* (Unpublished doctoral dissertation). Boston University, Boston, MA.

Nieto, S. (2003). *What keeps teachers going?* New York, NY: Teachers College Press.

Northeastern Section American Chemical Society Award Nomination Letters. (2006-2015). Unpublished.

Olson, J. (1992). In search of the expert teacher. In *Understanding teaching: Beyond expertise*. Philadelphia, PA: Open University Press. (Reprinted from *American Journal of Evaluation*, 1-15, n.d.)

Palmer, P. (1998). *The courage to teach: Exploring the inner landscape of a teacher's life*. San Francisco, CA: Jossey-Bass.

Patton, M. (2001). *Qualitative research and evaluative methods* (3rd ed.). St. Paul, MN: Sage.

Perrone, V. (1991). *A letter to teachers*. San Francisco, CA: Jossey-Bass.

Pienta, N., Cooper, M., & Greenbowe, T. (2005). *Chemists guide to effective teaching* (Vol. II). Upper Saddle River, NJ: Pierson Prentice Hall.

Reeves, A. R. (2011). *Where great teaching begins: Planning for student thinking and learning*. Alexandria, VA: ASCD.

Reville, P. (2011, June 1). A new system for teacher evaluation [Blog post]. Retrieved from http://education.blog.state.ma.us/blog/2011/06/index.html

Rockoff, J. (2004). The impact of individual teachers on student achievement: Evidence from panel data. *American Economic Review Papers and Proceedings*, *94*(2), 247-252.

Roy, S. (2007). *The complex classrooms of three award-winning Ontario high school physics teachers* (Master's thesis). Toronto, Ontario: Queen's University. 13:48:42.481

Saphier, J. (2008). *The skillful teacher* (6th ed.). Acton, MA: Research For Better Teaching.

Schön, D. (1983). *The reflective practitioner*. New York, NY: Basic Books.

Secondary Chemical Education Task Force (Ed.). (2012, February). *American chemical society guidelines and recommendations for the teaching of high school chemistry* (Publication No. 2nd Ed.). Washington D.C.: American Chemical Society.

Seidman, I. (2006). *Interviewing as qualitative research: A guide for researchers in education and the social sciences*. New York, NY: Teachers College Press.

Shulman, L. (2004). *The wisdom of practice: Essays on teaching, learning, and learning to teach* (S. Wilson, Ed.). San Francisco, CA: Jossey-Bass.

Smith, C. (2013, March). There's teaching, and there's teaching. *Education in Chemistry*. Retrieved from http://www.rsc.org/education/eic/issues/2013March/teaching-school-university-transition-lecture.asp

Soar, R., Medley, D., & Coker, H. (1983). Teacher evaluation: A critique of currently used methods. *Phi Delta Kappan*, *65*(4), 239-246.

Spencer, J. (1999). New directions in teaching chemistry: A philosophical and pedagogical basis. In *Journal of Chemical Education*. Washington D.C.: American Chemical Society. (Reprinted from *Journal of Chemical Education*, *76*(4), 566-569, 1999, April)

Stone, R. (2004). *Best teaching practices for reaching all learners: What award-winning teachers do*. Thousand Oaks, CA: Corwin Press.

Stone, R. (2015). *Best practices for high school classrooms: What award-winning secondary teachers do*. Thousand Oaks, CA: Corwin Press.

Sweeney, A. E., Bula, O. A., & Cornett, J. W. (2001). The role of personal practice theories in the professional development of a beginning high school chemistry teacher. *Journal of Research in Science Teaching*, *38*, 408-441. http://dx.doi.org/10.1002/tea.1012

Tate, P. (2001). Excellence in teaching: Myths and legends. In T. Arnold (Ed.), *Facing change: Proceedings of the AIESEP World Sport Science Congress* (pp. 1.45-1.51). Queensland, Australia: Association Internationale des Escoles Superieures d'Education Physique and School of Health and Human Performance.

Taylor, T. (2009). Chemical education regional awards for excellence in high school teaching. *Journal of Chemical Education*, *86*(5), 546.

Tell, C. (2001). Appreciating good teaching: A conversation with Lee Shulman. *Educational Leadership*, *58*(5), 6-11.

Thompson, G., Warren, S., & Foy, T. (2008). What makes a teacher outstanding? A contrast of teachers and African-American high school students' perspectives. *Journal of Urban Learning Teaching and Research*, *4*.

Tobin, K., & Fraser, B. (1990). What does it mean to be an exemplary science teacher? *Journal of Research in Science Teaching*, *27*, 3-25. http://dx.doi.org/10.1002/tea.3660270103

Vanderkam, L. (2014). *A wise giver's guide to cultivating great teachers and principals*. Washington, DC: The Philanthropy Roundtable.

Yeigh, T. (2008). Quality teaching and professional learning: Uncritical reflections on a critical friend. *Australian Journal of Teacher Education*, *32*(2), 1-15.

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