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The Experience of Teaching Online Secondary Science

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THE EXPERIENCE OF TEACHING
ONLINE SECONDARY SCIENCE

by

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Doctor of Philosophy – Curriculum & Instruction

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Dissertation Approval

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Abstract

The Experience of Teaching Online Secondary Science

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The experience of teaching online secondary science was investigated through the lens of developmental phenomenography. Recorded phenomenographic interviews were conducted with thirteen secondary science teachers who were teaching online in two countries and four states. After analyzing the transcripts individually and as a whole, seven themes were identified: (1) Virtual Labs and Learning, (2) Student Learning and Factors Involved, (3) Communication and Instruction, (4) Teaching as Collaboration/Social Aspect, (5) Teaching and Learning as Assessment, (6) Curriculum Effects on Teaching and Learning, and (7) Online Structure Effects on Teaching and Learning. The structures of awareness of these seven themes formed the overall structure of awareness of what it is to teach online secondary science. Some of the findings from this study included the need to both provide open-ended inquiry opportunities for online secondary students and to develop scientific argumentation practices in online secondary science courses. Implications developed from this structure of awareness for online secondary science teachers, virtual school administrators and virtual schools, and teacher education programs are discussed, and recommendations are provided for areas of future research.

Acknowledgements

“I don’t even know what an online science classroom looks like”.

After having considered a number of topics for my dissertation, Dr. Janelle Bailey finally brought clarity with that simple statement. Thank you, Dr. Bailey, for asking the question that allowed me to separate the wheat from the chaff.

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I am particularly grateful to many of the faculty members at UNLV for their part in my development as a researcher and instructor. Dr Hartley provided me with multiple hands-on opportunities at experiencing the inner workings of academia. Dr. Strudler supported me during my first try at independent research and was always there to test out ideas or to vent about the state of educational technology. I thank him for the many ways he helped familiarize me with the academic mores. Dr. Shaoan Zhang helped me develop research collaboration skills and Dr. Michael McCreery provided experience as to how to write an article based on the research

provided by another. Dr. Karen Grove's guidance was instrumental in acclimating my transition from a face-to-face teacher to a successful online instructor.

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Dedication

“On and on you will hike, and I know you'll hike far
and face up to your problems whatever they are.

You'll get mixed up, of course, as you already know.
You'll get mixed up with many strange birds as you go.
So be sure when you step. Step with care and great tact
and remember that Life's a Great Balancing Act.
Just never forget to be dexterous and deft.
And never mix up your right foot with your left.

And will you succeed? Yes! You will, indeed!
(98 and 3/4 percent guaranteed.)

KID, YOU'LL MOVE MOUNTAINS!

So...
be your name Buxbaum or Bixby or Bray
or Mordecai Ali Van Allen O'Shea,
You're off the Great Places! Today is your day!
Your mountain is waiting. So...get on your way!”

Seuss. (1990). *Oh, the places you'll go!*. Random House Childrens Books

I dedicate this dissertation to my husband, Steve Finch, whose support made it possible for me to find my mountain. He was my consultant/confidant/cheerleader as I hiked my way through a myriad of careers and degrees to at last discover my true calling in academia. And once I found my way he was there again to assist me through the stressful times, providing the guidance needed for me to maintain focus on both the small and overarching goals, as well as helping me to see the light at the end of the semester tunnels. Steve, without your confidence in my capabilities and your skill at helping me to refocus, I surely would have lost my way.

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Chapter 1 Background to the Study

“...the Internet is bringing us closer than we ever thought possible to making learning – of all kinds, at all levels, any time, any place, any pace – a practical reality for every man, woman, and child” (Isakson & Kerrey, 2000, p. 1)

These sentiments, stated fourteen years ago by the Web-Based Education Commission, continue to be the driving force behind the current K-12 online education push. The commission identified four areas that required a call for action: “Greater access to broadband connectivity, guidance in the best uses of the Web for learning, understanding of how people learn differently with the Internet, and content that leverages the powerful capabilities of the Web” (Isakson & Kerrey, 2000, p. 4). Over a decade later, there were 750,000 K-12 online course enrollments and an estimated 310,000 students attended fully online schools in 30 states during the 2012-2013 school year (Watson, Murin, Vashaw, Gemin, & Rapp, 2013). Part of the reason for the influx of these enrollments is due to the perceived benefits provided by online education options for states and school districts (Picciano & Seaman, 2009; Tucker, 2007). Given the growth of K-12 online education, the question must be asked; has the call for action by the commission been met in this type of learning environment?

The purpose of this chapter is to provide the reader with an understanding of the current K-12 online education environment. Having a better understanding of this environment helps to further drill down and explore the issues specific to online secondary science education, which was the focus of this study. Chapter 2 will explore online secondary science teaching and learning issues in more depth. The rest of Chapter 1 will briefly describe the implications of K-12 online learning for states, school districts, administrators, teachers, and students. By providing an overview of the implications of the online setting for these stakeholders, an understanding can

be developed about the ways in which online secondary science teaching may be impacted by the environment under which it occurs. Before proceeding with this endeavor, common terms will be provided which may be unfamiliar to the reader.

Definitions and Terms

The International Association for K-12 Online Learning (iNACOL, 2011) has developed a set of online learning definitions to “provide states, districts, online programs, and other organizations with a set of definitions related to online and blended learning in order to develop policy, practice, and an understanding of and within the field” (iNACOL, 2011). To aid in this effort, terms used throughout this paper will observe the definitions provided by iNACOL in Appendix A, Table 1. Further clarification on the different categories of online schools (Appendix A, Table 2) was developed by Clark (2001). This report identified and defined seven different types of K-12 online schools. The categories are based on governing bodies, instructional purpose, and whether or not the school is accredited. Watson et al., (2013) employed a similar labeling method but eliminated the College and University-Based Virtual Schools and added a Blended School category. As the data for this study was derived from secondary science teachers who taught their courses in a fully online environment, the blended school category will not be discussed.

As of the 2012-2013 school year, there were 338 full-time virtual schools, with a total enrollment of 243,000 students (Miron, Gulosion, & Horvitz, 2014). Although private education management organizations (EMOs) only account for 44% of the full-time virtual schools in operation, they account for 80% of the enrollments. Average enrollments in private EMOs are also larger than their nonprofit counterparts; 1,230 students versus 470 students. Miron et al. (2014) reported that fewer minority, low-income, disabled, and students designated as English-

language learners (ELL) attend virtual schools when compared to public school enrollments. Twenty-six states operated state virtual schools offering supplemental courses during the 2012-2013 school year, with a total of 740,000 course enrollments. Of these enrollments, Florida Virtual School (FLVS) accounted for 410,000 enrollments. The figures for enrollments are not surprising given the mandate contained in the National Broadband Plan (Federal Communications Commission, 2010, p. 244) to “change kindergarten through twelfth grade (K-12) and postsecondary course accreditation and teacher certification requirements to allow students to take more courses for credit online and permit more online instruction across state lines”. Given the support by the federal government for online learning, it is important to understand the implications of online learning from the perspective of K-12 stakeholders; states, school districts, administrators, teachers, and students.

Implications for States, School Districts, and School Administrators

The implications for states, school districts, and administrators are very similar and they will be treated as one group. These implications include financial considerations, structural capacity, program development and evaluation, teacher recruitment and development, and student access and learning. Financial considerations associated with K-12 online education, though important, will not be covered in this chapter as the purpose of this study was to help provide an understanding of K-12 online education as a teaching environment.

One of the most important benefits online secondary education affords these parties is the ability to more fully provide for the needs of their students (Huerta, Rice, & Shafer, 2014; Picciano, Seaman, Shea, & Swan, 2012). Incorporating online credit recovery facilitates students’ abilities to obtain enough credits to graduate (Tucker, 2007). Students in rural areas are no longer denied access to courses due to the lack of qualified teachers, particularly in the

areas of mathematics and science (Picciano & Seaman, 2009). Online secondary education affords administrators the ability to provide individualized learning for students, schedule courses they otherwise may not be able to offer due to lack of qualified teachers, and address overcrowding concerns in brick and mortar schools (Watson et al., 2013). Students in more highly populated areas have greater course selection because school districts and school administrators can choose from a variety of vendors (Huerta et al., 2014). Regardless of school size or location, online options allow schools to serve a variety of students whose educational needs might otherwise not be met; students who are hospitalized or homebound, professional athletes, students who want to work at their own pace, and as homeschool support (Huerta et al., 2014; Picciano & Seaman, 2009; Rice, 2006).

With the adoption of the Common Core State Standards (CCSS) another perceived benefit can be identified. School districts believed students enrolled in online courses will be better prepared for the upcoming computer-based CCSS assessments (Picciano et al., 2012). School districts and school administrators also believed that by experiencing online courses now, students will be more successful in the future when taking college online courses. Online secondary courses can also help schools to move beyond the “seat time” metric, allowing students to learn the content at their own pace (Huerta et al., 2014).

This is not to imply there are not significant challenges for states where online secondary education is concerned. Students may have increased access due to online options, but there are questions regarding the quality of the online content (Miron et al, 2014; Watson et al., 2013). There is a lack of research that evaluates curriculum and programs, or that identifies supports that teachers and students may need to be successful in the online environment (Tucker, 2007). Schools use multiple vendors and content is decentralized presenting difficulties when assessing

the quality of the course materials (Miron et al., 2014). Evaluating learning materials can also be difficult due to the research focus on postsecondary online learning; little research has been conducted on how K-12 students learn via the Internet (Cavanaugh, Barbour, & Clark, 2009). Even if quality learning materials were available, there is still a question of equitable access, particularly in rural towns and areas of poverty where students may lack the high speed Internet access required to participate (Tucker, 2007; Watson et al., 2013). An estimated 69% of U.S. households have broadband access (McConnaughey, Goldberg, Neogi, & Brocca, 2013), however this access can vary by socioeconomic level. Students from low socioeconomic status (SES) backgrounds have less access to the Internet when compared with students from high SES backgrounds (Holloway, Green, & Livingston, 2013). If these stakeholders plan to consider K-12 online education as a method for ensuring student choice, more resources must be committed in order to decrease this digital divide.

Even if equitable access were ensured and the quality of online secondary curriculum were not a concern, there is still the matter of recruiting and preparing teachers to teach online (Kennedy & Archambault, 2012; Miron et al., 2014). Other than a few self-report surveys (Archambault & Larson, 2015), current research provides little direction on the skill-set online teachers should possess in order to help students learn in that environment. This makes it problematic for school administrators to recruit new teachers or provide professional development opportunities for current teachers (Anderson, Augenblick, DeCescre, & Conrad, 2006). The lack of research in online teacher development stems from the fact that little is known about the structures that must be in place to produce effective learning outcomes for students in online secondary courses (Cavanaugh et al., 2009; Huerta et al., 2014). Therefore, it is difficult

to know what type of training may be necessary to ensure online secondary teachers have the requisite skills for the online education environment (Picciano & Seaman, 2009).

As this discussion illustrates, online learning is not a quick fix to help broaden the educational opportunities for students. Addressing educational concerns is not as simple as moving face-to-face content online. Teaching and learning online in K-12 education presents new challenges that must be identified and addressed in order for effective learning to occur in online secondary science courses.

Implications for Teachers

Before delving into the implication of online education for secondary teachers, an overview of this population will be provided. Archambault and Crippen (2009) conducted a survey of teachers who had taught or were teaching online K-12 courses in state sanctioned schools in the United States. Demographic information was collected, and open-ended questions such as “Describe your overall experience with teaching online K-12 students” (Archambault & Crippen, 2009, p. 367) were asked in order to provide a deeper understanding of this population. Of the respondents, 75% were female, 91% were white, and the mean age range was 36-45. Sixty-two percent had master’s degrees, with 13% of those having obtained a master’s degree in educational technology. The authors proposed that teachers attracted to online education may have “a stronger interest in issues related to educational technology” (Archambault & Crippen, 2009, p. 369) and that they felt an emphasis in technology would better prepare them to teach in that environment.

The majority of the teachers, 80%, taught all of their courses online. Seventy-four percent taught in the core curriculum subjects, evenly spread between mathematics, science, language arts, social studies, and humanities, indicating that a majority of the teachers taught at the

secondary level, with 87% teaching in their area of expertise. The majority of the respondents (42%) used content providers naming Apex Learning, K-12 curriculum, and Virtual High School as the primary vendors, while 38% developed their own curriculum. The rest used content developed by a curriculum specialist or obtained content from a colleague.

The teachers described above would be acknowledged as experienced teachers who are qualified to teach in their content areas. Understanding their experiences teaching online could provide insight on the differences between teaching face-to-face and teaching online. Understanding the choices they make as online teachers, or choices made for them, in regard to curriculum could help inform teacher development and teacher education programs. Finally, exploring the different challenges they face that are unique to the online environment can help develop an understanding of the structures that need to be in place to ensure effective instruction occurs.

Online secondary teachers are faced with many challenges due to the nature of the learning environment. Much of the research concerning online education has been conducted in the higher education context and cannot be readily generalized to the secondary population (Borup, Graham, & Davies, 2013; Knowles, 1973). Secondary students demonstrate lower degrees of autonomy, requiring a greater degree of teacher engagement (Borup, Graham, & Drsydale, 2013; DiPietro, Ferdig, Black, & Preston, 2008). Because of these issues, many teachers enter into the online setting unprepared. Some states, such as Virginia, Minnesota, and Georgia, are moving towards online certification of teachers but few other teacher preparation programs are incorporating this type of teacher development. In a national survey Kennedy and Archambault (2012) found that only 1.3% of teacher education programs partnered with K-12 online learning programs to provide field service experiences for their teacher candidates and

many preparation programs simply did not address the issue of online K-12 education. Lack of knowledge of the K-12 online environment was listed as one of the main reasons for not providing such experiences as well as not including K-12 online content as part of the coursework required for certification. This situation must be addressed as teachers who have demonstrated quality teaching in the face-to-face classroom are not necessarily successful in the online environment (Davis & Roblyer, 2005; DiPietro et al., 2009). In order to prepare teachers to effectively teach online, teacher preparation programs must be revised. Prior to that, research is needed to identify specific knowledge and competencies required using digital instructional technology to improve adolescent student learning outcomes (Borup et al., 2013).

Course design is another important factor of the online learning experience for adolescent students. Teachers must be able to chunk content into small pieces in order to help lessen online student anxiety (Borup et al., 2013; DiPietro et al., 2008). Providing concrete deadlines not only for assignments but for course progress, and sharing those deadlines with parents can help students manage their efforts more effectively. Online K-12 students also lack the same level of motivation as adult online learners, requiring K-12 online teachers to use methods to increase student motivation to complete necessary coursework. This includes monitoring work in progress and other classroom management techniques. Successful K-12 online teachers have used such methods as presenting materials in multiple ways and accessing the course every night to ensure students knew help was always available (DiPietro et al., 2008).

Online secondary teachers must also have a higher degree of technical knowledge (Comas-Quinn, 2011; Dawson, Dana, Wolkenhauer, & Krell, 2013). While teachers at brick and mortar schools may be able to affect student learning outcomes using traditional methods, the nature of the online environment demands that the online teacher have a greater educational

technology self-efficacy. From understanding the nuances of the learning management system and how those nuances affect student interaction with course materials (Liu & Cavanaugh, 2011), to purposeful pedagogical selection of technology tools, thoughtful use of technology within the bounds of the learning context is crucial. Another challenge for online secondary teachers is to stay abreast of the latest developments in educational technology. As stated by one teacher “There’s so much change with the technology, so much change with the material that you really need to be opened to that change as the technology develops and not be [sic] static with your material” (DiPietro et al., 2008, p. 17).

Perhaps the most important challenge for online secondary teachers is the facilitation of discourse (Borup et al., 2013; Dawson et al., 2013; Teclehaimanot, You, & Singer, 2013). The Community of Inquiry theoretical framework described the confluence of teaching and social presence and their importance in supporting cognitive presence (Garrison, Anderson, & Archer, 1999). Effective communication has been identified as an important factor in the development of teaching and social presence, leading to cognitive engagement among online learners (Garrison, Cleveland-Innes, 2005). A large challenge for the online secondary teacher is to help online secondary students develop online communication skills, as well as the need for the teachers to develop those skills themselves. Both online students (Borup et al., 2013) and online teachers (Teclehaimanot et al., 2013) experience isolation if effective modes of communication have not been mastered. Teachers new to online teaching can feel disconnected from their students, fellow teachers, and their own identity as teachers (Hawkins, Barbour, & Graham, 2012). Online secondary students require assistance developing online collaboration and presentations skills in order to effectively move through their coursework and achieve their learning goals (Davis &

Roblyer, 2005). Knowledge of technology tools and the affordances they provide for online communication, as well as mentoring online students on the use of these tools, is crucial.

Despite these many challenges, K-12 online teachers do report there are benefits associated with teaching in an online environment. The benefits discussed in the literature included being “able to work with students on an individual level” (Archambault & Crippen, 2009, p. 377), the ability to move past the time barrier in order to “meet students at their own level and accelerate their process as needed” (Tucker, 2007, p. 3), and the rewards of working with inner city students without the worry of living or working in the inner city. Online secondary teachers have more freedom to work with their students on an individual basis. Time not spent on classroom management provides teachers the ability to spend more time on instruction (Archambault & Crippen, 2009; Tucker, 2007). Finally, the ability to extend teaching beyond time and geography constraints has allowed highly qualified teachers to continue working as teachers when they otherwise may not have due to such limitations (Tucker, 2007).

Overall, more is known about the challenges faced by online secondary teachers than the benefits experienced from teaching online at the K-12 level. Much work still remains in understanding how to prepare preservice teachers to become effective online teachers, or the types of professional development required for current teachers transitioning to K-12 online education. It is important that research continues to be conducted that can examine the data in depth to determine how best to prepare online secondary teachers and preservice teachers. Developing an understanding of the online secondary science learning environment will provide guidance as to the types of instruction and supports necessary for teachers that will enable them to help students learn science effectively in that environment.

Implications for Students

This section will focus on the most important stakeholder, the students. Few empirical studies exist which examine student learning outcomes associated when students interact with the materials online. Many studies have provided evidence that online K-12 learning outcomes were equivalent to those experienced in face-to-face classrooms, but not enough detail was provided to help identify what characteristics of online K-12 education led to those learning outcomes (Cavanaugh, Gillan, Kromrey, Hess, & Blomeyer, 2004). There were also questions as to where the learning occurred as many students enrolled in online K-12 courses were concurrently enrolled in face-to-face schools and may have sought help from their face-to-face teachers. Another issue is that many online K-12 education studies do not meet the criteria for methodological quality (Means, Toyama, Murphy, Bakia, & Jones, 2009). This limits the ability to identify moderator variables effecting online K-12 learning. Given the lack of quality research on learning outcomes in the area of online secondary education, the topics discussed in this section included the reasons students would elect to take online courses and the student characteristics that have so far been identified as necessary for effective learning in an online learning environment.

As discussed in the section on states, school districts, and administrator perspectives, two of the primary reasons students elected to take online courses were for credit recovery and to gain access to resources not otherwise available (Huerta et al., 2014; Picciano et al. 2012, Queen & Lewis, 2011). In over 1.8 million enrollments in distance education, 62% of those enrollments were for credit-recovery and 29% of the enrollments were for advanced placement (Queen & Lewis, 2011). However, the credit-recovery curriculum has been called into question as it was believed the quality of these courses was deliberately lowered in order to increase graduation

rates (Picciano et al., 2012). There were also concerns that this student population did not fit the characteristics identified as necessary for effective learning in an online environment. Some of those characteristics are high motivation, self-regulation, time management skills, and the ability to work independently. It should be noted that these skills were identified with adult learners (Knowles, 1973), and that further research needs to be conducted in order to establish what supports are required to help adolescents develop these skills so that they might be successful in an online environment.

Providing course access to students was also discussed as a reason to implement online K-12 education. Students may live in rural regions or other small towns that do not have qualified teachers in core content areas such as mathematics or science (Cavanaugh et al., 2009). Students may not be able to attend brick and mortar schools as they may be hospitalized, incarcerated, professional athletes, or they might need a flexible schedule in order to work (Rice, 2006). Other students may wish to enrich the curriculum provided by their local schools. Incorporating online courses to their regular school schedule can allow students to pursue coursework that is of interest to them (Huerta et al., 2014; Rice, 2006).

From students' perspectives, online secondary students reported that attending classes online allowed more flexibility in their education (Bolstad & Lin, 2009). Some students felt they had more flexibility on homework assignments compared with their face-to-face classes, and other students enjoyed the ability to cover the online course content at their own pace, as "the online curriculum gives the program the capacity to meet students at their own level and accelerate their progress as needed" (Tucker, 2007, p. 3). This flexibility extends beyond what is considered to be 'class time'. Bolstad and Lin (2009) found that students discussed course

materials with peers using the course information and communications technology (ICT) outside of regular classroom hours.

Perceived benefits of online secondary learning are more than logistics (Bolstad & Lin, 2009; Cavanaugh et al., 2004). Online secondary students have demonstrated greater improvement in critical thinking skills, were better able to make decisions, had improved time management skills, improved problem solving skills, and exhibited increased creative thinking abilities when compared to those students who had never enrolled in online courses (Bolstad & Lin, 2009). Online secondary students also reported increased engagement with their online coursework when compared with their face-to-face coursework and stated this was due to the authentic nature of the assignments. Lastly, these students felt that they learned more useful study skills from their virtual school teachers. However most of these improved skills were discussed in one report and may not necessarily be representative of online students as a whole.

Not all learning skills showed improvement for students enrolled at the virtual school. Online learners demonstrated less improvement in their speaking and listening skills when compared to their counterparts who had not enrolled in online courses. Virtual school students demonstrated low organizational skills and they had difficulty communicating with their virtual school instructors. The virtual school students also felt they had less quality time with their virtual school teachers. There are limitations to these results as they were developed from self-reported data, conducted at one New Zealand virtual school (Bolstad & Lin, 2009).

As with the previous stakeholders in online secondary education, along with perceived benefits come perceived challenges. Perhaps the biggest challenge is that the difference between adult learners and adolescent learners in the online context is not yet fully understood. As has been previously discussed, adolescents learn differently than adults (Knowles, 1973). Secondary

students must have “maturity, self-discipline, and a certain command of basic skills (reading and mathematics) in order to succeed” (Picciano et al., 2012, p. 134) in online courses. Online secondary teachers must help online secondary students develop self-regulation and motivation.

There is evidence suggesting that secondary students require more social structure when compared to adult learners. For example, the quality as well as frequency of social interactions positively correlates with online secondary students completing online courses (Borup et al., 2013). Without effective and frequent communication from the online teacher, or student-student communication, online secondary students will begin to feel isolated (Bolstad & Lin, 2009; Borup et al., 2013).

The nature of the online medium can present challenges as well. Reading skills become more important in an online learning context with programs that are heavily text-based. Students who do not have strong reading skills, or are English-Language Learners (ELL), will be at a disadvantage in an online text-heavy environment (Cavanaugh, Gillan, Kromrey, Hess, & Blomeyer, 2004). The digital divide can prevent online students from accessing online course content from home, limiting the time they can spend interacting with the course materials (Holloway et al., 2013). Online student demographics are skewed toward white students, generally with a population that is 75% White, 10.3 % Black, and 11% Hispanic (Huerta et al., 2014). The literature does not discuss the reason for the disparity, though part of the answer may be that low income homes tend to have less access to the Internet or computers than higher income homes (Holloway et al., 2013). Finally, perhaps the biggest challenge for all stakeholders, persistence and graduation rates are lower for online secondary students when compared to their brick and mortar counterparts. The graduation rate for full-time online

secondary students was 43.8%, compared to 78.6% for secondary brick and mortar students (Huerta et al., 2014).

Interestingly, while the literature does provide a plethora of perceived benefits as well as challenges faced by online secondary students, little has been written concerning the reasons behind these benefits and challenges. There is a need for continued research in order to fully understand how and under what conditions secondary students learn in an online environment.

Summary

This chapter began by identifying four areas requiring action in order for the Internet to help make learning “of all kinds, at all levels, any time, any place, any pace” (Isakson & Kerrey, 2000, p. 1) a reality for all. Evidence was provided demonstrating that none of the four areas have been sufficiently addressed. Appendix B contains the summary tables of the implications of online education for states, school districts, schools, and administrators (Table 3), teachers (Table 4), and students (Table 5). As pointed out by Watson et al. (2013) and Holloway et al. (2013), broadband connectivity has not increased enough to overcome the digital divide. The socioeconomic status of school neighborhoods and students can generally point to where this divide occurs. We still do not have an understanding of the structures and supports required to ensure K-12 students learn effectively online (Cavanaugh et al., 2009; Huerta et al., 2014), and therefore we cannot identify how the Internet can best be used for learning. In line with understanding how the Internet can best be used, more research must be conducted to better comprehend how adolescents learn differently than adults in order to help them be successful in an online environment (Means et al., 2009; Picciano et al., 2012). Finally, empirical evidence needs to be developed that can guide school districts, schools, administrators, and teachers in

developing effective online course content for secondary students (Miron et al., 2014; Watson et al., 2013).

Despite the call for action not being met, many secondary teachers are expected to teach and many secondary students are expected to learn in the current online environment. As has been shown in this chapter, there are many perceived benefits as well as challenges faced by online secondary stakeholders, but little has been written concerning the reasons behind these benefits and challenges. The fact that the K-12 learning environment appears to be an ‘unknown’ for many in education (Kennedy & Archambault, 2012; LaFrance & Beck, 2014) has led to a lack of training in teacher education programs (Cavanaugh et al., 2009; Miron et al., 2014; Watson et al., 2013) and to a lack of program evaluations and standards. The purpose of this study was to shed light, through the lens of the online secondary science teachers’ experiences, on what made teaching online secondary science unique and what instructional strategies and supports might be required to ensure effective teaching in that environment.

Purpose and Significance of the Study

The overall lack of understanding of teaching and learning in K-12 online education has deep implications for online secondary science education. One of the main populations served are students without access to qualified science teachers (Cavanaugh et al., 2004; Hodapp, Hehn, & Hein, 2009; Tucker, 2007). Given the national push to expand the number of students in science, technology, engineering, and mathematics (STEM) degrees and careers (National Research Council, 2011), ensuring online secondary science students are able to learn effectively in an online environment is critical.

The purpose of this study is to begin to develop a holistic view of online secondary science education by developing an understanding of what it is to teach in that space. This

understanding will provide a more indepth insight than that obtained from self-report surveys. To provide data to help understand how online secondary science teachers perceive teaching and student learning in that space, the data from this study was used to answer the following research questions:

1. How do online secondary science teachers experience their teaching while teaching their courses online?;
2. How do online secondary science teachers experience their students' learning while teaching their courses online?

It is believed that this understanding can provide the beginning framework for steps that may need to be taken in areas such as teacher education and professional deveopment, online secondary science student support, online secondary science teaching and learning standards, and online secondary science program evaluation. If our nation is to expand its 'STEM capable workforce' and increase STEM literacy throughout the population, it is important that all students receive effective instruction in whatever learning environment they choose.

Chapter 2 Review of the Literature

One of the primary reasons many stakeholders implement online secondary education is the lack of qualified core content teachers at the local level, particularly in the subject areas of mathematics and science (Picciano & Seaman, 2009). However current research does not provide a good understanding of the characteristics of effective science instruction in this type of environment (Cavanaugh, Barbour, & Clark, 2009; Tucker, 2007). In order to understand how teachers teach in an online context, it is essential to know how they experience this context (Marton & Booth, 1997). Prior to developing this understanding, it is important to discuss what is currently known about secondary science education in order to appreciate how the online learning environment may or may not impact those experiences.

Secondary science education presents some unique challenges for the online environment. Students come to their science courses with understandings synthesized from their interactions of the world (Chi, 2005). This necessitates the use of inquiry activities which aid student understanding of complicated topics such as the *nature of science* (Schwartz, Lederman, & Crawford, 2004). The challenges discussed by teachers transitioning their face-to-face curriculum to a virtual high school include the difficulties of conducting labs when face-to-face instruction cannot occur as well as ensuring students are moving through the content at similar paces in order to facilitate interaction with one another. Another area of difficulty encountered by the teachers was "...taking a topic which was largely experiential and making it alive in the online environment" (Lowes, 2005, p. 14). These challenges imply that what may work well pedagogically in the face-to-face secondary science classroom may not transfer to the online secondary science course. A review of pedagogical practices of both science education and

online education are provided in order to afford an understanding of why this type of curriculum transfer may not result in effective science learning.

Characteristics and Practices of Secondary Science Education

Science education learning standards. Before discussing the characteristics and practices of secondary science education, context will be provided by grounding the activities that occur in the learning standards on which they will be based. Given that many states implement their own standards, the National Science Education Standards (National Research Council, 1996) and the Next Generation Science Standards (NGSS, 2013) are a good alternative for providing guidance on effective K-12 science instructional practices.

The National Science Education Standards (National Research Council, 1996) provide guidance on science teaching, teacher professional development, assessment, science content, science education programs, and science education systems. The science *teaching* standards describe what teachers should be able to do and understand as well as judge whether students are making progress with their science learning goals. The science *content* standards describe expected student outcomes, not curriculum. These standards “outline what students should know, understand, and be able to do in natural science” (National Research Council, 1996, p. 103). Finally, the science *education* program standards describe what must occur at the school and school district in order for students to learn science and for teachers to teach science.

A more recent set of national science standards has been made available for American schools; the Next Generation Science Standards (NGSS, 2013). These standards are comprised of three dimensions: (a) practices, (b) crosscutting concepts, and (c) disciplinary core ideas. The framework used evidence-based knowledge to provide an understanding of what is required for a student to be considered proficient in science and encompasses four domains: (a) life sciences,

(b) physical sciences, (c) earth and space sciences, and (d) engineering, technology, and applications of science. The purpose of including a discussion of science learning standards is to provide a view of not only what occurs in a secondary science classroom, but also the learning goals and standards those activities are meant to address in today's classrooms.

Argumentation, inquiry, and instructional elements. Both the National Science Education Standards (1996) and the Next Generation Science Standards (2013) emphasize the need for secondary science students to conduct science investigations in a manner similar to true scientific investigation. Best practices in the classroom include incorporating authentic science questions that address issues experienced by students (National Research Council, 1996). The NGSS extend the definition of inquiry provided by two frameworks, science and engineering. Inquiry in science consists of using investigation to answer questions, whereas engineering solves problems by implementing design practices (NGSS, 2013).

For the secondary science classroom, inquiry activities typically occur during the laboratory portion of the class. As stated by Hofstein and Lunetta (2003), “the laboratory has been given a central and distinctive role in science education, and science educators have suggested that rich benefits in learning accrue from using laboratory activities” (Hofstein & Lunetta, 2003, p. 28). In order to achieve the promise of inquiry investigations, labs must be investigative in nature as opposed to comprising a recipe-type set of procedures (Bybee, Powell, & Trowbridge, 2008). By participating in these types of inquiry labs, secondary students can use their own experiences, ideas, and knowledge to design the procedures required to answer the question or solve the problem under investigation (Hofstein & Lunetta, 2003).

Scientific inquiry does not begin and end during lab activities. Part of the inquiry process demands that students be able to communicate to the outside world their understandings and the

connections they made to broader concepts (National Research Council, 1996). Once students have gathered data, either in the science classroom or beyond school walls, they must be able to participate in discourse about the knowledge and beliefs implied by those data. This type of discourse, otherwise known as scientific argumentation, “is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in revision of an explanation” (NGSS, 2013, 2nd paragraph). In order to facilitate effective argumentation in the classroom, teachers must develop democratic, tolerant environments and ensure that scientific norms are followed during the construction of the arguments (Duschl & Osborne, 2002).

While inquiry and argumentation have been identified as key components of science education, many “*good teachers*” (Hofstein & Lunetta, 2003, p. 47) do not use inquiry methods in their science classrooms. Their findings concluded that science teachers do not often have the support structures in place to provide for effective inquiry activities; class sizes may be too large or there may be a lack of laboratory equipment or space. Science teachers may not have the time or the skills to differentiate the lab activity to account for the diverse needs of the students. Quite often science teachers resort to recipe style labs which contain task lists and focused post-lab questions, rarely allowing student input or fostering student engagement. The higher level secondary science classes can fall under the influence of academia as secondary science teachers teach in a manner they believe best prepares their students for college science courses, which tends to follow a more teachercentric education model (Hofstein & Lunetta, 2003).

The National Research Council, hoping to overcome such limitations to science education, sought to identify successful K-12 science, technology, engineering, and mathematics (STEM) programs in an effort to develop criteria that would identify effective STEM programs. The identified effective STEM programs could then be used to help develop additional criteria

that could pinpoint measureable data for empirical research as well as identify areas where data sources needed to be developed (National Research Council, 2011). The committee established three goals with which to measure the effectiveness of STEM instruction. Those goals were to:

1. Increase the participation of minorities and women in advanced STEM degree programs and STEM career fields and to increase the overall number of students in advanced STEM degree programs and STEM career fields,
2. Increase and diversify the STEM workforce, and
3. Increase the number of non-STEM related degree students in STEM programs to ensure a STEM literate population.

By using these goals and identifying successful STEM schools based on student STEM outcomes, STEM instruction, and STEM school-level practices, the Committee developed characteristics of effective STEM instruction that appeals to students early in their education career. This allows STEM programs to provide educational experiences based on student interest and experiences and uses those experiences to sustain engagement and interest. These characteristics are (National Research Council, 2011, p. 18-19):

1. To actively engage students in science throughout their school careers,
2. Effective teachers use their knowledge of student understanding to help students apply STEM practices,
3. Students engage with the natural and material world to experience how scientists investigated and found answers to questions and problems,
4. Students engage in scientific investigations and engineering design projects based on core ideas in science in order to become deeply familiar with those core ideas thereby,

5. Developing identities as STEM learners by practicing science, engineering, and mathematics.

The committee recognized that this type of instruction would be difficult for most U.S. schools and has developed a set of five elements, separate from the above characteristics, to guide policy and educators to improve STEM education for all K-12 students (National Research Council, 2011). The first element pertains to a coherent set of standards and the curriculum developed based upon those standards. Mathematical ability is required for higher level science and engineering practices requiring all students to have grade level math proficiency. Therefore standards must reflect this association between the two subjects. The second element is that teachers must have deep content knowledge and understand how to teach their subject. Ten to twenty percent of science and mathematics teachers do not have a related degree in the subjects taught. The third key element addresses assessment and the need to assess complex thought processes. Multiple choice items narrow the curriculum to basic skills. The fourth key element is to increase instructional time in mathematics and science, particularly at the elementary level. The fifth and final element is to provide equal access to high quality STEM programs by addressing discrepancies across schools and classrooms such as access to resources, teacher expectations, and adequate laboratory equipment. It is believed that implementing these elements will ensure that the characteristics and practices identified as successful for science instruction will be present in science instruction.

Characteristics and Practices of Online Instruction

‘Three generations of distance education pedagogy’. A framework for distance education pedagogy based on three learning theories was developed by Anderson and Dron (2011). The three learning theories contained in this framework, behaviorism, constructivism, and connectivism, are described within the context of the community of inquiry framework (Garrison, Anderson, & Archer, 2000). The development of these pedagogies determines the type of educational technology required. This suggests that technology limitations might determine the pedagogy that can be implemented. While many teachers consider themselves to be pedagogically driven, it cannot be denied that “technology sets the beat and creates the music, while the pedagogy defines the moves” (Garrison et al., 2000, p. 81). Each affects the other. The three pedagogies that will be described are cognitive-behaviorist, social-constructivist, and connectivist.

Cognitive-behaviorist pedagogy. Cognitive-behaviorist (CB) pedagogies subscribe to the behaviorism learning theory, typified by Gagne’s nine events of instruction (Gagne, 1974), and are best applied when the learning goal has specific, pre-determined outcomes. The outcomes are typically not authentic and non-contextual, contain clear learning objectives, and exist outside of the learner and the context under which the learner studies (Anderson & Dron, 2011).

Cognitive presence in the CB pedagogy distance education model is addressed by providing clear, ordered learning instructions. Efficiency of learning overrides learner-centered contextual factors. *Social presence* is almost nonexistent and the student maintains a high degree of freedom in regards to the location and pace for learning. Teaching presence primarily exists as didactic instructions, which may attempt to express some personality, but the primary function of

the teacher is as a grader of the assignments. The strengths of this model are its scalability and the freedom provided for the learner. It is also a rather inexpensive model as there is not much need for a technology infrastructure to support instruction (Anderson & Dron, 2011).

Social-constructivist pedagogy. The second model discussed is Social-Constructivist pedagogy (SC), harkening back to the ideas of Vygotsky (1986) that learning is a social endeavor. With the advent of asynchronous and synchronous communication, distance education can shift to a more student-centered model wherein the social nature of learning and knowledge creation can be incorporated in the instructional design. Rather than utilizing a rigid instructional design, the affordances of flexible social co-construction of knowledge are recognized and accounted for (Anderson & Dron, 2011).

Cognitive presence in the SC model is a more authentic experience than the previous CB model, where learning can now take place in real-world contexts. This pedagogical model was developed in reference to online higher education courses (Anderson & Dron, 2011) and this type of authenticity does not necessarily apply in the more controlled structure of secondary science education (Bolstad & Lin, 2009; Cavanaugh et al., 2009; Miron, Gulosino, & Horvitz, 2014). The learning content is not quite as flexible in the K-12 distance education environment as state standards and school district defined curriculum must be followed (Huerta, Rice, & Shafer, 2014; Watson, Murin, Vashaw, Gemin, & Rapp, 2013).

New technologies provide affordances for social and teaching presences required for social-constructivist pedagogy. Students and teachers can communicate using asynchronous and synchronous video or audio, and they can interact in immersive virtual worlds. There is an increase of cost in both time and money as social interaction increases. Synchronous online communication restricts freedom of time, and in some places geography if broadband limitations

exist. Infrastructure costs rise as well as the demand for hardware such as webcams and microphones increases and bandwidth must be improved to stream video effectively. The SC model is not as scalable as the CB model; increased evaluation time required by the teacher to assess knowledge generation places constraints on course size (Anderson & Dron, 2011).

Connectivist pedagogy. The third model, the connectivist pedagogy of distance education, does not apply as closely to the online secondary science environment. The connectivist learning theory states that “learning is the process of building networks of information, contacts, and resources that are applied to real problems” (Anderson & Dron, 2011, p. 87). Connectivism implies a level of autonomy and self-regulation that is rarely observed in online secondary students (Borup, Graham, & Drysdale, 2013; DiPietro, Ferdig, Black, & Preston, 2008). It has been included in this discussion for completeness.

The three pedagogies described are not tied to a particular subject. However they could be used as a framework for an online secondary science classroom. The purpose of this discussion was to provide an understanding of the relationship between technology and the pedagogies that could be employed for online secondary science instruction.

Online learning standards. The National Science Education Standards and the Next Generation Science Standards address the learning goals associated with science education but do not address the method in which the courses are taught. The International Society for Technology in Education (ISTE) (ISTE Standards, 2014) has taken the lead in this area by developing standards addressing the ways in which technology can be used to facilitate learning. These standards do not address online learning specifically but do provide some guidance as to how technology can support student learning.

The International Society for Technology in Education has identified essential conditions which are identified as critical to the use of technology for student learning (Essential Conditions, 2014). These conditions outline what is required for student-centered learning approaches by describing the types of digital curriculum, school leadership, assessment and evaluation, and community and government support necessary for digital aged learning. The standards are categorized by audience and include sections for students, teachers, and administrators as well as other online learning stakeholders.

The standards for students focus on using digital resources for collaboration, communication, critical and creative thinking, and the ability to research and process by evaluating the proper sources and identifying the best digital tools to use for specific tasks. Teacher standards include mentoring students in the area of digital citizenship, guiding students on how to use digital resources effectively for work processes, assessing student learning digitally, and inspiring students to work collaboratively and creatively with their peers. Administrator standards include the charge to provide visionary leadership, to advocate professional digital learning among teachers, and most importantly as change leaders both as policy advocates and to ensure continuous improvement by utilizing technology driven data (ISTE Standards, 2014). While these standards do not result in specific learning goals, they can provide guidance on first steps for the basic structure, technology needs, and dispositions required of the stakeholders to begin creating an effective learning environment.

Cyberinfrastructure cognitive affordances. Six unique affordances have been identified within the cyberinfrastructure for STEM education (Martinez & Burton, 2011). This “broad informational network” affords students the ability to connect to “real-time data sensors” (Martinez & Burton, 2011, p. 17) and large scientific data bases. The tools needed to visualize

and analyze this data are also made available. Teachers have access to real-world data and are able to provide authentic learning experiences for students. These affordances are not limited to the online secondary science classroom and could be experienced by traditional classrooms as well. But given the nature of the online environment, access to these affordances is more crucial for student learning as resources such as those that are available in face to face classrooms can be limited in the online course (Andresen, 2009; DiPietro, 2010; Reuter, 2009).

Real-time access. The first affordance is the real-time access to original scientific data. Databases such as NASA Wavelength (NASA Wavelength, 2014) provide data and images for use by teachers and students. Guidance is provided in the form of grade-level lessons that have been developed by educators and the lessons have undergone a vetting process. Use of current data to identify and find solutions for problems in the real world provides authentic experiences, allowing students to understand the nature of science, how scientific knowledge develops, and improves student learning outcomes (Donovan & Bransford, 2005). This first affordance ties into the sixth affordance of *messy data* (Martinez & Burton, 2011). Students will have to address messy data involving problems that use real data that have not been *cleaned up* in order to allow easily calculatable results. Students will also have to determine the procedures necessary to obtain answers to their questions and will not be provided with step by step processes. Immersion in real data will help students cultivate the metacognitive structures required for the inquiry skills necessary for *doing science* (Schraw, Crippen, & Hartley, 2006).

Distributed expert networks. Providing online secondary science teachers and students access to distributed expert networks is the second affordance. Scientific knowledge is increasing at a rate too vast for a single individual to master (Martinez & Burton, 2011) and knowledge of research has become distributed among individuals. Social media and other web-based

communication has made collaboration between scientists transparent, allowing those outside of the discipline to observe the social nature of scientific inquiry and helping teachers and students more clearly understand the nature of science (Abd-El-Khalick, Bell, & Lederman, 1997; McComas, 2002).

Analytic and visualization tools. The third affordance, analytic and visualization tools, help interpret the real-world data found online. These tools allow the detection of small effects in a large data-pool in a timely manner. Online secondary science students can now explore the evidence for global warming from real-time data rather than having the analysis presented as facts by the teacher.

Source documents. The fourth affordance is the instantaneous retrieval of source documents. Students and teachers have access to original scientific publications through the use of online subscriptions and access to electronic document archives (Martinez & Burton, 2011). The current open access movement continues to democratize access to source documents (Yiotis, 2013). Open access journals provide access to those who do not subscribe to paid journals, truly “signifying the democratization of knowledge” (Yiotis, 2013, p. 160). Open-access articles will allow students to view science as a changing body of knowledge rather than static, as may be inferred from textbooks.

Communication with experts. The fifth affordance, as well as one of the more important aspects for online secondary science education, is the ability to conduct public discourse with science experts and others who share an interest in developing scientific knowledge. Students can participate via videoconference weekly in a Virtual Star Party (Lewis & Cain, 2014) hosted on Google+, a social networking site that connects professional astronomers and astrophysicists in real time with the public. Many scientific communities have open discussion boards and social

networking sites that can provide a window for both educators and students into the world of scientific discourse.

Messy problems. The sixth and final affordance is the ability to address problems that are *messy*. Students who primarily use texts for instruction are introduced to problems with clear problems and clear answers. Data have been cleaned resulting in only one correct solution and in many cases procedural steps have been provided. Students are not allowed ownership of the problem as they conduct the “intellectual work that makes discovery possible” (Martinez & Burton, 2011, p. 24). Accessing real data sets forces students to make decisions and participate in a true inquiry process.

The common thread which runs through all six affordances is one of openness. Data is now open to those outside the identified scientific community. Educators and students have the ability to conduct discourse using both written and verbal methods with expert scientists. And students can now work with expert scientists in the advancement of scientific knowledge by using the affordances of the cyberinfrastructure.

Argumentation in the online secondary science course. Argumentation is an important component of the learning process in a secondary science classroom (Duschl & Osborne, 2002). Given the social nature of learning (Vygotsky, 1986), it is important that argumentation be incorporated in the online secondary science course. There are six affordances provided by the internet for online argumentation: (a) scripting for collaboration, (b) access to data and analysis tools, (c) synchronous and asynchronous communication, (d) group optimization strategies, (e) co-creating and sharing artifacts, and (f) tools that increase awareness of the contributions of the individual and group participation (Clark, Touchman, Martinez-Garza, Ramirez-Marin, & Drews, 2012).

Scripting is an instructional method that can make collaborative dialogue more productive (Fischer, Kollar, Mandl, & Haake, 2006, p. 2). Within the context of education scripting utilizes structured collaboration, providing scaffolding that helps prompt group interaction. Hesse (2006) argued that the *compensating features* of computer supported collaborative learning (CSCL) negate the need for such a structure. Rather, *awareness* of the group is advocated, where *awareness* means having information about the “group, participation of group members, activities, and...even interest of the collaborator” (Hesse, 2006, p. 95). It is expected that, based on this awareness, the collaborators will know how to conduct an effective online discussion and argument. In order to develop their arguments, students can acquire real-time data of the group participants and have access to online analysis tools allowing them to make meaning of that data, thereby providing relevance to their arguments (Martinez & Burton, 2011). Asynchronous communication allows for student reflection of the argument, enabling the student to develop more nuanced responses (Kreijns, Kirschner, & Jochems, 2003), while synchronous communication can aid in real-time discussions, assisting in social construction of knowledge and helping to create social presence among students (Ryman, Burrell, & Richardson, 2009).

Another argumentation management technique online secondary science teachers can apply is grouping strategy. Optimizing strengths and weaknesses in a small group setting, as well as facilitating the development of trust within the group, provide an environment for richer communication between group members (Tu & McIsaac, 2010). As the group works together during inquiry and the subsequent argumentation process, visualization tools can be used to connect group members and display all data sources and analyses (Kirschner, Buckingham-Shum, & Carr, 2003). Finally, to help students maintain focus of the ultimate goals of the

discussion process, online awareness tools provide measures of who participated and how, the conditions of the task, and the history and context under which the process has developed thus far, thereby allowing group members to assess the quality of each member's contribution and participation (Hesse, 2006) . An online secondary science course which incorporates these six affordances should provide the necessary environment allowing online secondary students to participate in and contribute to scientific argumentation activities.

Inquiry in the online secondary science course. Inquiry is considered a cornerstone of science instruction around the world as it is perceived to help students better understand complicated science topics, such as the nature of science (Abd-El-Khalick et al., 1997; Schwartz, Lederman, & Crawford, 2004). Traditionally inquiry activities have been visualized as *hands-on*, but recently automation and technology have begun to stretch that definition. Several studies have indicated that online simulations can lead to better conceptual understanding when compared to their hands-on counterparts (Finkelstein et al., 2005; Ma & Nickerson, 2006) . This is not to suggest that online secondary students are not afforded the experience of hands-on activities; many programs include the use of inquiry kits, or *kitchen science*, complete with instructions and lab notebooks (Reuter, 2009). There are three broad categories of laboratory experiences available for online secondary courses: (a) hands-on, (b) simulations, and (c) remote labs which allow students to use Internet connections to manipulate robotically controlled laboratory equipment (Ma & Nickerson, 2006). Which, if any, of these three methods are incorporated into an online secondary science class is determined by the teacher. To see whether the characteristics and practices discussed in this section occur in online secondary science courses, the next section will offer examples of online science practices provided by the literature.

Inquiry practices in online secondary science courses. Thirty-five online secondary science teachers located in the United States were surveyed to develop an understanding of the nature of the laboratory activities implemented in their courses (Crippen, Archambault, & Kern, 2013). They found that laboratory activities were conducted for an average of 90 minutes per week and that hands-on labs were favored over remote labs or simulations. While 63% of the reported activities were student-centered, scientific discourse was rarely a part of the lab activity (6%). This result may have been due to the fact that student collaboration was only required for 2% of the reported activities. The dearth of student discussion during the inquiry process may also have been due to the lack of comfort felt by the teachers toward online communication in relation to monitoring and motivating students in a virtual environment (Crippen, et al., 2013).

While the activities were considered to be student-centered, the delivery of the activity was usually teacher-directed. Typically students conducted labs individually, completed a lab report, and took a quiz based on the collected data in order to exhibit conceptual understanding. Teacher responses indicated one of the barriers they faced in implementing labs that could result in increased student science knowledge; "...The whole concept of doing labs and writing lab reports that engage thinking is hard to do with limited contact with the student" (Crippen, et al., 2013, p. 1042).

Similar findings in relation to student learning were noted when Waight and Abd-El-Khalick (2011) investigated the Biology Student Workbench (BSW), a web-based inquiry tool. The BSW provided several databases and analysis tools that enabled students to conduct virtual research, and the high school version incorporated teacher professional development. The researchers found that teacher views and attitudes towards the purpose of inquiry activities had

an effect on learning outcomes. Many teachers felt students should use labs to practice the scientific method and to confirm previous findings.

The BSW was purposely designed with computational and visualization affordances to allow for inquiry practices. However, it was found that in many instances a teacher-centered linear approach was implemented, with teachers providing detailed instructions on the use of the BSW rather than encouraging student-centered inquiry practices to develop. A teacher-centered model was used as many of the teachers did not believe that their students would be able to navigate the complexity of the BSW without detailed instructions (Waight & Abd-El-Khalick, 2011). As in the previous study, there was minimal discussion or scientific argumentation surrounding the lab activities. The results indicated that the students did retain science facts by using the BSW, however there was little evidence of higher order of thinking that true inquiry practices are proposed to facilitate (Anderson, 2002). These examples of online secondary science courses demonstrate that facilitating argumentation and inquiry practices in an online environment can be problematic.

Teaching Online Secondary Science Courses

There is a lack of empirical research in the area of K-12 online education (Archambault & Crippen, 2009; Cavanaugh, Barbour, & Clark, 2009; Huerta et al., 2014). This lack is even more apparent when one decides to hone in on a particular subject and grade level, such as online secondary science education. An EBSCO search using the search terms *online secondary science*, *online secondary science education*, *online secondary science teacher*, *online secondary science student* and variants such as *distance* replacing *online* and *high school* replacing *secondary* was conducted. In total, 141 articles were retrieved. However, after looking at the articles, it was found that only eight articles pertained to fully online science education. The rest

of the articles either discussed the use of web-based resources in face-to-face science classrooms or they did not pertain to online secondary science education. Of the eight articles which discussed online science education, none offered a holistic view of an online secondary science teacher or online secondary science student.

As can be seen from the EBSCO search, there is a dearth of articles that describe the experiences of teachers who teach online secondary courses. Of those that did include a discussion of online secondary science teachers, the focus was on specific aspects the science course such as inquiry activities (Crippen et al., 2013) or online argumentation (Martinez & Burton, 2011) rather than the experience as a whole. Articles such as these placed the spotlight on teacher application of instructional techniques rather than on teacher experiences.

This same lack of empirical research focusing on teaching experiences extends to K-12 online teachers in general. The benefits and challenges of K-12 online teaching were discussed in the earlier overview of online K-12 distance education (Borup et al., 2013; Hawkins, Graham, & Barbour, 2012; Watson, Murin, Vashaw, Gemin, & Rapp, 2013) and provided a broad view of teaching online in that environment. This section will relate the findings of two articles that probed more deeply into the experiences of K-12 online teachers.

Pedagogical beliefs of online secondary teachers. Sixteen in-depth interviews of online successful teachers explored the beliefs online teachers held of their instructional roles in order to understand online teacher instructional strategies in relation to their use of pedagogy, technology, and content (DiPietro, 2010, p. 329). Using a constructivist view of knowledge, DiPietro developed a theoretical description of the pedagogies utilized by K-12 virtual school teachers. Five themes emerged after analyzing the interview transcriptions, email correspondence, memos, and materials shared by the participants; (a) connecting with students,

(b) fluid practice, (c) engaging students with content, (d) managing the course, and (e) supporting student success.

Teachers felt that personal connections were important for student success. In the virtual environment this meant communicating effectively using the course discussion boards. Teachers described how they provided structure and support by self-monitoring their students' communication by monitoring language and emotional tone. Monitoring communication was important as many teachers did not want miscommunication to negatively impact student interest, particularly given the nature of text correspondence and the ease with which miscommunications can occur (Kreijns et al., 2003) .

The majority of teachers who teach at state virtual schools are employed full time in face-to-face classrooms and they teach at the virtual school on a part time basis. For some this meant switching from *giving knowledge* to *guiding knowledge*. Teachers found that teaching practices online involved engaging “students in dialogues to support content learning” thus making “the learning fluid and moldable” (DiPietro, 2010, p. 337). This practice also increased the commitment to individualized learning which meant providing students what they needed as they needed it.

The switch from *giving knowledge* to *guiding knowledge* demonstrated teacher belief that student engagement was essential. This belief reflected the perception that all students could learn given the right setting and strategies. Practicing this belief in the online context included incorporating interactive technologies and alternative assessments. Teachers presented the content in multiple ways, using text and multimedia, and provided multiple chances for students to interact with the course content (DiPietro, 2010).

Teachers believed that effective course management ensured positive and equitable educational experiences for the students. They also believed the online experience could be similar to the face-to-face experience. Course management included safeguarding against plagiarism and ensuring student communication did not involve inappropriate language and remained respectful. Some teachers also related the importance of identifying when students were experiencing personal crises. Using their instincts based on having gotten to know their students, and reaching out to the student's face-to-face school or mentor, were the practices used to help students succeed in their online courses (DiPietro, 2010).

Finally, online K-12 teaching employed many practices and strategies to support student success. Scaffolding learning, providing specific learning goals, and responding quickly to student questions or communications were used to provide student support. As one teacher stated "virtual school teachers [sic] have to be very responsive and quick natured so that the student is not stumbling and frustrated...for high schoolers and middle schoolers the frustration, once that hits, they kind of give up" (DiPietro, 2010, p. 340).

These practices indicate that there are differences in the experiences of teaching face-to-face as opposed to teaching online. The importance placed on relationship building and being able to understand students well enough to provide individualized instruction and a safe course environment means that teachers must be adept with virtual communication technologies. Many teachers will need to reconsider teacher-centered pedagogies and apply more effective student-centered learning methods (Borup et al., 2013).

Sage without a stage. Cultural historical activity theory was used to describe teacher practices situated in high-school distance education (Murphy & Rodriguez-Manzanares, 2009). Data consisted of 90-120 minute structured interviews of 13 teachers, all with 11 or more years

of teaching experience in the face-to-face environment before teaching online, as well as management and support staff employed by the Centre for Distance Learning and Innovation (CDLI). The center is located in the province of Newfoundland and Labrador, Canada. Teachers used synchronous and asynchronous methods and courses were taught from multiple locations.

There were several similarities between the teachers discussed in DiPietro's (2010) article and the teachers discussed in this article. Both sets of teachers came from the perspective of teacher-centered environments where "you were the source" and "students are there to be taught" (Murphy et al., 2009, p. 8). The emphasis that communication with students requires a *conscious effort*, particularly in this context as teachers and students could experience the temporal separation of two time zones, was a theme in both papers. The potential for interaction at any hour of the day was discussed by DiPietro (2010), and this possible level of interaction was accepted by the teachers interviewed at the virtual high school as well.

The lack of physical clues as a method for identifying student comprehension caused the teachers in this study to identify alternative online tools for this purpose (Murphy & Rodriguez-Manzanares, 2009). As one enterprising teacher discussed, "The tools are what they are. I don't see them as being constraining. I think we just have to make the best use of them" (Murphy & Rodriguez-Manzanares, 2009, p. 10). Teachers learned to rely on private text communication, primarily the instant messaging feature for both the synchronous and asynchronous communication systems. Surprisingly, some teachers acknowledged that the online affordances provided better communication with their online students than they had with their face-to-face students; "I can't recall having some of the contact with students in the regular classroom that I have now that I'm online" (Murphy & Rodriguez-Manzanares, 2009, p. 10).

Another surprising finding was that collaboration between teachers seemed to occur more naturally for the teachers in the online education environment than it did in their face-to-face environments. One teacher went so far as to discuss the isolation felt when the door of his classroom closed, yet he did not feel this same isolation when teaching online. He felt the online communication tools resulted in sharing that “happens naturally” (Murphy & Rodriguez-Manzanares, 2009, p. 11).

The change to online tools disrupted the teaching methods as well. Many teachers felt the strategies used in their face-to-face classrooms did not make sense in the online environment. They believed that the online classroom did not support their learned practice, reinforcing the previous discussions about the need for teacher training which focuses on the online learning environment (Kennedy & Archambault, 2012). Not only did they have to change their approaches to teaching, they had to change their beliefs about teaching and learning. When technology is used effectively for student learning, learning activities become student-centered rather than teacher-led (Apple Computer Inc., 1995; Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur, & Sendurur, 2012; Tucker, 2007).

Learning in Online Secondary Science Courses

There is scant literature on teaching and teacher experiences in relation to fully online secondary science teaching. For fully online secondary student learning it is practically non-existent. The student voice occasionally appears as part of a survey or by accessing online course learning artifacts (Missett, Reed, Scot, & Callahan, 2010), but the point of view of the student regarding interpretation of those artifacts is not presented. Therefore this section will present an overview of two studies that discuss online science student characteristics and how those

characteristics may affect the implementation of learning strategies employed by online science teachers.

Characteristics of students in internet-based science learning. The literature search for the meta-analysis conducted by Lee et al. (2011) limited articles that discussed empirical evidence of learning in science education which occurred in Internet-based science learning environments (ISLEs). Articles that discussed both secondary and higher education environments were included so not all characteristics may pertain to the online secondary science learner. The characteristics discussed relate to learning in the ISLEs. The authors further listed their finding as sub-categories such as demographics, prior knowledge, self-efficacy, attitudes towards learning, motivation, conceptual understanding, conceptual change, and general cognitive skills.

Middle school and high school female students were found to perform better than their male counterparts if the learning design was self-paced, however the overall learning gains for either gender were not discussed. This is a concern as typically high school students of both genders have been shown to need help developing self-regulation in terms of learning (Azevedo, Winters, Moos, & Greene, 2005; Picciano, Seaman, Shea, & Swan, 2012). On the other hand, males performed better than females when conflict was involved. Males preferred environments that required negotiation and were more at ease with expressing critical judgments. This dynamic could pose problems during argumentation or course discussions in mixed gender online courses, making it more difficult for the teacher to maintain the safe course environment needed for effective social learning in the online environment (Andresen, 2009; Duschl & Osborne, 2002; Kreijns et al., 2003).

The research surrounding simulated design-based projects conducted in ISLEs indicated that the achievement gap was reduced for low socioeconomic (SES) students, Hispanic students, and African American students. The authors suggested that the iterative process involved in such inquiry provided new learning opportunities for these groups. This is contrary to much of the literature on distance education, where low SES students, African American students, and Hispanic students have been shown to perform worse than their Caucasian and Asian counterparts in online environments (Bolstad & Lin, 2009; Huerta et al., 2014).

The student-centered nature of ISLEs resulted in lower learning gains by low-achieving high school students (Lee, et al., 2011). It was suggested that perhaps this student group required a more teacher-centered approach when learning online. Students with lower domain knowledge also benefited from multiple representations of misconceptions. Viewing these representations during discussions with teachers helped with a more mature development of the nature of science (Lee, et al., 2011).

Student Internet self-efficacy was shown to play a role when students used the Internet to search for science information. Interestingly, Internet self-efficacy was shown to be a predictor of search outcomes but not learning outcomes, something teachers may need to consider when designing assignments and assessments. The opposite was demonstrated to be true for academic self-efficacy (Lee, et al., 2011). Generally students expressed positive attitudes towards ISLEs, particularly as they felt online courses provided more control over the pace of their learning, corroborating Tucker's (2007) conclusions.

Glimpses into Online Secondary Science Courses

Advanced placement K-12 online science course. The need to address access to rigorous science curricula to underserved academically advanced and gifted students led to the

development of a distance education course created by the University of Virginia (Missett et al., 2010). The target population for this course was students living in rural areas and who were economically disadvantaged. Given this goal it was determined by the researchers that an internet-based course would be the most suitable delivery system. The researchers also felt that this method would increase the technological self-efficacy of the students and help them to develop technology content knowledge and to develop reasoning skills that would allow them to reason in a similar manner to scientists.

The project created by the graduate students, faculty, and staff at the University of Virginia, Project LOGgED ON, included course content developed from the College Board's Advanced Placement (AP) Environmental Science course (College Board, 2015) incorporating best practices in both science education and gifted student education was presented in a case-based format. Course goals included increasing the skills and knowledge of the students in order to prepare them for advanced science schoolwork, provide communication between peers, help students develop independent learning strategies, and to provide real-world experiences that the online study of science affords. Authentic experiences included topics on dynamic Earth systems, the global impact of human populations, environmental issues such as renewable resources and sustainability, and ethics and environmental laws. The course consisted of 16 cases where authentic environmental issues were presented. Students had asynchronous access to expert scientists via videos created specifically for the course, primary source reference materials, and the instructor provided open-ended questions to act as guidance on the issues that were considered to be most important for further investigation. The study was conducted over a 2-year period (Missett et al., 2010).

Recruitment for instructors occurred at science education conferences and similar venues. It was expected that the instructors would have had previous experience teaching gifted students. Thirteen of the 16 instructors hired for the project had doctoral degrees in science and the remaining three had master's degrees in science education. Participation by students was not limited based on the project's goals and SES or ethnic background status was not confirmed. Demographic information came from the school districts in which the students were shown to reside based on enrollment information. It was determined that the majority of the students most likely fit the desired profile for the project goals. One-hundred thirty-eight students with ages between 12 and 17 years old enrolled. Eighty-eight students participated during the first year; 40% were male and 60% were female. Fifty students participated during the second year and no gender distribution information was provided for this year (Missett et al., 2010).

Self-regulation skills were required as students we expected to read the cases prior to accessing the resources and open-ended questions, though how this skill was assessed was not included in the article. Students also were expected to take notes, complete tests and quizzes, conduct lab work, and complete a final case resolution. Scientific argumentation was conducted as students were expected to participate on the discussion board by responding to open-ended questions posed by the instructors.

The results of the study show that for Year 1, 59 students completed the course and received course credit. Fifty-four of the students took the AP Environmental Science exam with 17 students receiving a score of 3 or higher, representing that they had earned college credit. Forty-one students received course credit the second year, 25 took the AP exam, and 7 students scored 3 or higher. The discussion posts were coded and analyzed for evidence of learning and engagement expressed by the students. It was determined that all the students exhibited factual

content knowledge and that many were able to demonstrate higher level thinking skills. The coding also indicated that students were engaged in the content and were able to relate the course content to real-world examples in their own lives, and were able to make connections across content areas (Missett et al., 2010).

Interestingly the article does not discuss using the case study resolutions as indicators of learning. Given that the case resolutions were described as the end result of the other activities it would seem to be an important artifact to incorporate to provide further evidence of the learning that may or may not have occurred during the course. It was also difficult to determine if the goal of reaching students with limited access to advanced science courses was met as no demographic data, other than gender, was provided for the actual participants (Missett et al., 2010).

Interview with virtual high school instructors. Two online secondary science teachers were interviewed about the instructional practices they engaged in while teaching at a virtual high school (Clark, 2013). One teacher taught Chemistry and the other teacher taught Biology. Both were employed by a virtual high school (VHS) in a large school district located in a Southwestern state in the United States. As of the 2011-2012 school year, 148 students were enrolled; 49.3% white, 35% Hispanic, 14% African American, and 8.1% Asian (Clark County School District, 2013). Prospective students took aptitude tests measuring their ability to work independently, but students were still allowed to enroll if the tests indicated a low ability for independent work. VHS operates on a ‘regular’ school schedule from August to late May and is intended for students who cannot attend brick and mortar schools due to scheduling conflicts or similar issues.

Each teacher worked with an instructional designer to develop her course curriculum, adhering to the school district’s curriculum guideline and the state standards for science. The

chemistry and biology teachers interviewed used a mix of eBooks and simulations, favoring open source materials. The lesson modules were accessed via SoftChalk which is part of the Blackboard learning management system. The eBooks chosen contain interactive materials such as simulations, and contain formative and summative assessments (Clark, 2013).

Both teachers start with a *big question* and ask students to reflect on its meaning. Prior knowledge is accessed, students reviewed the learning objectives and vocabulary for the unit, and completed assignments which helped them reflect on their learning growth. To address the Common Core State Standards on Science literacy, students participated in at least one argument for each module. Blackboard Collaborate, which affords videoconferencing, was used for group activities and collaboration (Clark, 2013).

One of the biggest barriers to providing effective science instruction mentioned by both teachers was the difficulty they had implementing hands-on inquiry activities. It is district policy to not provide experimental kits as those under 18 cannot assume liability for hazardous activities. Many parents, perceiving scientific equipment to be inherently dangerous, were unwilling to sign waivers. At the time of the interview the on-site lab had yet to be used due to student scheduling difficulties and the teachers felt it was unrealistic to use the lab for individual students. There were plans to produce a series of video labs using the onsite facilities so that students might observe such activities. Both teachers used simulations, such as McGraw Hill Education's® Virtual Frog Dissection, to provide laboratory and inquiry activities for the students (Clark, 2013).

Both teachers were aware of their students' varied schedules and made an effort to be available for questions or other needs during the weekends and evenings. Both of the teachers stated that they responded within 24 hours to student questions or communications. The school

district also has a homework assistance hotline that is available to all students, and the link is provided on the VHS website. For the 2011-2012 school year 83.1% of the VHS students graduated as compared to a 66.4% graduation rate reported for the school district. However, it should be noted that at the time of the interview VHS did not have a system in place to ensure the work submitted was completed by the student receiving credit. Exams were not proctored at that time as well (Clark, 2013).

A look at an online high school biology course. Learner characteristics and learning environment characteristics for two groups of secondary students were evaluated for their effects on learning achievement in an online Biology course. Using hierarchical linear modeling, Liu and Cavanaugh (2011) found that the number of times students logged into the learning management system (LMS) and the amount of time spent on the LMS were positive and significant. This duplicates the results of Macfadyen and Dawson (2010) when comparing frequent course access and time spent as a predictor of academic achievement and suggests sustained time on task. The majority of the students who participated in the two groups for the study were White, with a very small sample size for Asian, African American, Native American, and Hispanic students. There were also very low numbers of students who had individualized education programs (IEP) (learning ability factor) or who had participated in the free and reduced lunch program (SES factor). The researchers acknowledged that the physical schools the students attended may have had an effect on their academic achievement. The dependent variable used to measure student learning achievement were their scores on the exam administered at the end of the semester.

There was a significant negative correlation between participation in free and reduced lunch and student final score for the first group but the relationship was insignificant for the

second group. It was suggested that the second group displayed no significant correlation due to their growing maturity in participation in the online Biology course, but it may also have been due to the low numbers of students enrolled in the program (Liu & Cavanaugh, 2011). No other significant correlations were found for the other variables tested. This study suggested that frequent access to and time spent on the LMS positively correlated to student learning outcomes. This finding is not surprising if it is assumed that these metrics indicated time on task (Liu & Cavanaugh, 2011; Wang & Newlin, 2000). These results indicate that time on task can be one metric which online secondary science teachers could use to monitor the progress of their students.

Why Understand Online Secondary Science Teacher Experiences?

Various concepts concerning science education and online secondary science education have been discussed. Pedagogical implications and learning standards for both science education as a whole and online education have been presented. Effective practices, such as argumentation and inquiry, have been identified and methods described as to how these could be incorporated into an online secondary science course were discussed. Finally, some examples from the literature were examined to help provide context on what online secondary science might look like, or what the results might be, of teaching science in an online environment. One could argue that all of the components of teaching an online secondary science class have been presented in this chapter, yet these separate discussions do not come together to help provide an understanding of the holistic experience of teaching in that environment.

Teachers discussed the mechanics of teaching their online courses but not how they experienced their own teaching in an online environment, or how they experienced their students' learning (DiPietro, 2010). Similar findings of teacher online instructional methods were

presented as well as a comparison to teachers' face-to-face classroom methods (Murphy & Rodriguez-Manzanares, 2009). While teachers in both studies reported that their teaching methods changed, most likely due to the use of technology, there was no attempt to gain a deeper understanding of the overall experience of teaching online, and neither article had a focus on online secondary science courses. The purpose of this study is to address these gaps in the literature.

Purpose of and Significance of the Study

This study will employ developmental phenomenography to develop an understanding of the experiences of online secondary science teachers, and to analyze and structure the data in order to help inform the design of online science teacher preparation and online science teacher professional development. Data from the study will be used to develop an structure of awareness which identifies what it means to teach secondary science online. Providing this understanding will allow for deeper insight as to how the whole (teaching secondary science online) is related to the parts (instructional components of the online course) (Marton & Booth, 1997). It is imperative to obtain an understanding of how teachers experience aspects of online secondary science education in order to understand the instructional choices they make when teaching online secondary science. For example, given the importance of argumentation and inquiry activities to the acquisition of science knowledge (Duschl & Osborne, 2002; Hofstein & Lunetta, 2003), understanding how online secondary science teachers experience these instructional components in an online environment could inform teacher professional development programs, curriculum development, and provide guidance as to the types of supports teachers require to be successful teaching science online. More importantly, the data may provide insight into patterns of variation and invariances among teachers and between the different teaching environments of

face-to-face classrooms and online courses. Comparing these variations and invariances can help identify how science teaching occurs online (Ling Lo, 2012).

In order to provide an understanding of the experience of teaching online secondary science, the following research questions were used as a starting point for developing the phenomenographic interview questions used to collect the data for this study:

1. How do online secondary science teachers experience their teaching while teaching their courses online?;
2. How do online secondary science teachers experience their students' learning while teaching their courses online?

Chapter 3 Methods

This study used a developmental phenomenographic framework (Bowden & Walsh, 2000), to explore how online secondary science teachers experienced teaching science in an online environment. Developmental phenomenography provided a method for analyzing and structuring the data in a way that can help inform the design of online science teacher preparations program and online science teacher professional development. Variation Theory is another term for developmental phenomenography, with Variation Theory generally being applied to research where the phenomenon in question is the classroom structure and student learning (Bowden & Walsh, 2000). The term *developmental phenomenography* was used for this dissertation in order to indicate that the purpose of this study was to seek an understanding of how online secondary science teachers experience teaching online and then apply what has been learned about that phenomenon to enable a change to occur.

Developing this understanding is essential as there has been a push to incorporate online courses as part of the K-12 learning experience (Isakson & Kerrey, 2000; Miron, Gulosino, & Horvitz, 2014; Watson, Murin, Vashaw, Gemin, & Rapp, 2013). These enrollments continue despite the lack of empirical studies pertaining to teacher preparation, student learning, or curriculum development for an online environment (Cavanaugh, Barbour, & Clark, 2009; DiPietro, Ferdig, Black, & Preston, 2008; Kennedy & Archambault, 2012). Given that the lack of access to highly qualified science teachers is one of the reasons secondary students enroll in online courses (Cavanaugh, Gillan, Kromrey, Hess, & Blomeyer, 2004; Hodapp, Hehn, & Hein, 2009), it is critical that we begin to develop an understanding of how teaching occurs in online secondary science education. Developing such an understanding can help inform online science

teacher development, online science teacher education programs, and provide an understanding of the types of curriculum and programs that work best for online secondary science courses.

To develop an understanding of online secondary science education in order to begin to comprehend how those who teach science in an online environment approach that teaching, developmental phenomenography was used to answer the following research questions:

1. How do online secondary science teachers experience their teaching while teaching their courses online?
2. How do online secondary science teachers experience their students' learning while teaching their courses online?

By comparing the structure of awareness developed from the data of this study to current research on what has been demonstrated to be effective for both science teaching and learning, methods for preparing online science teachers and developing curriculum which will help improve student learning outcomes can begin to be identified.

Developmental Phenomenography

The term 'phenomenography' was first used by Marton (1981) to describe a research method where the researcher oriented herself towards the participant's experience about the world. This differs from phenomenology's first order perspective of understanding the phenomenon by offering a second order perspective of understanding the *experience* of the phenomenon. The researcher cannot observe what an online teacher believes or thinks about teaching science online, therefore phenomenography was employed to allow for a second-order perspective. Phenomenography provides a method that allows the researcher to describe the variations in which a phenomenon could be experienced by different people (Pang, 2003). Those experiencing a phenomenon experience this phenomenon in fundamentally different ways,

primarily because different aspects of the phenomenon will be in focus for each person experiencing the phenomenon, creating different levels of discernment (Åkerlind, 2009). Some reasons that researchers would use phenomenography are to: (a) describe conceptualizations of the phenomenon that are directly relevant to those involved in the phenomenon, (b) allows the experiences to be communicated in the language of those who experienced the phenomenon, and (c) the analyses of the data uses the participants' language and meaning rather than pre-defined terminology (Entwistle, 1997). While phenomenography can provide a qualitative description of the different ways in which a phenomenon is experienced, it is an empirical methodological practice without a theoretical basis. In order to understand what is behind the variation of experiences, developmental phenomenography must be used (Bowden & Walsh, 2000; Tan, 2009).

Developmental phenomenography, also referred to as 'new phenomenography' or as the 'Variation Theory of Learning', was developed to provide a theoretical methodology that brings understanding to the individual's experiences (Marton & Booth, 1997; Tan 2009). The theoretical basis for developmental phenomenography was conceived from Gurwitsch's (1964) "*The Field of Consciousness*". This field of consciousness resides in experience which consists of a definite structure and within certain contexts. Past experiences, the condition that experience is temporal, the point of view from which the phenomenon is experienced, and the fact that the phenomenon is understood as the experience and not as the phenomenon are all aspects of the field of consciousness. The variation between the phenomenon and a similar phenomenon is also an important aspect in that it provides understanding as to what makes a particular phenomenon unique. For this study, the comparison between the experiences of teaching online secondary science face-to-face versus teaching secondary science online provided that essential variation.

Ontological assumptions and the structure of awareness. Developmental phenomenography provides the ontological assumption that to experience a phenomenon one had to think about the experience, that the experience depends on the context or environment in which it occurs, that the experience of the phenomenon depends on a reality outside of the individual (i.e., the overall purpose of the experience), and that the phenomenon and the conception of the phenomenon are related (Svensson, 1997). By providing the means to understand the ontology of the phenomenon through the analysis of the structure of awareness, developmental phenomenography helps cultivate insight as to the variation that exists between the categories of the phenomenon (Ling Lo, 2012; Marton & Booth, 1997). By analytically developing the structure of awareness, the researcher can identify what is in the focal awareness of a person during the experience. Identifying the focal awareness of the participants guides the researcher as to what the participants discern to be critical aspects of the phenomenon. Understanding how critical aspects can vary, as well as recognizing the possible variations of the critical aspects, is required in order to learn about and understand the phenomenon (Dahlin, 2007). By providing a developmental approach to phenomenography, i.e., a particular context, changes may be able to be made that alter the way the phenomenon operates in the world (Bowden & Walsh, 2000).

The anatomy of the structure of awareness. In order to identify the critical aspects of a phenomenon, a structure of awareness must be developed from the data (Marton & Booth, 1997). The structure of awareness consists of three parts; (a) the theme, (b) the thematic field, and (c) the margin. The referential aspect or the theme, the internal horizon, is a critical aspect of the phenomenon and defines the experience of the phenomenon. A phenomenon can have multiple themes. The structural aspect or thematic field, part of the external horizon, is directly related to

the theme and consists of the structural aspects that are simultaneously present during the experience of the phenomenon. The margin, which is also part of the external horizon, consists of aspects that are not related to the theme but do play a part in affecting how the theme is experienced. Figure 1 provides a graphical representation of a possible structure of awareness for this study.

Figure 1. Structure of Awareness of an Online Secondary Science Teacher

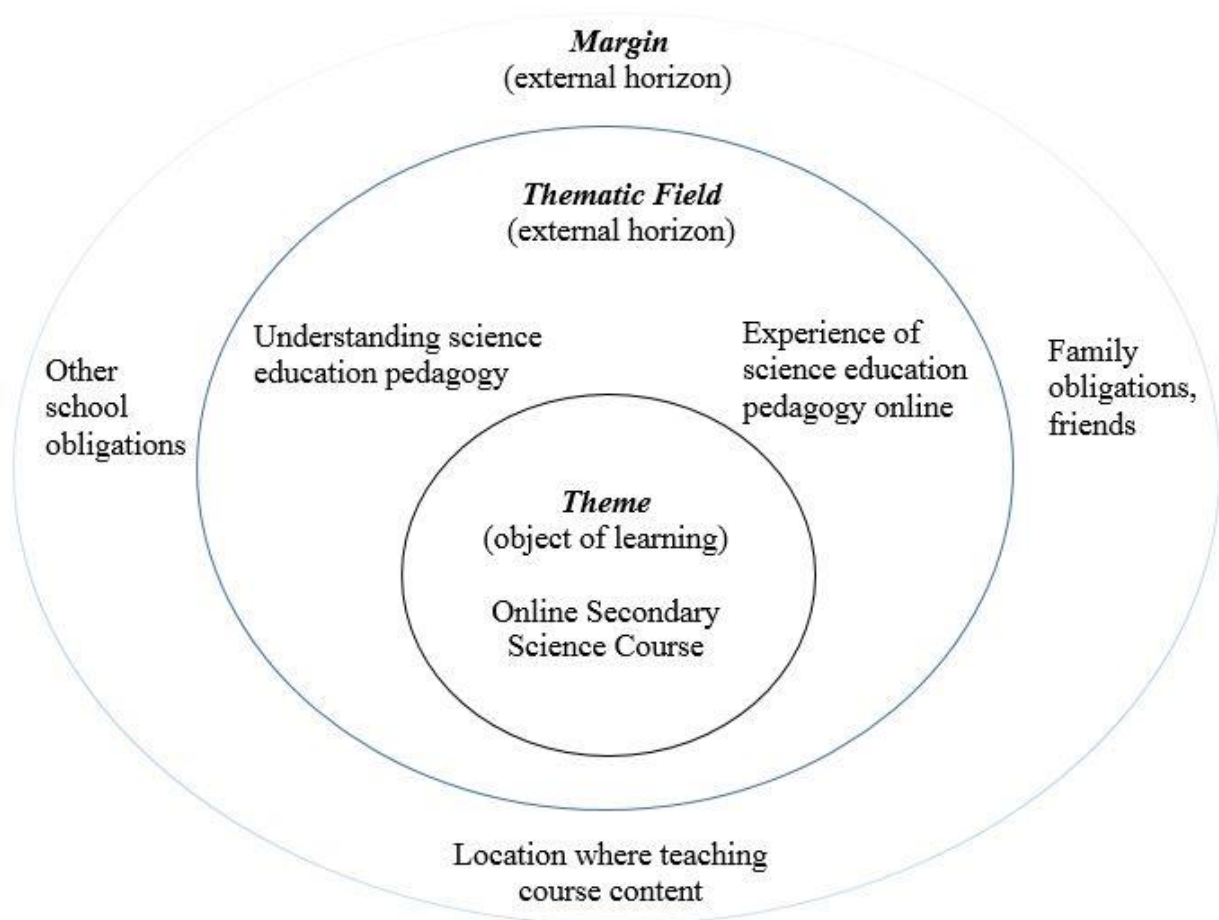


Figure 1. Model of Structural Awareness for online secondary science teachers. The phenomenon (theme) is the primary focus but that focus can be based on prior knowledge, links made to the external horizons (Thematic Field and Margins), and time.

Unlike *old* phenomenography, conceptions are no longer compared when applying developmental phenomenography. Rather they incorporate outcome spaces which consists of the variations of conceptions and together create the overall structure of awareness. The purpose of

this shift is to answer ‘why’ rather than simply ‘what’. Developmental phenomenography provides an explanatory framework that is absent from phenomenography. This allows the exploration of the differences in order to understand the nature of the variation by focusing on the pedagogical, theoretical, and analytical aspects of the experience of the phenomenon (Pang, 2003, Tan, 2009). By answering questions from a developmental phenomenography perspective; (a) the theoretical perspective by answering the question *how is the phenomenon experienced?*; (b) the analytical aspect by answering the question *what are the different ways in which the phenomenon can be experienced?*; and (c) the pedagogical aspect by answering the question *what causes these different ways of experiencing the phenomenon?*, we can begin to explain the phenomenon and its relationship to similar phenomenon (Tan, 2009). Answering these questions can help the researcher identify the critical aspects, the common experiences shared by all participants and the variations between participants, and the meanings behind these similarities and variations.

These similarities and variations are crucial to the understanding of the phenomenon of teaching online secondary science education (Marton & Booth, 1997). To understand something we must discern its features. In order to discern those features, we must discern variations of the features (Marton & Pong, 2005). To understand what a car is, we must be able to identify those features that distinguish it from other vehicles such as a truck, a motorcycle, or a bicycle. By using developmental phenomenography, this study explored the variation between teaching science in the traditional environment versus the online environment, the similarities of the experiences encountered by the participants when teaching science online, and the variation of experiences among the participants when teaching science online. A structural awareness of what it means to teach secondary science online was then developed in order to create meaning of

what it is to teach an online secondary science course. Using developmental phenomenography to describe the variation of the experiences of online secondary science teachers helped identify how curriculum choices, school structure, teacher training, and administrative guidelines affected the experience of teaching online secondary science.

Participants

Phenomenography offers a second-order perspective aimed “at describing peoples’ experiences of various aspects of the world” (Marton, 1981, p. 177). In order to ensure credibility of the data, the participants selected for the study must be appropriate and relevant to the central research question and represent the full variation of the experience (Collier-Reed, Ingeman, & Berglund, 2009). Participant sample size guidelines vary between 10 subjects, the minimum number required to find variation among participants, and 20 subjects, the maximum number of participants in order for the data analysis to be manageable (Prosser, Trigwell, & Taylor, 1994; Trigwell, 2000).

Participants for this study had to have experienced teaching secondary science online as well as be employed by an accredited online school in North America. Those teachers who volunteered also had to be willing to be digitally recorded during an extended (40+ minute) Skype interview. For these reasons purposive non-probability sampling was used (Merriam, 2014). In order to recruit public school online secondary science teachers, required applications were completed for the public school districts’ review boards. Schools in different sections of the United States with clear descriptions of their external research application process were contacted. The school districts contacted were Denver Public Schools, Atlanta Public Schools, Oregon Public Schools, Des Moines Public School, Salt Lake City School District, Florida Virtual Schools, and the Boise Virtual Academy. Once school districts had agreed to allow their

teachers to participate in the study, they contacted virtual school principals and provided them with the recruitment letter developed by the researcher. Teachers who wished to volunteer for the study then emailed the researcher and indicated their willingness to participate.

Principals of charter schools were contacted via e-mail to request permission to contact online science teachers at their school. Finally, broad requests for participants were posted on Twitter and the International Society for Technology in Education (ISTE) Online Learning and STEM communities. This entire recruitment process resulted in a sample size of 13 online secondary science school teachers, 11 female and 2 male. Two taught earth/space science, 5 taught Biology, 2 taught chemistry, and 4 taught physical science. As of the date of this dissertation, the number of online secondary science teachers are not tracked (Watson et al., 2013). Therefore it is not known if this gender ratio is consistent with the general population.

Data Sources and Data Collection

Demographic surveys. The purpose of the demographic survey was to determine the variation that existed among the participants and to provide a context for the interviews. The survey instrument (Appendix B) included items such as gender, age, number of years teaching both face-to-face and online science courses, geographic location, and content area of science taught. The results of the survey were also used to provide possible explanations for patterns found in the interview data.

Teacher interviews. Introductory Skype interviews were offered to the participants in order to obtain a level of comfort and trust before participating in the data collection interviews. All of the participants felt comfortable with the researcher and did not feel they required 2 Skype sessions. After about 5 minutes of general discussions the data collection interviews began.

Second-order phenomenographic conceptions reside within the context of the relationships between individuals and the task or phenomenon. They are dynamic and context-dependent, but the assumption is that conceptual patterns can be identified (Marton, 1981). In order to develop a structure of awareness, the interview questions used in phenomenographic interviews must identify critical variation in the group's experience of the phenomenon (Cope, 2004). Rather than simply comparing the variations experienced by the participants, applying developmental phenomenography allows the researcher to triangulate the phenomenon from the perspectives of what was experienced, what is possible to experience and what was learned about the phenomenon under study. This allows the researcher to identify common experiences and critical aspects that are shared and that vary between participants (Bussey, Orgill, & Crippen, 2013). Interview questions helped identify the structure of the experiences, how and to what degree the experiences varied, what separated the internal and external horizons, and brought meaning to the phenomenon. In order for the data from the interviews to be credible, the interviewer should have a shared experience of the phenomenon (Collier-Reed et al., 2009). This provides the interviewer and the interviewee with a common language as they share definitions of the phenomenon. While the researcher has not had the experience of teaching a secondary online science course, she has taught online and she has taught face-to-face secondary science courses, which provided her with similar experiences and vocabulary surrounding those experiences as the teachers interviewed.

The phenomenon for this study was teaching secondary science in an online environment, therefore the interview questions focused on the topics of instruction and the teachers' perceived student learning. In developmental phenomenography interviews are semi-structured and use only a few key predetermined questions (Collier-Reed et al., 2009). The

questions related to the participants' experience of teaching secondary science online and to their experience of their students' learning online.

The role of the researcher was to "assist the participants in exploring and elucidating their ideas as they endeavor [sic] to express them" (Dortins, 2002, p. 210). Follow-up questions similar to those posed by Prosser, Trigwell, and Taylor (1994) were employed; "What do you mean by 'teaching in this subject'?" (Prosser et al., p. 219). The researcher ensured that the follow-up question structure expressed the experiences of the participant and not the researcher. This was accomplished by using the terms contained in the responses of the interviewees in order to help restrict bias in the data (Cope, 2004). The interviews were conducted via recorded videoconferencing using Skype™ and Screencast O Matic and lasted between 35 to 60 minutes. The transcripts were transcribed verbatim and in such a way as to "ensure that the structure and content of the interviews are richly reported" (Collier-Reed et al., 2009, p. 348).

The Development of the Phenomenographic Interview Questions

Four questions were developed to identify the structure of awareness. 1) "*What has the experience of online science teaching been like for you?*" was developed to help define the internal horizon of the online science course. 2) "*How do you perceive your science teaching in the online environment?*", and 3) "*How do you experience your students' learning?*" were developed to help define the thematic field. Finally, 4) "*Why did you choose to teach in an online environment?*" was developed to help define the external horizon of the experience of teaching online secondary science.

During a trial interview it was determined that these four questions were insufficient to prompt the participant reflection required to relay the full experience of teaching online secondary science. The majority of the participants had taught in brick and mortar classrooms

before teaching online. In order to bring about a better understanding of the overall experience of teaching online secondary science and to help these participants reflect on the experience of teaching secondary science online, the following questions were included:

- 5) *What do you find to be different about the experience of teaching online compared with face to face?*
- 6) *How did you experience yourself as a science teacher online?*
- 7) *What are some positive aspects about teaching online? Negative aspects?*
- 8) *What are your beliefs regarding virtual school teaching and the pedagogical practices you implement?*
 - a. *How do you experience scientific argumentation?*
 - b. *How do you experience investigatory practices/science experiences?*
- 9) *What resources do you use to teach in an online environment?*

Question 8 deviated slightly from the general nature of phenomenographic questions. This was due to the phenomenon under investigation, online secondary science. Given the importance placed on argumentation and investigatory practices to science education (Duschl & Osborne, 2002; Hofstein & Lunetta, 2003), the researcher felt that it was important to make explicit reference to both instructional practices in order to prompt reflections in these two areas. This practice is supported when prompts are deemed to be required in order to ensure the interview focus aligns with the goals of the study (Francis, 1993).

The final question, *“If a university approached you and said they were going to include an online component in their teacher education program, what would you advise they incorporate in that program?”*, was designed to help the participants reflect more deeply about their online teaching experiences, prompting them to think about what those experiences meant

in terms of their ability to teach online. The questions were tested again with a second trial interview and were shown to prompt for deeper reflection on the phenomenon of teaching science online.

Analysis of the Data

The basic unit of analysis of phenomenography is the unit of conception (Marton & Pong, 2005). A conception is defined by two aspects, the referential aspect and the structural aspect. The referential aspect defines the fundamental meaning of the unit; the structural aspects identify specific features of the concept (Figure 2). The structural aspect can be further divided into the external and internal horizons (Marton & Booth, 1997). The internal horizon defines the structural presence of the object, its components. The external horizon refers to the other contexts in which the experience has occurred.

Figure 2. LMS System Unit of Conception

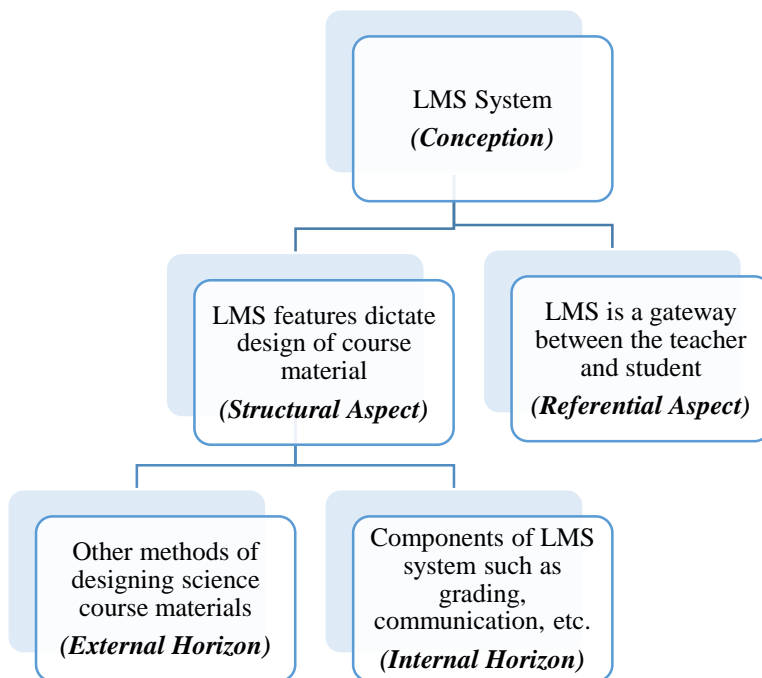


Figure 2. Hierarchical representation of a possible unit of conception for the proposed study, illustrating the relationships between the components of the conception. Note: this representation of the unit of conception is a modified example from Marton and Booth (1997, p. 91).

A two-step process was used to analyze the transcripts. Step one involved identification of conceptions in terms of meaning and variation in meaning. Themes were identified and units formed as evidence of overall meaning developed. Throughout the second step the structure of the conceptions were identified. During these steps the researcher bracketed, or “held back known theories and prejudices in order to be fully and freshly present to the individual’s conception under investigation” (Sandbergh, 1997, p. 209), knowledge concerning the phenomenon. The data analysis was deemed complete when each theme provided unique insights on how the phenomenon was experienced. There was a hierarchical and logical structure and relationship between the themes, and the number of themes was parsimonious (Åkerlind, 2012). Finally, the outcome space consisting of all of the themes identified was be justified and presented in a table that provided a summary of themes and their distinguishing features, or aspects of variation. The similarities and variations contained in the data was used to explain the experiences of teaching online secondary science courses and provided evidence as to the ‘why’ of those experiences.

Validity of the data. The validity of the data was addressed by providing justification for the outcome space presented. A structure of awareness methodology was used to define the margins, thematic fields, and themes (Cope, 2004). This structure was used to provide justification of the interview questions asked of the participants. The researcher used a phenomenological reduction technique to remain unbiased (Sandbergh, 1997). This included authentically orienting the phenomenon, describing the experiences rather than explaining the experiences, employing horizontalization by treating all experiences as equally important, and conducting iterations using a variation of themes until stability of interpretation had been achieved. Finally, what individuals conceived as reality, how individuals conceived reality, and

relating the ways these realities are conceived was used as a correlational factor to help explain how the researcher identified the various themes.

Reliability of the data. Phenomenography does not lend itself to interrater reliability as it does not allow for a “form of replicability in the sense that it gives a measurement of the extent to which other researchers are able to recognize the conceptions identified by the original researcher, through his/her categories of descriptions” (Sandbergh, 1997, p. 205). In order to address the issue of reliability, the researcher thoroughly documented interpretive steps taken and the critical stance the researcher had towards those interpretations (Åkerlind, 2012).

Chapter 4 Results

This study investigated the experience of teaching online secondary science through the lens of developmental phenomenography. Online secondary science teachers from four states and two countries participated in recorded Skype interviews to in order to address the following research questions:

1. How do online secondary science teachers experience their teaching while teaching their courses online?;
2. How do online secondary science teachers experience their students' learning while teaching their courses online?

Analysis of the Data

The phenomenon of interest for this study was the experience of teaching secondary science in an online environment. Developmental Phenomenography was chosen for the analysis of the data as it provides a method to investigate the variations and similarities of experiences of the participants. These variations and similarities can be attributed to the prior lived experiences of having taught secondary science in the traditional classroom setting, and the variation of experiences that occur between the online secondary teachers as they teach secondary science online. By identifying these similarities and variations, a description of how the participants conceive of aspects of teaching online secondary science can be developed (Bowden, 2000).

The analysis of phenomenographic interviews is not only concerned with the relationship between the participants and the phenomenon; by its nature it also includes the researcher's perspectives as it is the researcher who determines what constitutes those similarities and differences (Burns, 1994). Developmental phenomenography focuses on the experience of the phenomenon, not the phenomenon itself, and the experience of the researcher affects how the

data is interpreted. Therefore the researcher's background in relation to the study is of consequence to the analysis. The researcher for this study has taught secondary science in the traditional classroom but not in the online environment, and has taken online science courses at the post-secondary level. The researcher has taught online courses at the post-secondary level, but the courses were not related to science. The researcher has also conducted studies on effective methods for teaching in the online environment. Interpretive awareness is important in order to present the experiences of the participants and not of the researcher (Sandberg, 1997). Care was taken to describe the experiences while withholding any prejudices the researcher may have had on the phenomenon, and all participants were treated equally.

The analysis of the data was conducted by one researcher. Reliability checks, such as interjudge reliability, were not conducted. Sandberg (1997) argues that interjudge reliability is not an effective check of the data analysis for developmental phenomenography. Interjudge reliability cannot take into account the interpretive awareness of the original researcher. Cope (2002) points out that due to the temporal nature of the experiences, and therefore the data, reliability takes on a different meaning when compared to other qualitative methods. Therefore, as the themes from the data were constructions of the researcher, the following sections will describe the process of the discovery of the themes in order to provide a better understanding of how those themes were developed.

Interview analysis procedures. The categories of description leading to the themes contained both structured and unstructured categories. The unstructured categories developed from the data and reflect the relationship the participant has with the phenomenon of online secondary science teaching as reflected in the descriptions of their experiences. The structured categories developed from the research questions which focused specifically on two aspects

considered to be important in science education; inquiry experiences and scientific argumentation. After the final analysis, scientific argumentation was not developed as a theme as the majority of the teachers and students did not participate in this practice. Once the categories of description were identified their structural relations were defined by developing the structures of awareness of the themes.

In order to begin the analysis, the phenomenographic interviews were transcribed and subsequently emailed to the participants to check for the accuracy of the transcriptions. The researcher began the process by reading the entire text. A second pass through the transcriptions were made with a focus on the responses to individual questions. During this reading passages that included the “what” the participant was focused on in terms of the experience prompted by the questions, and “how” the participant described that experience were assigned to categories. The next step was to read through the categories to find similarities and differences in order to develop themes which could contain the categories. The final step was to group the descriptions of categories into stable themes and create structures of awareness for those themes in order to develop the overall outcome space for the experience of teaching online secondary science education.

In order to have a full variety of experiences, only those categories of descriptions that were experienced by a majority of the participants were developed into themes. For example, one participant felt that “politicking” was a negative experience of online secondary science teaching:

[20:17:0-22:06.0] **ST4.** (politicking). I’m not good at politicking whatsoever...I was like, I can do my job, and I can do it well. Oh, I’m sorry, you don’t like my politicking..But that’s more my personality. Obviously everybody has different types of personality. And we all bring that to the table.

Participant ST4 was the only teacher that discussed the experience of “politicking” and peer personality. Therefore this experience, the experience of peer personalities, was not used to create a category of description, and was not considered to be a theme given the goal of developmental phenomenography to identify similarities and variations in experiences within a common theme. The development of the seven themes; (1) Virtual Labs and Learning, (2) Student Learning and Factors Involved, (3) Communication and Instruction, (4) Teaching as Collaboration/Social Aspect, (5) Teaching and Learning as Assessment, (6) Curriculum Effects on Teaching and Learning, and (7) Online Structure Effects on Teaching and Learning, are described below.

Development of the theme ‘virtual labs and learning’. The twelve categories of description that contributed to the theme of ‘Virtual Labs from Learning’ came from:

- Interview Question 1, “*What has the experience of online science teaching been like for you?*”,
- Interview Question 2, “*How do you perceive your science teaching in the online environment?*”,
- Interview Question 5, *What do you find to be different about the experience of teaching online compared with face to face?*”,
- Interview Question 6, “*How did you experience yourself as a science teacher online?*”,
- Interview Question 7, “*What are some positive aspects about teaching online? Negative aspects?*”,
- Interview Question 8b, “*What are your beliefs regarding virtual school teaching and the pedagogical practices you implement? b. How do you experience investigatory practices/science experiences?*”, and the final question,

- *“Is there anything else you would like to add?”.*

The 12 categories of description along with corresponding representative passages appear in Table 6 in Appendix C.

These 12 categories of description could lead to several themes; student learning, student collaboration, and effective curriculum development. Given that one of the constructed questions focused on the lab experience of the online secondary classroom, it was determined that the commonality was virtual labs and how they may, or may not, lead to student learning. Therefore Theme 1 is titled Virtual Labs and Learning.

Development of the theme ‘student learning and factors involved’. The nineteen categories of description that contributed to the theme of ‘Student Learning and Factors Involved’ came from:

- Interview Question 1, *“What has the experience of online science teaching been like for you?”*,
- Interview Question 2, *“How do you perceive your science teaching in the online environment?”*,
- Interview Question 3, *“How do you experience your students’ learning?”*,
- Interview Question 5, *What do you find to be different about the experience of teaching online compared with face to face?”*,
- Interview Question 7, *“What are some positive aspects about teaching online? Negative aspects?”*,
- Interview Question 8, *“What are your beliefs regarding virtual school teaching and the pedagogical practices you implement?”*,
- Interview Question 9, *“What resources do you use to teach in an online environment?”*,

- Interview Question 10, *“If a university approached you and said they were going to include an online component in their teacher education program, what would you advise they incorporate in that program?”* and the final question,
- *“Is there anything else you would like to add?”*.

The 19 categories of description along with corresponding representative passages appear in Table 7 in Appendix C.

These categories of description come together to create the them ‘Student Learning and Factors Involved’ as they helped identify the factors that the participants feel are related to students learning in an online environment, ways in which teachers identify student learning in an online environment, identified road blocks to student learning online, and beliefs about the abilities of students to learn science in an online environment.

Development of the theme ‘communication and instruction’. The twenty-one categories of description that contributed to the theme of ‘Communication and Instruction’ came from:

- Interview Question 1, *“What has the experience of online science teaching been like for you?”*,
- Interview Question 2, *“How do you perceive your science teaching in the online environment?”*,
- Interview Question 5, *What do you find to be different about the experience of teaching online compared with face to face?”*,
- Interview Question 7, *“What are some positive aspects about teaching online? Negative aspects?”*,

- Interview Question 10, *“If a university approached you and said they were going to include an online component in their teacher education program, what would you advise they incorporate in that program?”* and the final question,
- *“Is there anything else you would like to add?”*.

The 21 categories of description along with corresponding representative passages appear in Table 8 in Appendix C.

There were several subthemes within the categories of descriptions listed above. The miscommunication that can occur between students and teachers in when using digital forms of communication, the amount of time teachers must spend simply communicating and teaching students via phone, email, and text, communicating with parents, and language barriers that occur between teachers, students and parents. These subthemes help offer an overview to the issues involved with the role communication has with instruction in an online educational environment, leading to the theme of communication and instruction.

Development of the theme ‘teaching as collaboration/social aspect’. The thirteen categories of description that contributed to the theme of ‘Teaching as Collaboration/Social Aspect’ came from:

- Interview Question 5, *What do you find to be different about the experience of teaching online compared with face to face?”*,
- Interview Question 7, *“What are some positive aspects about teaching online? Negative aspects?”*,
- Interview Question 9, *“What resources do you use to teach in an online environment?”*,
and

- Interview Question 10, *“If a university approached you and said they were going to include an online component in their teacher education program, what would you advise they incorporate in that program?”*

The 13 categories of description along with corresponding representative passages appear in Table 9 in Appendix C.

The categories of descriptions represented in the table above demonstrate a need for human interaction. This theme includes categories of description that pertain to both the academic arena as well as the social. The majority of the participants did report feeling supported by their virtual school peers and administrators. However, all of the participants reported a need for human contact to alleviate feelings of isolation, whether it be face to face meetings with colleagues, or face to face meetings outside of the school environment. This led to the theme, teaching as collaboration/social aspect.

Development of the theme ‘teaching and learning as assessment’. The eleven categories of description that contributed to the theme of ‘Teaching and Learning as Assessment’ came from:

- Interview Question 2, *“How do you perceive your science teaching in the online environment?”*,
- Interview Question 3, *“How do you experience your students’ learning?”*,
- Interview Question 5, *What do you find to be different about the experience of teaching online compared with face to face?”*,
- Interview Question 7, *“What are some positive aspects about teaching online? Negative aspects?”*,

- Interview Question 8, “*What are your beliefs regarding virtual school teaching and the pedagogical practices you implement?*,”
- Interview Question 9, “*What resources do you use to teach in an online environment?*”, and the final question,
- “*Is there anything else you would like to add?*”.

The 11 categories of description along with corresponding representative passages appear in Table 10 in Appendix C.

The categories of descriptions discussed in the table above focus on various ways in which assessment plays a role in both teaching and learning in online secondary science education. Some of the subthemes for this larger theme were the difficulties of identifying plagiarism, attempting to determine if students were “faking” knowledge, and how to identify authentic student work in both verbal and written assessments, resulting in the theme teaching and learning as assessment.

Development of the theme ‘curriculum effects on teaching and learning’. The eighteen categories of description that contributed to the theme of ‘Curriculum Effects on Teaching and Learning’ came from:

- Interview Question 1, “*What has the experience of online science teaching been like for you?*”,
- Interview Question 2, “*How do you perceive your science teaching in the online environment?*”,
- Interview Question 3, “*How do you experience your students’ learning?*”,
- Interview Question 7, “*What are some positive aspects about teaching online? Negative aspects?*”,

- Interview Question 8, 8a, and 8c *“What are your beliefs regarding virtual school teaching and the pedagogical practices you implement?”*
 - a. *How do you experience scientific argumentation?*,
 - b. *How do you experience investigatory practices/science experiences?”*,
- Interview Question 9, *“What resources do you use to teach in an online environment?”*,
- Interview Question 10, *“If a university approached you and said they were going to include an online component in their teacher education program, what would you advise they incorporate in that program?”* and the final question,
- *“Is there anything else you would like to add?”*.

The 18 categories of description along with corresponding representative passages appear in Table 11 in Appendix C.

The variation in experience that can be found when using developmental phenomenography was very apparent for this theme, and the subthemes reflect that variations. Some of the subthemes identified were lack of creativity in the area of teaching, low-level assignments and assessments, the ability to have more time to help students given that the teachers did not have to create content, and the difficulty teachers experienced in terms of individualizing instruction when they used premade curriculum. Not all of the participants used premade curriculum, three of the participants were able to create their own content. This variation in curriculum development, and how that development influenced teaching and learning, resulted in the theme curriculum effects on teaching and learning.

Development of the theme ‘online structure effects on teaching and learning’. The twenty-three categories of description that contributed to the theme of ‘Online Structure Effects on Teaching and Learning’ came from:

- Interview Question 1, *“What has the experience of online science teaching been like for you?”*,
- Interview Question 2, *“How do you perceive your science teaching in the online environment?”*,
- Interview Question 3, *“How do you experience your students’ learning?”*,
- Interview Question 4, *“Why did you choose to teach in an online environment?”*,
- Interview Question 5, *What do you find to be different about the experience of teaching online compared with face to face?”*,
- Interview Question 6, *“How do you experience yourself as a science teacher online?”*,
- Interview Question 7, *“What are some positive aspects about teaching online? Negative aspects?”*,
- Interview Question 8, *“What are your beliefs regarding virtual school teaching and the pedagogical practices you implement?”*,
- Interview Question 9, *“What resources do you use to teach in an online environment?”*,
- Interview Question 10, *“If a university approached you and said they were going to include an online component in their teacher education program, what would you advise they incorporate in that program?”* and the final question,
- *“Is there anything else you would like to add?”*.

The 23 categories of description along with corresponding representative passages appear in Table 12 in Appendix C.

The categories of description described in the above table all point to the affects the online environment has on both teaching and learning. These categories were viewed in a more general context than those which pertained, for example, to the theme of Virtual Labs and

Learning. Some of the subthemes described the flexibility online teachers enjoy, the lack of classroom management issues, and the increased workload experienced by teachers. These themes helped lead to the development of the theme, online effects on teaching and learning.

Structures of Awareness of the Themes

In order to ensure validity and reliability of the analysis and interpretation of the data, developmental phenomenography requires that the analytical process be transparent and that the process of developing the structure of awareness of the phenomenon be described (Cope, 2004). Several iterative readings of the transcripts, both individually and as a whole, were conducted during which time themes were identified. Structures of awareness were generated for each theme and are presented in Table 10 through Table 16 below. The participants' experiences contained both structure and meaning, often referred to as the 'anatomy of experience' or 'ways of seeing' in developmental phenomenography (Ling Lo, 2012; Yates, Partridge, & Bruce, 2012). The structure of awareness, also referred to as 'Unit of Conception' in old phenomenography (Figure 2 above), contains a referential aspect, which is the meaning of the experience, and the structural aspect, the combination of features on which the participants focused as they experienced the referential aspect of the phenomenon. The structural aspect in turn is made up of two elements, the internal horizon and the external horizon. The internal horizon consists of the features that constituted the thematised focus placed on the phenomenon by the participants. The external horizon contains the features that the participants experienced as relevant to that theme and that were part of their background of experience. (Ling Lo, 2012; Yates et al., 2012).

The researcher's interpretive awareness is evident in the descriptions of the structures of awareness and in the representative quotes chosen for each theme (Akerlind, 2012). Once the

structures of awareness for the themes were developed, the overall structure of awareness for the phenomenon of teaching online secondary science was created (Figure 3). This overall structure of awareness identifies the critical aspects of teaching online secondary science (Marton & Booth, 1997).

The results of the analyses of the transcripts as a whole resulted in seven qualitatively different themes of description for the conceptions of awareness. Two themes focused on learning, one theme focused on teaching, and four themes focused on both learning and teaching. Structures of awareness of the conceptions of awareness are presented below, along with representative quotes for each theme. Given the complex nature of the conceptions of awareness it is impossible for one quote to represent the full definition and they are for illustration purposes only. The categories of description identified were: (1) Virtual Labs and Learning, (2) Student Learning and Factors Involved, (3) Communication and Instruction, (4) Teaching as Collaboration/Social Aspect, (5) Teaching and Learning as Assessment, (6) Curriculum Effects on Teaching and Learning, and (7) Online Structure Effects on Teaching and Learning.

Structures of awareness for each of the categories have been created to provide a form of measurement to confirm reliability and validity for this study (Cope, 2004). The structure of awareness provides a glimpse into the mind of the researcher and demonstrates how the researcher analyzed the data, providing interpretive awareness. Given that whole transcription analysis was used, it is important to show how the data was delimited from the whole and how dimensions of variation (DoV) within the themes were defined. The resulting structures of awareness for this study demonstrated linear relationships between the DoVs and are presented in Tables 13-19.

Theme 1: Virtual labs and learning. The teachers had a clear dichotomy in regard to their conceptions of awareness of student learning with virtual labs. Virtual labs were believed to be either more effective or as less effective than face-to-face labs. Those who felt that virtual labs were inferior in the online environment compared to those in the face-to-face environment believed virtual labs were not as engaging due to the lack of physicality. The “one size fits all” nature of the virtual labs used by the teachers was also discussed as a negative. Students were not given the opportunity to engage in science practices such as creating their own questions, collecting their own data, and finding their own answers as the virtual labs tended to lead down one pathway. Other issues that were believed to prevent virtual labs from improving student learning were the difficulties encountered in regard to student collaboration. Barriers to collaboration included students either lacking the desire or the social skills to interact with their peers as well as scheduling difficulties.

In terms of differences, it's been a challenge to try to find some hands-on experiences for my online class obviously. The lab work though has been a concern of mine so I've tried to adapt some existing labs to make them more, I guess to provide students with some lab experience because I've always felt that was sort of neglected with online. ...But the virtual labs, I find, it's really hard to find virtual labs that are authentic in the sense that they contain some openness for mistakes. They tend to be very generic and very like one pathway to the right answer kind of deal. So I've found that that's been a real challenge. (ST10)

Teachers who held the conception of awareness that virtual labs could lead to student learning felt that virtual labs could be more effective than face-to-face labs, particularly as it was believed they could receive better results with virtual labs. Virtual labs were also viewed as superior due to the lack of classroom management issues; students were believed to be more focused on the concepts when conducting virtual labs than their counterparts in traditional classrooms. The effectiveness of the learning experience was believed to increase when students were allowed to collaborate on virtual labs in break-out rooms within the learning management

system, and when students were able participate in scientific argumentation concerning their results with their peers. Teachers felt that an increased understanding was reflected in work submitted after conducting the virtual labs. Virtual labs were also seen as providing learning experiences to students who did not have access to materials. The development of the structure of awareness for virtual labs and learning appears in Appendix D, Table 13.

Okay for chemistry we have virtual labs and they're actually pretty good. For the flame lab, I could never get these types of results in a laboratory. We had the chemicals and stuff and some of them, like the copper burned really green, and the sodium burned really yellow, but other colors like potassium it was really hard to see the purple in the flame, it wasn't really obvious. And if the burners were contaminated, then no holds barred. You know if your burner was contaminated your results weren't good. (ST8)

Theme 2: Student learning and factors involved. The participants in this study held the belief that students could learn science in an online environment. Identifying whether such learning had occurred, however, was an issue of concern. The lack of student physical cues led teachers to question whether learning had actually occurred. During the live lessons students could click on “thumbs up” or “thumbs down” to signify understanding, but the teachers believed this allowed the students to “fake” understanding. The participants felt that knowing the student was an important component of identifying student learning, although this could prove difficult to accomplish given that some participants had large class sizes. Verbal cues, intonation, and speech patterns served in place of facial cues during phone calls. Textual cues were also used as teachers were able to recognize authentic student writing versus instances of plagiarism. The experience of student learning was perceived partly to be the result of the types of supports available to students. Supports which assisted student learning included special education teachers, counselors, help desks, tutoring, and coaches. The teachers experienced frustration due to one type of support; that of parents as coaches. Parents of secondary students tended to hold

the belief that their students had the ability to self-regulate their learning and did not provide the type of coaching support envisioned by the schools.

The teachers identified factors that contributed to the difficulties students faced when learning science online. Student characteristics and demographics were prime concerns. Teachers believed successful online science students were those who were self-motivated, had good organizational skills, were self-regulated, and had a good command of the English language. Barriers to learning identified by the teachers were family obligations as some online students had children of their own, students lacked technology skills, some students were gone for long periods of time due to the need to attend rehabilitation and similar circumstances, and some students did not have a home environment which supported learning. The development of the structure of awareness for student learning and factors involved pears in Appendix D, Table 14.

I think a lot of that comes from, A) getting to know your students, a lot of that I can tell over the phone which is why we do the DBAs (*Discussion Based Assessments*) so frequently. You get to know their voices, you get to know their tone and their pauses. And you can tell when they start to ramble. If they start to ramble and they're kind of starting to try and make sense of something that's not making sense, that's kind of my indicator that I stop and I say "let's backtrack a little bit, let's go back to what you said first. Now why do you think that might be the case?" Or "what's going on with that?" I think a lot of it is that conversation you have over the phone, kind of those checkpoints. (ST7)

Basically f2f I love it, I love the face. Because you get to see the reaction, you get to see how "oh, I get it, I really really get it". Whereas online I'll ask them if it makes sense. They can type in "sure", but at home they're going (ST3 makes a confused facial expression). "I don't get it, I don't get it, but I'm going to type 'sure' so she'll stop buggin' me". (ST3)

Theme 3: Communication and instruction. The importance of broad online communication skills were prevalent throughout the data. Strong text and verbal skills were considered necessary in order to know how to convey proper emotion, elicit student engagement, and to provide feedback on assignments and assessments. Participants felt that those teaching

science online required deep content knowledge. At times the science concepts had to be conveyed using just words as some students did not have internet access at home so graphics and supporting visuals were not an option during tutoring sessions.

As with the experience of learning in relation to virtual labs, the teachers demonstrated a dichotomy on the ability to form relationships with online students. Some felt that text communication was too impersonal and that they could not demonstrate their full personality. Joking and sarcasm were not easily conveyed and could lead to student misunderstandings. Others experienced a deeper connection with their online students than they had with their face-to-face students, primarily because online communications were conducted one on one and there was more time to talk with individual students.

The lack of student writing skills and online etiquette led much of the communication and instruction to be teacher driven. Another factor that resulted in less student communication was that some student were shy or had no interest in interacting with their peers. Technology barriers were also present. Some student homes did not have Internet at home, or hardware such as webcams or microphones that could aid in communication. This led to teachers perceiving students as isolated. Teachers experienced language barriers as being greater in the online environment and felt their face-to-face ESOL strategies for science instruction were not as effective. The participants also felt they were able to provide better student feedback online as the asynchronous nature of the environment provided time to reflect.

Parent communication was considered to be more robust when teaching in the online environment as compared to regular schools. In many instances parents were online learning coaches for their children. The participants spent time on the phone discussing pacing plans with the parents. Parents were also updated on student progress and successes, as well as times when

plagiarism was suspected. The ability to convey proper emotion verbally or in text was considered to be vital for online teachers. Online teachers spent more time discussing life issues involving their online students, such as a death in the family, with parents more often than when they taught face-to-face. The development of the structure of awareness for communication and instruction appears in Appendix D, Table 15.

I think that there isn't a whole lot on effective communicating with students online. You know, what works, what doesn't, what should you include, what shouldn't you include, what should you focus on. So I think it's a very different environment. You have to type a lot of your comments. So you have to have strong written skills. You have to be focused on what exactly you're trying to teach them and what you're wanting them to get out of it. And I think because there's such a focus on written and maybe verbal...Because I think we just assume that since teachers are teachers they're good communicators online and that's not necessarily the case. And also I think with students, they are very, because communication in a sense can be so, it's so open. Like once you write an email it's out there and you can't necessarily control how a student takes it. It's not like you can vary the tone of your voice or use your facial expressions to sort of give them an idea of your approach. So I think you have to be more careful in how you word things and to make sure to still be encouraging and...about getting your point across. (ST10)

Theme 4: Teaching as collaboration/social aspect. The participants of the study described opposite experiences in regard to professional collaboration. Those who taught in smaller virtual schools experienced little to no collaboration with other online science teachers. This was particularly an issue for those who taught multiple science subjects and who desired to share thoughts on best online teaching practices when teaching subjects outside their focus area. Teachers employed by larger virtual school programs felt they had a great amount of support from their fellow teachers and administration. These teachers were assigned to teams that in some cases met face-to-face on a regular basis to grade and to plan live lessons (lessons conducted synchronously with their students). Collaboration occurred virtually and face-to-face, with peers providing feedback on instructional strategies or commiserating over situations in the

online classrooms. There was a perceived culture of support and sharing in the online environment that some did not experience in the brick and mortar environment.

Despite feeling supported by their peers and administrators, the teachers felt that working from home was socially isolating. Online teachers spent much of their time texting or talking with students and missed adult conversations with professional peers. Adult family members either worked away from home or attended school while the online teacher worked alone at home, again causing feelings of isolation and the need for adult companionship. The development of the structure of awareness for teaching as collaboration/social aspect appears in Appendix D, Table 16.

So I can message, and everyone encourages you. If you have to look more than a minute for something, message someone. So the support is amazing. I've never felt so supported. There's a group of us that meet for coffee every Wednesday, we grade...But it's getting out and doing it is sometimes hard, because you know. I get home, my kids go to school, I go to the gym, and I'm like, I just want to go to work...the support has been amazing. The principals are super supportive, big troubleshooters. We have our team leads who are like our resource science teachers who will help out with kids that aren't working or any issues with parents or kids, they'll troubleshoot for us. Everyone's great. We all are very supportive of one another. (ST5)

Theme 5: Teaching and learning as assessment. Given that assignments and assessments were digital, online secondary science teachers use student data to help inform their instructional practices. Knowing which assignments students were behind on, how long students spent on the LMS website, how long a student had been in class, and student grades were used to provide remediation and informed future instructional strategies. This access to student data was believed to be important due to being unable to perform continuous formative assessments as compared to traditional classrooms. More local assessments were conducted using webcams to access student facial cues during live lessons and labs, or by looking for textual clues in emails and in written assessments. The teachers felt that assessing for science misconceptions helped

them gain a deeper understanding of how their students learned, thereby allowing them to individualize instruction.

Assessments were also used to check for student understanding and to affect student learning. Teachers felt their grading was more unbiased in the online environment as it was easy to access assignments without looking at the name of the student. Discussion based assessments helped teachers determine student misconceptions by forcing students to provide reasons for their answers. Given that students could Google most answers, teachers felt that open-ended questions were an important part of the assessment strategy. Plagiarism was seen as a pervasive problem with online science education, particularly when students fell behind in the course or were not confident they understood the concepts. Open-ended questions were used to check whether students could apply the concepts taught in the course. As many exams were taken on the computer at the students' homes and not proctored, open-ended questions were seen as essential to ensuring students had not simply 'Googled' all the answers.

The participants believed that online students would be more engaged if they could be in charge of their own learning. In order for this to occur, students had to be able to self-assess their own learning, or to at least receive immediate feedback. The teachers believed that online science students would quickly disengage if they did not believe they had a correct understanding on an assignment. It was important that interactive websites and other similar technology be used that could allow students to check for understanding. In some cases, teachers created short assessments that could be graded quickly. The features of learning management systems (LMS) affected the teachers' assessment experience. The LMS was seen to be either cumbersome, as in grading lab reports one at a time, or able to provide immediate feedback for

properly structured online assessments. The development of the structure of awareness for teaching and learning as assessment appears in Appendix D, Table 17.

And they even get instant feedback with the computer generated score. They know, did they get it, did they not get it? And then they have to email me if they didn't get it and get it reset and I can go over, "okay, well you missed these two questions, do you understand that"? And that kind of just streamlines where they're at, what concepts they might need to review. And in a big classroom (*referring to face-to-face classroom*) you don't really have that check for understanding right away. (ST9)

Theme 6: Curriculum effects on teaching and learning. Twelve of the teachers who participated in this study taught using preset curriculum. Teachers using a set curriculum found that their creativity as a teacher declined. They felt that teaching a set curriculum limited their ability to teach as they did not want to stray from the content presented in the modules. Some teachers felt that the set curriculum provided them with more time to spend on student communication as they did not have to spend time creating content. Given that the set curriculum could vary dramatically in both content and method from the way the teachers had taught science in the face-to-face classroom, the teachers felt it was very important that the curriculum be reviewed in order to understand the learning goals and the assessments that would be implemented. The set curriculum was considered to be lacking and many of the participants added their own resources, such as verbal explanations, to help with student understanding. The assignments and assessments were also found to be deficient. The teachers believed the assignments were set at too low of a level and did not challenge the students. The assessments were deemed to be poorly designed and only checked basic levels of understanding.

The teachers who were able to implement their own curriculum felt that by doing so they were able to stay current with their science instructional methods. The participants found that when they created content for their online classes they tended to look for technology resources, whereas when they created content for their face-to-face classes this was not necessarily the case.

These teachers felt this difference improved their skills in regard to teaching science and helped them gain a better understanding of student learning of science content. The development of the structure of awareness for curriculum effects on teaching and learning appears in Appendix D, Table 18.

My teaching's just more going over somebody else's lesson. I just support, I don't really feel like I have a lot of flexibility or freedom. You know we buy the curriculum and the way things are set up...it's hard to deviate, you know, to modify them a lot. So I feel like I'm just more of a facilitator just using my knowledge to help them improve just some general. You know, this is nature of science and the scientific method more that kind of stuff, but I'm not really doing much in terms of creating my own content or anything like that. (ST9)

Because I'm constantly finding things or coming across new things so it tends to help my instruction and my assessment practices, my teaching practices to be maybe a little bit more current, if that make sense. ... Just in terms of having access or having exposure to a lot of different technologies and information. To be aware of current trends simply because you're always searching, right? Or at least I am. Always searching for new things to incorporate and to try out and I think that's really exciting, it's an exciting space because it's still relatively new and there's lots of opportunity for growth and so I like that challenge. I like that challenge to keep trying new things, to see what works, see what doesn't work, kind of be more on the cutting edge rather than just redoing what everybody's always done the last 20 years. So I really appreciate that aspect because I think if I didn't teach online I don't think I would have had that exposure or those experiences. (SC10)

Theme 7: Online structure effects on teaching and learning. This theme includes conceptions of awareness that pertain to how the structure of the online environment affects teaching and learning. There were features of science instruction that did not seem as effective in the online environment when compared to traditional classrooms. Many of the participants had become science teachers because of the hands-on aspects of the course and the ability to model science concepts to their students. The teachers believed that this experience could not be conducted online, reducing their teaching effectiveness. Conversely, teachers felt that they had more time to teach, grade, and lesson plan more effectively due to the time saved by not having to deal with traditional classroom behavior management issues. Teachers also had the ability to

focus on one student at a time without having to take into consideration the rest of students that would have been present in a traditional classroom, leading to more individualized instruction. The model used by the virtual school to accept students also affected the teachers' perceptions of their ability to provide instruction. The continuous intake model as opposed to a semester-based model resulted in more administrative work and decreased the focus on teaching.

Developing teacher-student relationships online were perceived to be deeper when compared to the traditional environment as students could communicate more authentically online. Students were able to admit when they did not understand a science concept, or could express an interest in science without the worry of judgement from their peers. The participants did feel the lack of a physical student presence. The majority of the teachers had gone into the profession because they enjoyed being around their students. The synergy found in traditional classrooms between students and teachers was minimal or lost in the online environment. This particular lack of student interaction also led to feelings of being just "the teacher" as many virtual schools do not employ sports coaches or offer extracurricular activities. However, the flexibility afforded by teaching online helped to compensate for the lack of student contact. The participants were able to stay at home with their children, they could attend to family scheduling issues, and they were able to teach from any location as long as there was an Internet connection. This easy accessibility was considered a negative, however, in terms of the work hours associated with online teaching. Many students either attended school or worked during the day and therefore they had to complete their online coursework in the evenings and weekend, requiring the online teachers to be available during these hours.

The participants believed that the characteristics required to teach effectively online were similar to the characteristics identified as proving beneficial for online learning. They felt that

teachers who were self-motivated, had strong organizational skills, were good with time management, and had intermediate technology skills would be able to be successful in the online environment. These characteristics were deemed to be particularly important for teachers who taught at virtual schools with the continuous intake model. Not every teacher was considered to be a candidate for the online classroom. Teaching online was viewed more as an art form, requiring much patience, as teachers had to be able to motivate students working in a self-paced environment. All the participants felt they had gone from teacher to facilitator when they transitioned from the face-to-face class to the online class. Much of their time was spent troubleshooting technology issues for students and supporting students who were experiencing trouble completing online work or learning science concepts. As online teachers they no longer lectured to a class full of students, rather they provided resources and assistance based on the needs of individual students. The development of the structure of awareness for online structure effects on teaching and learning appears in Appendix D, Table 19.

Actually I find the teaching online a whole lot easier because I can get teaching done, I can get standards met, I can implement different strategies trying to get students to understand concepts and how things work as opposed to brick and mortar where you spend a lot of your time on discipline and 'herding cats', herd them around. But I feel I can get, I can teach! That time is to teach and I get that. (ST1)

I really really get to know my students a lot better than I did in a traditional setting. I feel like a lot of that is due to the fact that they feel more comfortable one on one. There's not that peer pressure to not want to raise your hand because the cute girl behind you is sitting. You don't want to, you know, you don't want to embarrass yourself in front of her or you don't want to mess up your reputation or anything like that. So you get to know the students a lot better. You get to know their individual circumstances a lot better. (ST7)

I get to teach to every student. It's one on one, aside from my weekly live lesson. I have some kids that need a whole bunch of my time and I have some kids that don't need me at all. They just need me for our discussions before an exam, and that's it. And I can really tailor the work for every student. And in a public school setting, or in a classroom setting, if a kid wasn't able to work for 4 weeks, they don't come to school for 4 weeks,

they're withdrawn. Here we can work with that if there are extenuating circumstances. I do like that they put the student first. (ST5)

Because sometimes I can still be working at 10:30 (*pm*) and 12 (*midnight*). Because you are never away from it. (ST3)

The Structure of Awareness of Teaching Online Secondary Science

The structure of awareness of teaching online secondary science consists of three parts; (a) the overall theme which is comprised of the conceptions of awareness developed above, (b) the thematic field, relating to the broader context of the themes (Gurwitsch, 1964), and (c) the margin, related to the theme and thematic field due to its effect on the overall experience of the phenomenon (Marton & Booth, 1997).

The theme. The theme of teaching online secondary science consists of those critical aspects that were in focus for the participants during the interviews (Marton & Booth, 1997). Seven critical aspects were identified in the interview data: (a) virtual labs and their effect on student learning, (b) the teachers' perception of their students' learning and the factors and student characteristics required for successful student learning outcomes, (c) the primary role communication has in online secondary science education, (d) the social and collaborative aspect of the online environment, (e) the role assessment plays in online secondary science education, (f) how the curriculum structure can affect teaching and learning, and (g) the overall effect the online environment has on teaching and learning secondary science.

The thematic field. The thematic field of teaching online secondary science consists of the structural aspects, both of the internal and external horizons, identified for the categories of description. The thematic field helps identify the broader context to which the theme is applied (Gurwitsch, 1964). For example, one of the broader contexts for the theme of virtual labs and learning is that virtual labs do not allow students to investigate their own questions. The thematic

field for teaching online secondary science appears in Table 10 through Table 15 above under the column heading “*Structural Aspect*”.

The margin. The margin consists of aspects occurring in the background that have an effect on the overall experience of the phenomenon, but are not materially related to the phenomenon. Experiences related to the margin are not included when developing the structures of awareness for the categories of description but they are still present in the interview data. A student’s health would be an example of an experience that is occurring in the margins which could have an effect on the overall experience of learning in an online secondary science course, but is not directly related to the course itself.

The theme, thematic field, and the margin are not clearly demarcated. There can be an ebb and flow between the boundaries as focal aspects change temporally (Booth, 1997). The structure of awareness represents the relationship that the participants have with the phenomenon of teaching online secondary science, particularly in relation to the experience of teaching science in a traditional classroom. This structure provides an understanding of what it is to teach secondary science online, and provides guidance on methods that can be used to improve the experience. Figure 3 below provides a graphical representation of the structure of awareness for online secondary science teaching. Not all of the aspects of the thematic field or margin are represented, due to space limitations. The terms chosen for each segment were based on the frequency with which they occurred in the transcriptions. For example, many teachers talked about the scores on exams as a method to identify student learning, which is described as “data analytics” under Thematic Field. The terms in the Thematic Field can relate to more than one Theme, particularly given the temporal nature of the experience of teaching online secondary education. The terms in the Margin were also topics that were in the forefront of the participants’

minds and discussed by a majority of the teachers interviewed. While the topics in the margin do not directly influence teaching science online, they can have an effect on the overall experience of teaching online secondary science education. As with the Thematic Field, these are temporal in nature and it is not expected that this structure of awareness would prove to be stable.

Figure 3. Structure of Awareness of Teaching Online Secondary Science

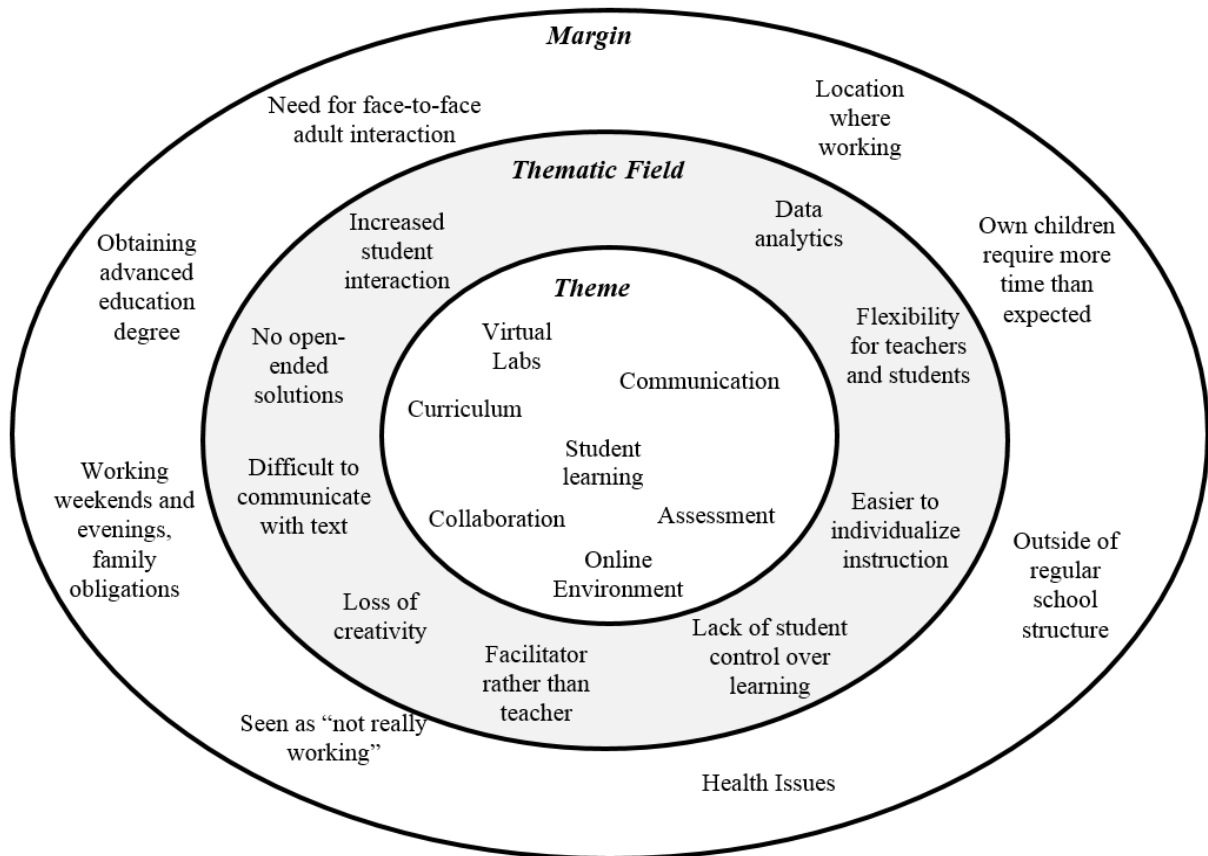


Figure 3. Model of the Structure of Awareness for teaching online secondary science. The aspects of the theme that are in focus can vary based on prior knowledge, links made to the external horizon (Thematic Field and Margins), and time.

Summary

This study sought to provide an understanding of teaching secondary science online by using developmental phenomenography to answer the research questions:

1. How do online secondary science teachers experience their teaching while teaching their courses online?;
2. How do online secondary science teachers experience their students' learning while teaching their courses online?

Seven themes were identified and structures of awareness were created for: (1) Virtual Labs and Learning, (2) Student Learning and Factors Involved, (3) Communication and Instruction, (4) Teaching as Collaboration/Social Aspect, (5) Teaching and Learning as Assessment, (6) Curriculum Effects on Teaching and Learning, and (7) Online Structure Effects on Teaching and Learning. Finally, the overall structure of awareness was created for the phenomenon of teaching online secondary science.

Chapter 5 Discussion and Conclusion

Summary of the Study

This study used developmental phenomenography to develop a holistic view of the experience of teaching online secondary science. This research methodology was used to investigate the phenomenon from a second order perspective, allowing the researcher access to the perspectives of the participants and discovering the qualitatively different ways they understood and experienced the phenomenon. Developmental phenomenography also provides insight as to the variation that exists between the phenomenon and a phenomenon that is similar. For this study the comparison was made between teaching secondary science online and teaching secondary science in a brick and mortar classroom. Ascertaining this variation can provide a clearer understanding of what makes teaching online secondary science unique.

Thirteen online secondary teachers from four states and two countries participated in recorded phenomenographic Skype interviews. The purpose of the interviews was to collect data to answer the research questions: (a) How do online secondary science teachers experience their teaching while teaching their courses online?, and (b) How do online secondary science teachers experience their students' learning while teaching their courses online? After member checks of the transcriptions were completed, the researcher analyzed the data for themes and the structure of the themes. Structures of awareness were developed for seven categories of description: (1) Virtual Labs and Learning, (2) Student Learning and Factors Involved, (3) Communication and Instruction, (4) Teaching as Collaboration/Social Aspect, (5) Teaching and Learning as Assessment, (6) Curriculum Effects on Teaching and Learning, and (7) Online Structure Effects on Teaching and Learning. Finally the overall structure of awareness was developed for the phenomenon of teaching online secondary science. The overall structure helps to identify the

critical aspects of teaching online secondary science (Marton & Booth, 1997), enabling stakeholders to change the way the environment of the phenomenon operates (Bowden & Walsh, 2000).

Discussion and Implications for Online Secondary Science Instruction

RQ1: How did online secondary science teachers experience their teaching? The structure of awareness created from the data for the phenomenon of teaching online secondary science highlighted several critical aspects identified by the teachers. The critical aspects for the experience of online secondary teaching developed from the data were: (a) teacher isolation, (b) the importance of developing technology skills, (c) teacher collaboration, (d) curriculum design affects, (e) communication, and (f) online environment effects. One of the goals of developmental phenomenography is to not only identify these aspects, but to use the results of the data analysis to propose methods or changes that can improve the phenomenon (Bowden & Walsh, 2000). Therefore the implications of the results in regards to teacher education and teacher development will be discussed.

Teacher isolation. The results of this study concur that online secondary science teachers experience various forms of isolation (Hawkins et al., 2012; Techlehaimanot et al., 2013). These feelings of isolation revolved around three areas; (1) the need to have face-to-face interactions with adults, (2) the need to have face-to-face interactions with colleagues, and (3) the need to feel part of the school structure, to play a bigger role than as “just the teacher”. Similar findings were reported by Hawkins, Graham, and Barbour (2012).

Importance of technology skills. Much of the discussion concerning the implementation of educational technology revolves around the theoretical concept of TPACK; technological, pedagogical, content knowledge. The technology skills discussed in this study concerned to the

ability of the teachers to design instructional resources using technology and to trouble-shoot technology issues for both themselves and their students. In face-to-face courses teachers are advised that students can assist them in the actual use of technology (Kopcha, 2012), but the online teacher must be the expert (Comas-Quinn, 2011; Dawson et al., 2013). Students must be taught how to use the collaborative tools for a given learning management system (LMS), or how to format their assignments so that they can be viewed by the teacher. Developing intermediate technology skills was believed to be a priority for online secondary science teachers and the participants felt these skills should be taught as part of teacher preparation programs.

Teacher collaboration. Eleven of the participants felt that the teacher collaboration they experienced at their virtual schools was more robust than the collaboration they experienced at their face-to-face schools. There was a clear divide on this belief based on whether the teacher worked at a virtual school that had multiple science teachers compared to teachers that were the only science teacher working at their virtual school. Those who were single science teachers experienced the teacher isolation discussed above in terms of peer collaboration. Those working at multi-science teacher virtual schools described quick access to their peers through instant messaging, weekly team meetings either virtually or face-to-face where they graded or created lessons, and mentorship provided by their department or teacher leads. These types of avenues for connection are important in order to keep teachers from feeling disconnected from their peers (Hawkins et al., 2012). For those teachers who do not have a formalized support system, developing teacher connections through virtual personal learning networks (PLNs) can help provide that support (Trust, 2012). Teachers can access several social media sites that are designed to promote information sharing, learning, and communication. Today's easy access to videoconferencing software can also provide a way to find and develop an educator PLN.

Teachers have found that the aspects they consider to be valuable in face-to-face meetings can be replicated with videoconferencing (McConnell, Parker, Eberhardt, Koehler, & Lundberg, 2012).

Curriculum design affects. The effect on learning and teacher satisfaction in relation to curriculum design was discussed by the participants. Those teachers who used curriculum created for them, curriculum designed by either the school district or by a third party vendor, felt that this type of curriculum resulted in linear teaching that lacked creativity and provided limited learning options for their students. In some cases, participants at virtual schools which used a required curriculum were able to alter that curriculum to some degree by either adding or deleting content. But even in those cases the timeline of the required curriculum had to be followed, once again resulting in reduced feelings of creativity and teacher agency. The assignments and assessments that were part of the pre-made curriculum were viewed as “busy work” and to be at a “low-level”.

The curriculum source also had effects on the continuing professional development of the online secondary science teachers. Those participants who were required to use a set curriculum found that they were not as motivated to keep abreast of the latest instructional techniques, while those who designed their own curriculum found that content creation helped keep them up to date on new strategies. Some of their professional learning occurred as they searched for new and better resources for their online courses.

That teachers felt a lack of creativity and a reduction of teacher agency was not surprising as science teachers lean towards constructivist beliefs (Haney & McArthur, 2002). Science teachers tend to teach from the students’ viewpoint in order to identify student misconceptions. Therefore the curriculum must be flexible in order to address questions that the students value. Assessments become embedded within this type of curriculum, providing a more naturalistic

approach, requiring that they should be flexible in nature if students are to remain engaged in the content (King, 2006).

Communication. The participants stated that the majority of their teaching time was spent on communication, with some reporting they spent as much as 80% of their time on phone calls to parents and students. All of the participants felt that teaching science online required a greater amount of communication as compared to face-to-face. Computer mediated communication (CMC) and information technology communication (ICT) skills were considered essential. The participants had to be aware that text messages and emails could be interpreted differently from the intent in which they were delivered due to the lack of immediacy and physical cues (Jucker & Dürscheid, 2013). This proved particularly difficult for the secondary teachers as they were used to conveying their personalities through sarcasm and joking, two types of communication that at times came across as “mean” by their students. Some of the participants also expressed difficulty at incorporating language strategies in the online environment for their students for whom English was a second language (ESL), proving problematic given the technical language demands of science education (Lee, Quinn, & Valdés, 2013).

Contrary to having difficulty conveying their personalities, many of the participants felt that the one-on-one nature of the communication allowed them to get to know their online students at a deeper level than their face-to-face students. This mirrors the research on the importance of communication in regards to developing teaching and social presence (Borup et al., 2013; Dawson et al., 2013). In the online environment they were able to spend individual time with their students. The teachers felt that students were able to communicate more authentically as they were not subject to peer pressure and were able to express interest in or

difficulty with the science concepts, thereby sharing their true selves (Marriott & Buchanan, 2014).

Different levels of technology access proved problematic in terms of instruction. Some of the students gained access to their online courses at their brick-and-mortar schools and did not have internet access at home. This required the online science teachers be able to describe the science concepts using just their words over the phone without being able to provide supplementary graphics or visualizations. In this case the participants reported that deep content knowledge was required in order to successfully teach or tutor via this medium.

Online environment effects. The nature of the online environment accounted for both positive and negative teaching experiences. Positive experiences included the ability to focus more on actual teaching as classroom management was not an issue. The participants also felt there was more time for teaching as they did not have to attend as many department meetings, nor did they have to serve on committees. The teachers reported they were able to help students who normally would not thrive in a face-to-face classroom such as those who are homebound or have been hospitalized (Huerta et al., 2014), and that they could spend more individualized time with each student (Archambault & Crippen, 2009). The flexibility for both teachers and students in terms of geography and time was considered a primary reason for selecting to teach or to learn in an online environment (Picciano & Seaman, 2009).

Nine of the participants believed that teaching online did not feel as effective as in the traditional classroom, primarily because it was difficult to determine whether students understood the concepts. The inability to conduct “live” demonstrations or to model science synchronously was problematic as the teachers had chosen to teach science due to their perceptions of its “hands-on” nature and their belief that science learning is active (Driver,

Asoko, Leach, Scott, & Mortimer, 1994). Some of the teachers expressed that it was difficult to get used to not being in the physical presence of their students, while others felt this to be a positive aspect of teaching online. The online program structure could be problematic as well. The continuous entry model made it difficult to group students for learning activities due to the fact the students were rarely in sync in terms of their progression of the curriculum.

Implications for online secondary science instruction. The critical aspects identified from the data in regard to the first research question which focused on the experience of secondary science teaching were: (a) teacher isolation, (b) the importance of developing technology skills, (c) teacher collaboration, (d) curriculum design affects, (e) communication, and (f) online environment effects. These aspects offer guidance in the area of online secondary science teacher development for both teacher educators and school administrators, as well as provide administrators with strategies they can employ to help maintain teacher motivation. An overview of these implications can be found in Table 20 below.

One method to help reduce teacher isolation and provide face-to-face peer interactions, particularly for those online secondary science teachers who do not have colleagues within their virtual schools, would be to help develop or identify blended virtual learning communities (VLCs), which can provide a feeling of social embeddedness (Matzat, 2013). Blended VLCs could provide periodic opportunities for face-to-face peer interactions, addressing the need for more personal contact with both colleagues and adult. Teachers could also be encouraged to participate in virtual educator personal learning networks (PLNs) in order to find support of like-minded peers (Trust, 2012) and to participate in professional development. These recommendations relate to teacher collaboration as well.

To help preservice teachers understand some of the skills required to teach secondary science online, teacher educator programs could provide K-12 online learning experiences as part of their programs (Kennedy & Archambault, 2012). Both preservice and in-service teachers could be given access to technology courses in which they learn to create digital content for blended or online courses. Such courses could incorporate the universal design for learning (UDL) principles in order to help teachers understand how to develop curriculum that will be conducive for online learning (Rose & Meyer, 2002).

Teacher agency was identified as an important component for motivation by the participants. This result indicates that the online secondary teachers require control over the curriculum they teach in their courses (Savasci & Berlin, 2012). There were also indications that feelings of increased agency can lead to the ability of teachers to consider themselves “agents of change” (Robinson, 2012). Many of the online secondary science teachers felt that they were pioneers in terms of teaching in an innovative environment. Administrators and virtual schools could access the desire of these teachers to “lead the way” by including teacher input on the manner in which their courses should be taught.

In terms of communication, helping preservice and in-service teachers understand the nuances of digital communication was of primary importance for the participants. Professional development that includes an understanding of CMC and its overall context in education will alert teachers to effective uses as well as identify pitfalls that may be present (Luppicini, 2007). Online secondary science teachers’ craft knowledge can be developed so that they can instruct and tutor students with limited resources and limited internet access (van Driel, Verloop, & de Vos, 1998). This craft knowledge should include developing the aptitude of the online secondary teacher to recognize students who are linguistically and culturally diverse. Given the difficult

nature of communicating digitally (Luppichini, 2007) and the demands of the scientific language (Lee, Quinn, & Valdés, 2013), online secondary science teachers require a higher level digital communication skills compared to face-to-face teachers if they are to successfully instruct students who are culturally and linguistically diverse from the teacher (Chamberlain, 2005).

The transactional distance teachers felt from their students could be lessened by incorporating video or webcams into the instruction and by limiting the number of students enrolled in an online secondary science course (Wengrowicz & Offir, 2013). The use of synchronous and asynchronous video in online courses has been shown to improve feelings of social presence among online students (Borup, West, & Graham, 2012; Clark, Strudler, & Grove, 2015) but it remains to be seen if this holds true for online teachers as well. The use of video could also address the lack of science demonstrations given by the teachers. Online secondary science teachers could conduct demonstrations synchronously and asynchronously by recording the live demonstrations. Students who could not logon to the course during the live demonstration could access the recorded version at a time convenient to them.

Finally, virtual school districts and virtual schools must consider the impact of high course numbers on the quality of the teaching that can occur. The participants were experiencing increasing enrollment numbers for their courses and felt this impacted their ability to address the needs of all their students. While the researcher found little evidence in the literature to support this claim, the experience of the participants indicates this is an important factor for student learning.

Table 20

Overview of the Critical Aspects for Research Question 1 and Their Implications

Conceptions from the Data	Implications
Teacher isolation/Collaboration	<ul style="list-style-type: none"> • Virtual PLNs (Trust, 2012) • Blended virtual PLNs (Matzat, 2013)
Technology skills	<ul style="list-style-type: none"> • Online learning field experience (Kennedy & Archambault, 2012) • Universal Design for Learning (Rose & Meyer, 2002)
Curriculum design	<ul style="list-style-type: none"> • Teacher agency (Savasci & Berlin, 2012) • Teachers as agents of change (Robinson, 2012)
Communication	<ul style="list-style-type: none"> • Understanding CMC in education (Luppigini, 2007) • Craft knowledge (van Driel, Verloop, & de Vos, 1998) • Demands of the scientific language (Lee, Quinn, & Valdes, 2013) • Cultural and linguistic diversity (Chamberlain, 2005)
Online environment effects	<ul style="list-style-type: none"> • Video to develop social presence (Borup, West, & Graham, 2012; Clark, Strudler, & Grove, 2015) • Video to conduct online science demonstrations • Course enrollment numbers

RQ2: How did online secondary science teachers experience their students'

learning? The structure of awareness created from the data for how online secondary science teachers experienced their students' learning identified three critical aspects of student learning in an online secondary science course. The critical aspects for how online secondary science teachers experience their students' learning were: (a) inquiry and messy problems, (b) student characteristics and the support that online secondary science teachers believed resulted in successful student learning outcomes, and (c) assessment and identification of student learning. As with research question 1, the implications of these results will be discussed. Given that only

three critical aspects were identified, the implications will be discussed as part of the general discussion.

Inquiry activities and messy problems. Regardless of whether the participants developed their own curriculum or used required curriculum, many felt that the virtual simulations available were simplistic and did not allow their online students to participate in science practices (National Research Council, 2011). The teachers did agree that virtual labs could result in student learning, but the learning that occurred was comprised of understanding how to manipulate virtual lab equipment, basic conceptual understanding, and how to follow procedures (Brinson, 2015). Students were led to the answers and did not have the opportunity to work with data they had collected, which was contrary to their constructivist views of the science classroom (Haney & McArthur, 2002).

There are several methods virtual schools, administrators, teacher educators, and teachers can employ to help students develop and investigate their own questions. Free mobile phone applications such as the Physics Toolbox Apps are available that allow students to collect their own data (Vieyra & Vieyra, 2015). Online access to real-time scientific data, including graphics and grade-level lesson plans, is available through sites such as NASA Wavelength (NASA Wavelength, 2014). Using such data exposes students to “messy problems”, requiring that they understand the nature of the phenomenon in order to effectively analyze the data (Martinez & Burton, 2011). Students also have access to science experts via social media and web-based communication, allowing for collaboration and guidance on developing their questions (Martinez & Burton, 2011). Online secondary science teachers would require training with these various affordances in order to use them effectively.

Student characteristics and support. The data for this study replicated the findings of the literature in terms of the characteristics teachers perceived as necessary for effective student learning online (Picciano et al., 2012). Those characteristics include the ability of students to be self-motivated, organized, and to manage time effectively. Other types of student characteristics made the online environment attractive even if that form of instruction may not have been ideal based on online learning readiness indicators (Huerta et al., 2014). Teachers felt they were able to help students who otherwise would not have been successful in the face-to-face environment; students who were in rehab, in prison, or who had families of their own.

The student support structure consisted of tutoring sessions throughout the day, counselors, special education teachers, family liaisons, principals, and parental coaches. Not all of the schools provided these types of supports and many of these duties fell on the teachers, placing time constraints on their abilities to teach. Some of the supports for students included face-to-face tutoring, with eight of the virtual schools providing virtual tutoring sessions. Many of the participants made note that the parent-as-coach was not as successful as the virtual schools envisioned and that secondary students were primarily unsupervised at home. This was reported to be particularly the case when the parent(s) did not speak English. If virtual schools are going to consider parents to be part of the support structure, more effort needs to be made to ensure the parents have the time and ability to supervise their students' learning and that they understand the importance of their role (Waters, 2012).

Assessment and identification of student learning. The teachers experienced difficulty in identifying whether their students were learning the content. In their face-to-face courses many teachers relied on physical cues (Murphy & Rodriguez-Manzanares, 2009) which were unavailable to most of the participants as their students either did not wish to use the webcam

feature or they did not have access to webcams. Some of the participants were able to identify student learning based on speech patterns during telephone conversations, but most of the participants relied on assignments and summative assessments to determine student understanding. In the majority of the cases, no measures were put into place to identify whether student work had been completed by the student. The teachers discussed that this method had flaws as well, given the preponderance of plagiarism that occurs in online courses (Ma, Wan, & Lu, 2008).

One method that could be utilized to monitor student learning would be to incorporate learning analytics. Learning analytics is the “development of exploration of methods and tools for visual analysis and pattern recognition in educational data to permit institutions, teachers, and students to iteratively reflect on learning processes, and thus, call for the optimization of learning design” (Dyckhoff, Lukarov, Muslim, Chatti, & Schroeder, p. 220, 2013). By incorporating embedded formative assessments which utilize feedback loops into the curriculum (Vonderwell & Boboc, 2011), teachers can help students maintain their engagement in the course by providing a pathway for continuous assessment which can help improve student learning outcomes (Beebe, Vonderwell, & Boboc, 2010). These practices connect back to the ISTE Standards (2014) for continuous improvement from technology driven data.

Another obstacle cited in regard to identifying student learning was the large course sizes. Some of the online secondary courses had as many as 200 students. Given the other obligations the teachers faced in teaching online courses, it can be difficult to monitor the data of all the students in the course. Assisting students with self-assessment and peer-assessment could help shift the responsibility of learning from the students to the teachers. Scripts have been shown to promote higher levels of self-regulation, while rubrics and scripts can have positive effects on

student learning (Panadero, Tapia, & Huertas, 2012). Students also gain the added cognitive benefit by identifying their peers' mistakes and providing feedback on possible solutions (Lu & Law, 2012).

Absence of scientific argumentation. One of the interview questions concerned the practice of scientific argumentation in the online classroom. The data demonstrated that this was not a regular occurrence in the online secondary science classroom. One of the barriers noted was the inability to conduct synchronous sessions with students who had very different schedules, or who were in different stages of the curriculum. Similar barriers to scientific argumentation have also been reported by face-to-face secondary science teachers (Hofstein & Lunetta, 2013). This suggests that teacher preparation programs for science teachers may need to help their teacher candidates develop this skill regardless of their future teaching environment. Those teachers who attempted to implement scientific argumentation did so in the LMS breakout rooms, indicating that this was an important skill for online secondary science teachers.

Limitations of the Study

One of the limitations of the study pertains to the number of participants interviewed. This methodology requires at least ten participants to ensure variability of the experience, but no more than 20 due to the difficulty of analyzing the amount of data gathered during phenomenographic interviews (Trigwell, 2000). Therefore it cannot be known if the participants represent the full variation of the experience. There are also limitations particular to phenomenography. Developmental phenomenography does not consider students' prior knowledge and how that prior knowledge may affect their learning or experience of the object of learning. Given that secondary schools use instructional materials from multiple vendors (Miron, Gulosino, & Horvitz, 2014; Watson, Murin, Vashaw, Gemin, & Rapp, 2013), there may have

been unknown and unintended influences that acted upon the object of learning (Bussey, Orgill, & Crippen, 2013). Given that the students may also have attended brick and mortar schools, these students may have received help from science teachers located at these schools. This may have affected the way the teachers experienced their students' learning.

Another limitations for the study is that the answers to the interview questions were subject to context, time, and the individual. Therefore the structure of awareness developed for this study could change were the interview questions to be asked at a later date. However, the variation in the population and analyzing conceptions by group rather than by individual does allow the interpretation to extend to the population (Marton, 1981).

Future Research Indicated by This Study

The analysis of the data revealed further areas for research. Support systems such as coaches, tutors, and parent-coaches that were put in place by the virtual schools were discussed by the participants and have been highlighted in the literature (Watson et al., 2013). However, there are few empirical studies that provide evidence as to which supports, or combination of supports, are effective at promoting online secondary science student retention and learning. Particular attention should be given to investigating the effectiveness of parents as coaches and the types of supports the parents may require to help their students be successful in online environments.

The impact of class-size on the ability of online secondary science teachers to provide quality instruction is also an area for future research. Many of the teachers discussed how their increasing class sizes resulted in a decrease in the amount of quality time they could spend with their students, yet no empirical studies could be found on K-12 online class-size effects on student learning. Search terms "class-size K-12 online", "course size K-12 online", "class-size

K-12 distance”, and “course size K-12 distance” were used to conduct searches on Google Scholar, Academic Premier, and ERIC and no studies were generated. Given that blended and online learning advocates such as Horn and Staker (2011) support eliminating restrictions on class-size and teacher-student ratios for blended learning as a way to maximize blended learning, the effects of course-size on learning outcomes for online secondary science students needs to be better understood. The social-constructivist pedagogy implicit in effective science education has been shown to place constraints on face-to-face course sizes (Anderson & Dron, 2011). Therefore, it is important to understand the effects of course-size on the ability of online secondary science teachers to instruct their students.

In order to obtain a deeper understanding of teaching and learning science online, the current study should be completed with K-12 online secondary science students, online postsecondary science instructors, and online postsecondary science students. This study touched on the fringes of the student experience of learning secondary science online based on their teachers’ experience of their learning. Student voice is required to obtain a better understanding of what it is to learn secondary science online. The differences between the secondary and postsecondary structures of learning science online, such as curriculum control and student choice, could provide further variation with which to define the overall phenomenon of teaching science online (Marton & Booth, 1997).

One area this study sought to explore was how online secondary science teachers incorporated scientific argumentation into their online courses. Scientific argumentation is an important aspect of scientific practices and allows students to develop a better understanding of science concepts as they use evidence and persuasion for making sense of phenomena (Duschl & Osborne, 2002; NGSS, 2013). The participants cited reasons such as lack of synchronicity of

students and non-support in the curriculum for not including scientific argumentation as part of their courses. Investigating the use of audio and video resources to promote scientific argumentation could help address this lack. Affordances provided by asynchronous audio and video may help increase the social presence and group cohesiveness required to create class communities in order to effectively engage in such activities (Kreijns et al., 2003). Teacher-researcher partner action research in this area could help provide evidence for instructional methods that could be employed to incorporate scientific argumentation in the online secondary science course. The margins identified by the research methodology showed evidence of factors that could affect how teachers implement their instruction. These factors may not be known by a researcher; therefore a partnership between the researcher and the teacher could result in a better understanding of actual implementation practices, aiding in the analysis of the data.

A second area of exploration for this study was how inquiry practices were incorporated. A majority of the participants utilized virtual simulations which they found lacked authentic learning opportunities for the online science students. Students were unable to collect their own data or ask their own questions, key characteristics for effective investigatory practices (National Research Council, 2011). As with the suggestions for scientific argumentation, teacher-researcher partner action research could be conducted to investigate three areas: (a) how to help online secondary science teachers implement investigatory practices that use current science databases and student obtained data, (b) how to help online secondary science students develop their own questions to investigate, and (c) how to help online secondary science students use either current science data or their own data for investigatory purposes. This research could also help enlighten the field of online science education in regard to the engineering practices contained in the Next Generation Science Standards (NGSS, 2013). Instructional methods must

be found that help online secondary science students design solutions to problems found during their science investigations.

Conclusions

The results of this study provided data that was used to develop a holistic view of the experience of teaching online secondary science. Understanding this experience allows the education community to identify how to begin improvement in areas such as online secondary science curriculum development, online secondary student and teacher supports, and online secondary science program evaluations. Thirteen phenomenographic interviews were conducted with online secondary science teachers in four states and two countries. The interview questions were designed to determine how online secondary science teachers experience their own teaching and their students' learning. After analyzing the data as a group, seven themes emerged: (1) Virtual Labs and Learning, (2) Student Learning and Factors Involved, (3) Communication and Instruction, (4) Teaching as Collaboration/Social Aspect, (5) Teaching and Learning as Assessment, (6) Curriculum Effects on Teaching and Learning, and (7) Online Structure Effects on Teaching and Learning. Structures of awareness were created for each theme to provide transparency of the researcher's reduction of the data in order to establish that the results were reliable and valid (Cope, 2004). From these seven themes an overall structure of awareness of what it means to teach online secondary science was developed. This structure of awareness, consisting of the theme, thematic field, and margins, identified the critical aspects of teaching online secondary science (Marton & Booth, 1997). These critical aspects can provide guidance on how to "change the way the world operates" (Bowden & Walsh, 2000, p. 3).

Two areas specific to science education were investigated in the online context; scientific argumentation and inquiry practices. It was found that, for the most part, scientific argumentation

did not occur in the online secondary science classroom. The lack of synchronicity of student participation and non-inclusion in the curriculum were cited as reasons for not incorporating scientific argumentation. Inquiry practices were conducted using virtual simulations which did not allow for student generated questions or student data collection.

Implications for online secondary science teachers, virtual schools, virtual school administrators, and teacher educators were discussed, focusing on the need for a more student-centered approach to curriculum development. Areas for future research were identified in which teacher-researcher partners work together due to the nature of the online secondary science environment. The structure of awareness created for the phenomenon of teaching online secondary science is complex and research should be conducted in that context in order to properly analyze the data. Furthermore, there is a need for student data to provide a complete understanding of online secondary science education. Gaining this understanding will allow the education community to ensure secondary science instructional practices follow the guidelines of established science education principles (National Research Council, 2011; NGSS, 2013).

Appendix A

Definition of Terms

Table 1

iNACOL Online Learning Definitions Project Definitions of Terms

Term	Definition
Charter School	Public schools subject to the same, and sometimes additional, regulations as traditional schools. "Charters" are performance contracts specifying metrics to measure success and are accountable to local education and state agencies.
Competency-based Learning	Competency-based learning focuses on student mastery of content. Students demonstrate mastery by acquiring the ability to apply and create knowledge using skills developed as part of their learning objectives. Supports are differentiated and based on the learning needs of the student.
Credit Recovery	Refers to a student retaking a course which he/she did not receive credit for during a previous attempt. The focus is on receiving credit for academic completion.
Cyber school	Cyber schools offer students the opportunity to attend school online on a full time basis. Other synonyms are "online school", "virtual school", and "eSchool". Cyber schools may be charter, private, public, state sponsored, etc.
Full-time Online Program	Another term for Cyber Schools. These programs are subject to No Child Left Behind for assessing student outcomes. These may be charter schools.
Online Learning	Educational content and instruction are primarily provided using the Internet. Online learning is not to be confused with print correspondence courses. Synonyms include "virtual learning", "e-learning", and "cyber learning.
Online School	A state, charter, private, or public entity which delivers full-time educational content using the Internet.
State Virtual School	State virtual schools are created at the state level by the state legislation or other state-level agency. Students may enroll in one or more courses from anywhere in the state. Enrollments can be on a course by course basis and students rarely attend state virtual school on a full time basis, although there can be exceptions.

Table 2

Virtual School Profiles

School Type	Description
State-Sanctioned “State-Level” Virtual Schools	Online schools officially recognized by the state legislature or state governing body as providing, “Virtual school” access to students throughout the state. Examples are Michigan Virtual High School (MVHS) and Florida Virtual High School (FVHS).
College and University-Based Virtual Schools	An example of this type of school is the University of Nebraska. University online courses may be marketed to virtual schools. Independent-study high schools are established by universities.
Consortium and Regionally-Based Virtual Schools	Consortiums may be an intra or interstate combining of resources between smaller virtual schools or public schools. Cyberschool (Eugene, OR) and the Colorado Online Consortium are two examples.
Local-Education Agency-Based Virtual Schools	These schools provide supplemental online resources to students attending traditional schools.
Virtual Charter Schools	Examples are K12 Inc., generally used by homeschoolers. Run by regional education agencies. May be non-profit or for profit.
Private Virtual Schools	One example is the Christa McAuliffe Academy. Many of these are not accredited and target homeschoolers. They are non-profit.
For Profit Providers of Curricula, Content, Tools and Infrastructure	Examples are Apex Learning and Class.com. These companies provide course materials.

Appendix B

Summary of Implications for Online Secondary Stakeholders

The following tables provide summaries of the implications discussed in Chapter 1 for online secondary stakeholders.

Table 3

Summary of Implications for Online Secondary Education for States, School Districts, and Administrators

Implication(s)	Literature
Provide more fully for needs of students.	Huerta et al., 2004 Picciano et al., 2012
Online credit recovery	Tucker, 2007
Access to courses/highly qualified teachers for students living in rural areas	Irvin, Banks, and Farmer, 2009
Individualized learning, access to more courses, address overcrowding of brick and mortar schools	Watson et al., 2013 Huerta et al., 2014
Can provide education for students with limited access to brick and mortar schools.	Huerta et al., 2014 Picciano et al., 2009
Students enrolled in online courses might be better prepared to take computer-based assessments.	Picciano et al., 2012
Students enrolled in online courses might be better prepared to take online college courses.	Huerta et al., 2014
There are concerns about the quality of online courses due to decentralization and multiple vendors.	Miron et al., 2014 Watson et al., 2013
Few empirical studies providing evidence of supports and structures required by adolescents to be successful online learners.	Tucker, 2007 Cavanaugh et al., 2009 Huerta et al., 2014
Online learning research focused on higher education population; not much known on how adolescents learn online.	Cavanaugh et al., 2009
Issues of equal access and the digital divide; unequal across SES.	Tucker, 2007 Watson et al., 2013 Holloway et al., 2013

Recruiting and preparing teachers to teach online.	Kennedy & Archambault, 2012 Miron et al., 2014
Research has not identified skill set required to help students learn effectively online.	Anderson et al., 2006
Most teacher education programs do no address development of online teaching skills.	Kennedy & Archambault,, 2012

Table 4

Summary of Implications for Online Secondary Education for Teachers

Implication(s)	Literature
Most research on how people learn online conducted at post-secondary level and cannot be generalized to K-12 population.	Borup et al., 2013
Must be able to chunk content in small pieces to help lessen online student anxiety.	Borup et al., 2013 DiPietro et al., 2008
Must help maintain student motivation. Present material in multiple ways, access course frequently to ensure students know help is always available.	DiPietro et al., 2008
Must have a higher degree of educational technology knowledge and higher education technology self-efficacy in order to keep up with a constantly evolving environment.	Comas-Quinn, 2011 Dawson et al., 2013 Liu & Cavanaugh, 2011
Must facilitate discourse in order to create social climate; develop online communication skills for selves and students.	Borup et al., 2013 Dawson et al., 2013 Garrison et al., 1999
May develop feelings of isolation and loss of teacher identity.	Borup et al., 2013 Teclehaimanot et al., 2013 Hawkins et al., 2012
Can work with students on an individual level as they do not have to spend time on behavior or classroom management issues.	Archambault & Crippen, 2009 Tucker, 2007
Can extend teaching across time and geographical boundaries, allowing teachers to continue working when they may otherwise have had to discontinue teaching.	Tucker, 2007

Table 5

Summary of Implications for Online Secondary Education for Students

Implication(s)	Literature
Few empirical studies examine learning outcomes for online secondary students.	Cavanaugh et al., 2009 Means et al., 2009
Doubts about quality of online credit recovery courses; created to increase graduation rates. Students requiring credit recovery may not be ideal candidates for taking online courses.	Queen & Lewis, 2011 Picciano et al., 2012
Increase access to more courses and highly qualified teachers.	Cavanaugh et al., 2009 Rice, 2006 Huerta et al., 2014
Students felt online courses offered greater flexibility on assignments.	Bolstad & Lin, 2009
Ability to go at own pace.	Tucker, 2007
Online students demonstrated greater gains in creative thinking, critical thinking skills, decision making skills, and time management skills.	Bolstad & Lin, 2009 Cavanaugh et al., 2004
Online learners demonstrated less improvement in speaking and listening skills.	Bolstad & Lin, 2009
The difference between adult and adolescent online learning is not well understood.	Cavanaugh et al., 2009 Picciano et al., 2012 Roblyer & Marshall, 2002
Must develop self-regulation and self-motivation.	Picciano et al., 2012 Borup et al., 2013
Adolescents may require more social structure; effective and frequent communication from teachers and/or student-student interaction in order to not develop feelings of isolation.	Borup et al., 2013 Bolstad & Lin, 2009

Appendix C

Categories of Descriptions and Representative Passages from the Data

Table 6

<i>Categories of Description and Representative Passages for Virtual Labs and Learning</i>	
Categories of Description	Representative Passages
(1) Preference for “hands-on” lab experiences	[01:54.7-03:13.4] ST9 . Part of why I went into science, I love the hands-on nature. I used to take students to the (location in US) to scuba dive and check out coral reefs and so it's definitely been an adjustment.
(2) Virtual labs as more accessible/flexible	[01:54.7-03:13.4] ST9 . But with our population too a lot of them are in and out of rehab, they're having babies, they're doing other things so this fits really well with them.
(3) Lack of student collaboration on inquiry activities: lack of social skills, scheduling, content knowledge	[02:48.7-03:13.8] ST7 . And then their social skills, some of them are not, some come to us because they don't want any interaction with kids. So they don't want to talk, they don't want to use the microphone... I have tried to do, I did a couple of field trips when I taught earth science but it's hard because all of our students are all over the state so even trying to provide some hands-on opportunities isn't really consistent because our students are spread out and they have, a lot of them have kids or jobs that prevent them from attending those things anyway.
(4) Online labs have fewer classroom management issues	[18:24.1-19:20.8] ST2 . the labs are really, they're a lot easier to manage online. I mean, there aren't people chasing each other with dead rats or trying to cut off the head of a cat. [brick and mortar school name]. People aren't trying to poke each other with scalpels or just running around with glass...it's just a little bit safer.
(5) Simulations are “cookie-cutter”, closed ended, not authentic	[04:36.8-07:58.8] ST10 . The virtual labs have also been a little bit of a challenge...But the virtual labs, I find, it's really hard to find virtual labs that are authentic in the sense that they contain some openness for mistakes. They tend to be very generic and very like one pathway to the right answer kind of deal.
(6) Cannot conduct labs “on the fly”	[47:53.09-49:47.0] ST4 . Those opportunities to do cool stuff aren't really there. I would get potassium and I would explode it because I like doing that! So you can't obviously do that, you know. In a private school I'd be like off the fly let's go, we're going to do acids and bases of food. So tomorrow you need to

bring in your favorite food and we'll have a food party and we're going to test the acidity. Obviously you can't do those things. So that changes obviously

(7) Students enjoy simulations because they are computer-based

[13:43.3-15:35.4] **ST9.** So I think it's more, this generation loves the computer and they're very savvy at it and they feel comfortable with it and they do some really good work when they do engage and take their time and learn some cool concepts.

(8) Lack of engagement due to lack of "hands-on" experiences

[34:19.6-34:55.9] **ST1.** Yes, in that those who are hands-on or kinesthetic learners and need it, like me. If I had to do it I would be just like "oh scratch that, big deal". But to actually see it and do it and touch it, I need that tangible, you know. For me I need that hands-on. So... Oh, and the acid, when we are doing the acid test so there's bubbles on the video... But to do it live, it's just, it sends that awe effect.

(9) Virtual labs have dependable outcomes

[22:14.0-24:43.0] **ST4.** The advantage I see for that is that there's a pretty low margin for their error. I used to try to do phase diagrams, like the phases of water, and have them do the data, and their data was always wrong. You know it just leads to a lot of frustration and self-efficacy is not there, and a lot of that stuff. So it kind of eliminates that.

(10) Simulations as scientific skills practice

[21:17.2-22:34.0] **ST10.** They're a little more cookie cutter perhaps in their answers, not a lot of variation. Just some ways for students to actually practice some of the skills even if they are in somewhat of an artificial way.

(11) Liability issues with kits

[38:12.3-41:07.4] **ST13.** We no longer send lab kits to students' homes. They are under 18 and cannot sign the liability waiver, and the parents are afraid to sign them as well.

(12) Use of virtual labs leads to student learning

[20:26.7-12:42.8] **ST2.** I think they're still effective. I actually think they might be a little more effective online as there isn't... Like there isn't the goofing around with all of the kids everywhere and they don't really know what they're doing. And they are just like putting stuff everywhere. And in a virtual lab you can't do that, no it won't let you do that. Why? Why won't it let you click on that? Why won't it let you pour it there? And then you have to go back to the reading. Why won't it let you do that? So I feel like they are more effective. I mean the experience is different but the learning is definitely, I feel, more effective

Table 7

Categories of Description and Representative Passages for Student Learning and Factors Involved

Categories of Description	Representative Passages
(1) Perceived required students characteristics for online learning success	[38:04.2-38:51.9] ST1 . You can definitely learn online. It's not for everybody. You really have to be self-motivated and have very good organizational skills. Time management is huge because the students do have blocks of time to attend their 6 classes a day...they don't have the teacher, like in the classroom, on top of them saying "you have to get this done you have to get this done."
(2) Online population includes students with issues that prevent them from succeeding in f2f environment	[05:06.1-05:52.2] ST9we have certain requirements to be in the alternative high school. They have to be deficient in credits and then have some kind of major issues to, you know, drugs. A lot of them choose to come because they are behind in credits but they have to meet some kind of, I forget what the other requirements are, but deficient in credits for sure. Kind of behind. Many of them, I said this is kind of their last chance.
(3) Supports believed to be required for online learning success	[05:59.8-06:58.4] ST9 . Well, we have a lot of special ed students so we have a special ed teacher that works with us and she's really helpful and she'll go over labs and things with them too and come to class so she's listed as a teacher as well so she has access to everything I see. So she's a great support. We have our counselors, and then we have what are called family support liaisons.
(4) Belief that students can learn science online	[04:00.6-04:41.3] ST11 . The experience is good though. The interaction with kids during the live sessions, it can be really positive and the ideal situation, but then you also have problems and blockades that you face as an online teacher. But the experience overall as a whole, I feel like it is an effective way of learning, overall.
(5) Difficult to identify student participation during tutoring and live lessons	[04:45.9-06:13.4] ST11 . Like I have a kid in my senior project class, he'll log on and I'll try to communicate with him and he's clearly just left, not paying attention whatsoever.
(6) Online students require more motivational support from teachers	[39:03.4-41:05.6] ST7you have to have I would say very good motivation skills. Because a lot of times, because it is self-paced, kids don't want to work...But

	<p>helping them to kind of see the big picture and that it's not about this one assignment, it's about you getting this grade and you doing what you can do so that you can progress later on in life. This is about the future.</p>
(7) Difficult to identify student learning	<p>[26:51.4-27:53.5] ST6. It's very difficult to decide whether your student is grasping the material. Most of the time it's not, not being with them, not being physically with them, because you can't accomplish this, it has to be very well designed. But it comes down to what assessments...And when their proof of learning is a very poorly designed assessment, then how do I really know whether they are just parroting back information to me, or they're really digging deep and understanding. I don't necessarily know. They can even pass the course with an A and I won't 100% know if they really understood.</p>
(8) Students can be more authentic in the online environment	<p>[21:21.7-23:26.0] SC9. ...I almost feel like it's a safe environment so they share things like "I've never been good at science". You know, they wouldn't say this in a classroom but they'll share this with me in an email or like in a private session like "I've always been terrible at science and I'm doing better".</p>
(9) Online students can fake understanding	<p>[03:35.8-03:46.2] ST3. Whereas online I'll ask them if it makes sense. They can type in "sure", but at home they're going (<i>ST3 makes a confused facial expression</i>). "I don't get it, I don't get it, but I'm going to type 'sure' so she'll stop buggin' me".</p>
(10) Identify authentic student learning by knowing student voice and writing style	<p>[34:07.6-35:14.5] ST7. You get to know their voices, you get to know their tone and their pauses. And you can tell when they start to ramble. If they start to ramble and they're kind of starting to try and make sense of something that's not making sense, that's kind of my indicator that I stop and I say "let's backtrack a little bit, let's go back to what you said first. Now why do you think that might be the case?" Or "what's going on with that?"</p>
(11) Teachers must be able to anticipate confusion since not physically present with students	<p>[33:24.3-35:12.4] ST10. ...you do have to anticipate a lot more confusion a priori I guess online. So I've really tried to work hard to figure out where students might go wrong. Anticipate that and try and either include, either some direct, you know addressing misconceptions directly through some text or getting them to explore that a little bit more. Whereas in a classroom that's a little bit easier to</p>

	address, right, you can kind of do that on the fly. You kind of have to pre plan your misconceptions online.
(12) Lack of social learning for online students	[20:03.5-20:34.9] ST1. I guess the virtual student really has to be a little more self-motivated to learn the concept, um, and being that they are usually isolated in their own house as opposed to in a classroom where they can discuss with other students
(13) Importance of structured home life for student learning online	[34:07.6-35:14.5] ST7. The parents that are very very involved, even if they struggle for a little bit, if they have the support at home they tend to do very well. The ones that mom and dad aren't necessarily in the picture or maybe they're worrying about whether or not they're going to eat tonight or you know that kind of thing. We definitely get them through it but it's definitely a, I think they would do better in the brick and mortar setting.
(14) Ensuring student is the one doing the work	[32:42.0-33:30.3] SC8. Here's the deal, kids, we ask them personal questions before we do the DBAs. What's your mom's name, what's her phone number, what's your address, what's your birthday, what's your user name? We ask them of our students when they are on the phone for the DBAs so ideally we've identified who they are... The DBAs are crucial for online academic integrity and their work.
(15) Online learning not for every student	[45:42.0-46:44.0] SC4. ...not everybody does well. Some students, it's amazing. But some are just like, no. So I would say it's on the individual student. So some students thrive at it, like they love it. Some, it just doesn't, it just doesn't mesh well with them.
(16) Teachers do not feel as effective in helping students learn online	[01:44.9-02:17.8] SC5. I just don't feel that I'm as effective as I am in the classroom. And I'm not sure, to me, if the kids get science. It's more, there's someone that cares about them. I feel that I reach more kids that way (in the classroom) and virtually it's very hard to get a feel for that.
(17) Parents as coaches for high school online students not successful	[13:29.5-14:14.8] ST3. So it would have to be a parent (as learning coach) which is an issue I am seeing with the high school in that by the time they are in high school, the parents are out the door, both parents are working, so there is no learning coach. They are on their own. Parents

assume they are on the computer all day long. Which they probably are but not for school. And so that's a problem.

(18) Online learning provides more challenges and resources for students, breaks down geographical barriers

[48:03.3-49:10.0] **ST8.** It's another opportunity for the students who want to achieve and do more and aren't being challenged...And being able to learn online, it opens doors to kids in big cities and little cities so where they're born and where they're located is not limiting their ability to learn and their desire to find out information about these things.

(19) Difficulties for ESOL students due to text-based nature of online learning

[31:01.4-33:23.4] **SC3.** It's basic, and start off with a lot of vocabulary, use a lot of concept maps, use a lot of visuals, a lot of our students a good visual helps. Less words in your topics, more pictures for them to get that connection and stop assuming that everybody knows the easiest vocabulary

Table 8

<i>Categories of Description and Representative Passages for Communication and Instruction</i>	
Categories of Description	Representative Passages
(1) Using conversation to personalize instruction and assessment	[9:21.2-11:03.3] ST7 . So I'll ask them things like "what are you interested in?", "what was your favorite course?, why?", "what do you like to do with your spare time?" and that kind of thing. And I write all of that down so every time I talk to that kid on the phone I'll bring out my notes on what they said and I'll kind of reference that. So I can also tailor what we call our DBAs, discussion based assessments, which are essentially oral quizzes.
(2) Must be able to teach with just words (no visuals)	[10:38.5-11:28.7] ST8 . I think it's made me a stronger teacher because I'm not face to face with kids now unless I go live into my online classroom. I have to be able to have the words to describe and explain topics where normally I could sit down with a student in the classroom and pull out a piece of paper and draw pictures and have those, there's a visual. A lot of the times that stuff I have to do now is on the phone and I have to be able to use my words in a way that I can depict information or share information in a way that they can understand it.
(3) Digital communication can be difficult, lead to misunderstanding	[3:31.7-4:03.7] ST2 . The way you communicate with the students is different. Because in a classroom, I can say "hey everybody, it's going to be a great day", but in a chat box, because of the way they read it, it can be completely different. So a text message or a chat or an email the way I say it can be completely different from the way they read it so I have to be careful of how I word my emails or my chats.
(4) Include personal communication, not all school focused, develop relationships	[06:38.4-07:33.0] ST3 . I always try to ask "Hey, what did you guys do over the weekend?" to get that communication going. And they usually seem to enjoy that. Now last year we gave them a little bit more time, this year we've shortened it, but we even provide them time after class so... Even during class I'll ask certain questions, try to engage all of them. Encourage all of them.
(5) Teachers get to know students better in online environment	[06:59.5-09:04.0] ST8 : When you are talking to students on the phone, you usually have their undivided attention. There's none of this classroom pressure of being cool or

	saying anything stupid or... The student is able to really say, speak freely what is on their mind, what is their thoughts because there's no peer there to laugh at them or make them not want to say anything. So the student has the freedom or comfort to actually communicate with me without any type of repercussions that way.
(6) Difficult to get students to communicate with one another	[14:04.2-14:32.4] ST1. I mean, the communication part is probably the biggest (negative), having them interact and communicate with each other. Like the think-pair-share but you can still implement the wait time and...
(7) Difficult to communicate meaning to students who are low-level ESOL	[14:47.4-16:52.9] ST7. ...we have a lot of kids in (city name) that are very very low level ESOL kids...And in this particular setting because so much of it is self-paced, with Biology being very vocabulary heavy, you know, course, it's very hard for them to grasp that information when they don't even know what the word dinner means. You know, that's a little harder in the online setting than the brick and mortar setting.
(8) Asynchronous communication allows for more reflective feedback.	[12:51.7-`5:51.7] ST10. in a sense being online allows you to reflect more. When you're face-to-face and people have questions you kind of have to be on the ball, you have to "be there" in that moment whereas with online you tend to be able to take a step back, you can reflect on what you want to say.
(9) Difficult to communicate when not in physical presence of student	[25:53.9-26:21.1] ST1. ...have teachers get used to not being able to see their students. Learning how to communicate with them in a different way because you cannot just pull a kid aside and talk to them in the hallway after class. You can virtually but they can also just hit the button and disappear.
(10) Majority of teaching time spent on the phone contacting students and parents	[29:14.9-30:41.1] ST5. So we have to call because they haven't worked, a week or longer. We have kids during the grace period, when they're activated in the class there's a 2 week trial period. They have to do a certain amount of work during those 14 days with a certain grade, maintain a certain grade. If they don't they're withdrawn. You have to call them 2 weeks in a row and offer your help. And then we have monthly calls. Another thing I like is that I talk to all the parents.

(11) Importance of audio instruction to complement text	[29:30.1-30:00.1] ST6 . Even just repeating the material in a non-creative way, the audio input helps. That's most definitely is necessary. Even if it's poorly designed and awful, it needs to be done. It's that extra mode of information for the student. It's not just a repeat. It's having the audio and visual information, it's very important. For any online student.
(12) Use of webcams to increase physical presence	[21:27.0-22:22.1] ST7 . But I like to do it where they see me, at least, and if they have one I ask them to turn it on. So that way not only can I tell what the group is, you know that they're not on Facebook the entire time, but at least that way I can also see them, also read their facial expressions, and look and see where, you know when you're in a classroom you can look and see and know when they're confused.
(13) Feeling overwhelmed by flood of emails and phone calls	[11:27.8-13:28.4] ST2 . I was just so overwhelmed with the conversations from teachers and students and... Like conversations I mean emails and chats and phone calls. So just all the different conversations. So they can come to you, like BWAH (sweeping motion with hand) all at once. Like having a whole school just telling you...You're in the front of the stage and they're telling you "hey do this hey what's this" and you have to like answer them as you go. So I was so overwhelmed because I didn't know how to handle that.
(14) Communicating with students in their world, increase teacher availability	[04:30.2-09:05.9] ST7 . I never texted my students when I was in the brick and mortar classroom... You're always told there's boundaries... But when you are in this environment I have a separate work phone and all that so you get that availability of what's easy for them so you kind of enter their world... And they can feel like they can send a text at 10:00 at night and if I'm awake I'll reply and if not then I get back to them in the morning.
(15) Difficulty communicating with parents who do not speak English	[21:50.0-22:27.6] ST11we have a lot of students where the parents don't speak English. The kids do. So it's really difficult because if they want to they can hide behind that. And if we're not constantly on it to get a Spanish speaking person to communicate with that parent. The kid's telling the parent, "I'm doing all my work, I'm doing all my assignments", when in fact they're not. So that's a negative thing.

(16) Difficult to build rapport with student due to lack of physical cues	[27:21.0-27:42.2] ST1. Probably because they could see me, my personality, you build that rapport. You do kind of online anyway, it's so distant. I don't know, face to face is so personal and doing stuff chat is just not very personal.
(17) Importance of teachers understanding how to communicate online	[44:14.4-47:09.5] ST7. I would say a communication course...almost a parent communication course or a student communication course. Where you learn to effectively communicate with parents and students. Because you are doing that a LOT more online than you are in brick and mortar classes. You're not just sending home a letter in their folder, you're spending 30, 45 minutes, an hour on the phone with these families coming up with personalize pace plans, talking about how to manage your dying father with still sticking it out with school.
(18) Importance of proper phone intonation	[37:52.9-43:05.0] ST8. tone of voice. Delivery of bad news in a way that is compassionate. Because when you're on the phone with somebody you can have the most sincerest heart, but if you say "yeah I'm really sorry your mom died" (said in a very neutral tone, half heartedly). You don't believe what I'm saying if I say it like that. You have to, you know, you have to have that tone in your voice to really express what you're feeling. They can't see your face. They can't see the sincerity in your eyes or the sadness in your face. So phone etiquette, tone, communication skill would be huge...
(19) Provide lots of positive feedback	[29:28.5-29:45.2] ST2. Yes. A lot of exclamation marks and a lot of smilies. A lot of positive feedback like "oh that's so good", "good job", "GREAT", "WOOHOO", lol
(20) Understanding what makes for effective communication and presentation	[36:40.5-40:39.1] ST10. ...if you're doing screencasts or something like that, presentations, or oral skills that you get an opportunity to develop that or maybe have some discussions about what makes an effective communicator. Because I think we just assume that since teachers are teachers they're good communicators online and that's not necessarily the case.
(21) Difficult to communicate with all students due to large class sizes	[25:45.3-27:25.0] ST7. I think what also suffers with that many students is that the students lose the feeling that they can call and text you when they have trouble. It

becomes more of the feeling that you have to make an appointment, which there's really no way around it on my end because you have so many students. But it does, it's a little more difficult for the students I think.

Table 9

Categories of Description and Representative Passages for Teaching as Collaboration/Social Aspect

Categories of Description	Representative Passages
(1) Great amount of support from peers and administration	[14:11.0-16:02.5] ST8 . So in online schools everybody is readily accessible, willing to help, answer questions, not holding back. We share our information because our desired outcome is the best for our students and if that can happen by us working together, collaborating, sharing, then that's what we'll do.
(2) Isolating working alone from home	[4:44.0-5:23.9] ST5 . It's very isolating. [27:11.7-29:17.5] ST5 . Because I'm not in a classroom, I don't see people all the time.
(3) Isolating for students	[09:24.4-10:09.7] ST1 . We open up the chat room and let the kids chat back and forth. There's a few who will partake of that. It's just, I don't know. It just seems so isolated when it comes to the social part for our students.
(4) Unable to collaborate with other science teachers, need skills to develop virtual PLN	[27:11.8-28:42.5] ST9 . And just collaborative, you know, I wish I could collaborate with other science teachers that were teaching the same labs. They don't have that...So to be able to have a network, you know, if you were facilitating some teachers, just to keep that group to be able to share ideas...
(5) Only science teacher at virtual school.	[27:11.8-28:42.5] ST9 . We have a virtual high school but they do different things so I don't really feel like I have a, I'm like a lone teacher.
(6) Participate in virtual PLNs	[28:09.7-28:57.2] ST6 . Say that in a PLC in a school we would get together with you teammates and work on designing a lesson. I do the exact same thing with a group of teachers but instead of meeting in a physical building it would be online and the same thing is accomplished. All of the interactions between teachers in an online environment is written messages or it's online.
(7) Develop f2f relationships outside school environment to fight isolation	[40:27.0-41:00.2] ST1 . I have made sure that I have a group of friends that I meet up with once a month and go out to dinner. I am in book club so we meet once a month. Yeah, it's kind of, it's just different because I am very social so I call my mom a lot (laughter). But it is different. I, I don't know. I miss

the classroom but I like being home with the little one. Pros and cons.

(8) Meet peers face to face

[26:14.6-27:38.3] **ST5.** There's a group of us that meet for coffee every Wednesday, we grade.

(9) Need to communicate with person f2f rather than through technology

[11:27.8-13:28.4] **ST2.** I was just kind of tired of technology and I would just turn off the TV after I was done teaching, turn off my phone, I needed to talk to somebody. So I would go to the grocery store and make conversation with the meat guy. And say "hey, how do I season the salmon?" I just needed that.

(10) Feeling as though there are no coworkers

[35:20.0-36:24.0] **ST4.** Working from home sometimes not being very social. But that's my own fault, I could fix that, I could do stuff for that. There's no...it's like I don't really have coworkers.

(11) School conferences allowing online teachers to meet f2f

[41:14.7-42:36.2] **ST7.** We have the f2f conference once every year. So we get together for a couple of days and everybody will be in (city name) and we do that.

(12) Online as a nurturing environment for teachers

[23:41.3-24:28.8] **ST11.** Overall it's a positive experience, I love it. I've gotten to know my colleagues over the couple of years that I've been here and they're great. It's a caring, nurturing environment. Like the teachers, the staff, everyone's like really supportive and all that.

(13) Missing conversation with adults

[16:07.9-18:14.1] **ST8.** Well, I think I miss the one on one conversations with adults.

Table 10

Categories of Description and Representative Passages for Teaching and Learning as Assessment

Categories of Description	Representative Passages
(1) Teachers identify understanding by reviewing student work	[13:06.3-14:10.0] ST8because my students tell me they have a better understanding and I see that reflected in the work they then submit after we talk about , what they talk about lessons or labs or quizzes content. After we re-tutor and remediate I see the outcome of our discussions and the improved work performance.
(2) Verbal assessment strategies to probe for student understanding	[46:50.0-47:44.0] SC4 . And then obviously looking at their assignments and just how, listening to those verbal clues, that they say...So that's just more like, you have to have that ability to read the student when you're talking to them...I'm doing a DBA and I know this person is reading word for word off his notes. This kid has no idea what he's talking about because I can follow up with a question that probes deeper, and there'll be like, silence.
(3) Difficulties with plagiarism in online environment	[22:56.1-23:13.3] SC12 . It's really hard to know "did they get it" based on the exam scores because they can Google all the questions.
(4) Strategies to defend against plagiarism	[23:15.8-24:00.4] ST5 . So a lot of times they'll Google the question and the answer and can find, and they know to choose that way. But again, one thing I didn't think I would learn, I would be able to do online, is to know how my kids are. And reading responses I know if that kid wrote that.
(5) LMS features used for formative assessment	[24:05.9-24:26.6] ST9 . Yeah, just you know, like the green check, red check, chat, private chat, like "do you understand this". And if somebody doesn't reply you kind of check on them that way to see if they're understanding.
(6) Interactive features to provide feedback to students to identify need for further review	[24:03.7-26:52.2] ST9 . And they even get instant feedback with the computer generated score. They know, did they get it, did they not get it? And then they have to email me if they didn't get it and get it reset and I can go over, "okay, well you missed these two questions, do you understand that"? And that kind of just streamlines where they're at, what concepts they might need to review.

- (7) Reduce barriers that lead to plagiarism [30:27.5-32:24.9] **ST10**. And I think I find kids usually cheat if there's specific reasons, for specific reasons. Like for example if they don't feel competent. Then they're more likely to cheat. Or if they've gotten behind they're more likely to cheat. So I think if you can address some of those barriers, then you eliminate the need to cheat.
- (8) Formative assessment during live lessons [12:52.1-14:39.2] **ST11**. And then I ask questions during the live sessions, for those any who respond. And that's a good, informal quick way of assessing if they know what they're doing.
- (9) Need to develop peer and self-assessment strategies for student-centered learning [41:04.4-43:06.0] **ST10**. And certainly I've noticed that even with myself when we went to continuous intake model I scaled back some of my more collaborative and more inquiry based stuff. Simply because I felt like I didn't have the time to guide students as much as I would have liked. But to, maybe, think about assessment, to look at different ways of assessing, or helping students assess their own knowledge.
- (10) Difficulty getting students to complete assignments [24:48.9-27:47.9] **ST11**. As far as the labs go, I found that my students, they don't turn in assignments, if it's not... A lot of my assignments are quizzes, which is sad to say. Because they won't do, a lot of my kids will do the quizzes but they won't do an assignment that they have to read through directions and use these other essential, like, skills.
- (11) Easy for students to fake understanding online [16:03.1-17:09.3] **ST2**. There's the formative assessment, raise your hand, do this, but I just don't know because I can't see their puzzled look or their lost. They could raise their hand, they could give me a smiley, a thumbs up, I just don't know if they're truly learning it or not. It's harder for me to see. So I don't know.

Table 11

Categories of Description and Representative Passages for Curriculum Effects on Teaching and Learning

Categories of Description	Representative Passages
(1) Spend time helping students rather than creating content	[04:53.0-06:50.1] ST8 . So the online textbook or whatever you want to call it, lessons that they put together, are really done well...PowerPoints, guided notes, there's all of these awesome things put together to help teachers teach students. So now what I need to focus on is not so much creating this document or making this thing...I get to talk to the student now and help them understand concepts when they need my help.
(2) Must teach incorrect content	[06:04.9-06:34.6] ST5 . Some of the curriculum is wrong but I still have to teach it that way because that's what the test is on.
(3) Low level assignments/assessments	[06:50.9-07:13.9] ST5 . The assignments are an insult to their intelligence, it's busy work. And that's frustrating, they're not challenging at all.
(4) Does not feel like a teacher, reinforcing others' content	[12:49.4-13:35.9] ST9 . My teaching's just more going over somebody else's lesson. I just support, I don't really feel like I have a lot of flexibility or freedom.
(5) Teachers believe students need human element, something of teacher, in curriculum	[06:56.3-8:31.0] ST6 . That human element there. I mean, that is a very big challenge...But at least, that's the big point here, you can never teach an online course like this by having absolutely no "part of yourself". With no instruction that you designed, that you facilitate.
(6) Must teach curriculum in linear fashion, no time to review old material	[16:03.1-17:09.3] ST2 . So this is the schedule, we're gonna learn A Monday, B Tuesday, C. And in a brick and mortar class it's let's learn A on Monday and then hopefully we'll get to B. If not, then we can readjust to bring us back from A to B.
(7) Teachers take turns creating lessons	[23:57.3-25:50.0] ST13 . I've developed the Biology course twice now because we had a curriculum change a couple of years ago, two years ago, so I've developed it twice. Though I'm really responsible for developing the lessons and the structure, and populating it with whatever, you know, materials I sort of see fit.

(8) Must know current premade curriculum	[37:52.9-43:05.0] ST8go through the course material. Like I've gone through every module and every lesson and every lab and I've taken notes. So I have done the course. I know, because I have to be very careful what is my student getting in the online course versus what I used to teach in my classroom. So it may not be the same things. So one, whatever course you're teaching go through every module, every lesson, take notes so you know what your students have done or are expected to do so you know the expectations of them and what they're performing in their labs and their assignments.
(9) Premade curriculum as limiting	[37:06.8-38:22.7] ST5 . It's very limiting and it's hard. I think if they could, if they would give us a little more freedom to teach.
(10) Labs based on premade curriculum, students unable to generate own questions	[10:58.1-12:42.8] ST9 . I mean the labs are set for us, I don't create my own labs whereas we used to have more open-ended, or... I taught higher level science too. They would design experiments and you know you kind of provide them with the framework but they come up with their own questions and you kind of help them that way.
(11) Premade curriculum does not provide individualized learning opportunities	[12:49.4-13:35.9] ST9 . I don't really feel like I have a lot of flexibility or freedom. You know we buy the curriculum and the way things are set up, we just got a new platform so it's hard to deviate, you know, to modify them a lot. So I feel like I'm just more of a facilitator just using my knowledge to help them improve just some general.
(12) Teachers lose interest in PD, focus on online learning and not content area	[17:06.3-17:35.5] ST5 . they offer so many development opportunities but it's only geared toward virtual learning whereas I'm used to going to like... I did a research project with Cal Tech and NASA that took a few years. So I like to do space stuff and go outside of school and bring it back. But they don't really encourage that.
(13) Flexibility to teach during live lessons/tutoring	[28:09.8-28:34.4] ST8 . All I'm doing is doing my own personal live lessons that I teach, those are my own thing, and again I use resources from the lesson or I can get stuff off the internet, I can reference that.
(14) Teachers develop methods to still have control over teaching children science	[10:58.1-12:42.8] ST9 . So I volunteer a lot at my kids schools doing science now. So I can kind of keep some of that stuff going on. And my garage is still full from when I taught traditionally. I just had a bunch of my rocks out and I

created a little, rock samples for some kids, uh my friends' kids this weekend. So I kind of find other ways.

(15) Curriculum platform effecting student retention

[28:34.6-29:39.0] **ST11.** We used Plato or Edmentum last year and I would definitely not recommend that. It was scary. For every 10 kids, 5 of the kids would withdraw because they were having problems with the software.

(16) Online curriculum increases student reading time

[32:35.5-33:56.5] **ST7.** There's a lot more student reading than when I was in brick and mortar.

(17) Online curriculum more up to date than traditional texts

[20:33.4-21:14.0] **ST9.** And they do have great curriculum and current things so I feel like almost it's more up to date online than some of the textbooks. Sometimes you'd have older print textbooks that you're using and things that weren't really current. So I almost feel like it's more up do date.

(18) Searching for online content keeps teacher up to date on latest techniques

[8:24.3-10:19.9] **ST10.** I think the only piece would be feeling like it gives me a different perspective than I think some other science teachers. Because I'm constantly finding things or coming across new things so it tends to help my instruction and my assessment practices, my teaching practices to be maybe a little bit more current, if that make sense.

Table 12

Categories of Description and Representative Passages for online structure effects of teaching and learning

Categories of Description	Representative Passages
(1) Flexibility for teachers	[02:51.8-03:13.0] ST11 . Mainly, well I have 3 kids so, my wife is also a science teacher, she teaches in the classroom, so it's nice to have the flexibility now, being at home obviously. Also I have some medical issues that working from home is much easier for me.
(2) Must work non-traditional hours	[05:12.8-07:40.6] ST12 . Student schedules also mean that teaching hours are no longer restricted to regular course hours.
(3) Self-paced curriculum, no longer views self as teacher, rather as a facilitator	[16:58.7-17:57.0] ST7because so much of it is self-paced, I'm not necessarily teaching as much as I was. I'm not going through the curriculum from A to Z like I was in the classroom when I was teaching everything. What I'm essentially teaching more of now is what the kids aren't getting.
(4) Low level of student collaboration due to asynchronous model.	[04:36.8-07:53.8] ST10 . The other thing in terms of disadvantages that I don't like about teaching science online is the lack of collaboration. We run an asynchronous program and it's continuous intake so we've really moved away from doing anything, from having a structure that fosters any type of collaboration and I feel like that's important because my face-to-face classes that's something that I really try and incorporate and is valuable for students.
(5) Teachers spend more time teaching life skills rather than science content	[18:08.5-19:23.5] ST7 . I see myself as a little bit less as a science educator and more of an educator in general. More of a broad spectrum. Because, and this is something when I train our new teachers I try to tell them, "we are not here", especially in this environment with the students that we get, "we are not here teaching content, we are teaching life skills." Because a lot of them do not get that. They just don't have that at home. So things like leaving a voice mail, you call somebody and no one answers. I mean kids these days they just don't know to do that. So I find myself teaching less science and more just skills, just general skills. You know, how to, computer skills even. How to use Microsoft Word, how to enter the virtual classroom, a

	lot of problem solving. Or prioritizing, scheduling, prioritizing, I do a LOT of that. These kids just don't know how to do it.
(6) Changing to constructivist teaching style, more student-centered	[10:27.4-12:30.6] ST10 . So in some ways I think it's allowed me to take a step back from that lecturing approach...So I guess, in a sense that might be one way where the online has certainly influenced my views of teaching science.
(7) Teacher control over work schedule	[09:35.4-10:42.5] ST2 . Well for me, it's been kind of, I kind of set my own to-do list. If I want to work on my lesson plan from 8 to 9 I can do that. I don't have to have a set schedule. "Okay, I've got to teach first period, second period". And then I can answer emails...I don't know...like throughout the day. Call from 12 to 1, I don't know. But I kind of set my own schedule. And sometimes if I feel a little overwhelmed I can take my lunch at 9 in the morning.
(8) Fewer classroom management issues	[03:35.8-03:46.2]. ST3the difference is going to be how you manage the classroom. How I manage online is way easier than, you know, f2f.
(9) Adapt to environment in order to build rapport with students	[08:36.7-09:05.2] ST2 . Because I still have a way to build really good rapport with them and it's just... It's kind of like evolution. You just adapt to your environment. You know, this is the way it works online and I just find ways to 'enhance my characteristics' to survive in that environment.
(10) Get to teach every student	[03:17.4-04:16.1] ST5 . I get to teach to every student. It's one on one, aside from my weekly live lesson. I have some kids that need a whole bunch of my time and I have some kids that don't need me at all. They just need me for our discussions before an exam, and that's it. And I can really tailor the work for every student.
(11) Ability to individualize student learning	[04:11.3-05:24.4] ST6 . From the students' perspective is that you can individualize their learning, much easier than in a traditional classroom. Not that it's not possible, but they can move at their own pace in an online learning environment, blended learning environment. It's much easier to accomplish, it's easier to design and have them follow a certain pace. I'd say that is probably the biggest positive aspect.

(12) Online teachers viewed as being available 24/7	[05:50.2-08:31.0] ST6. ...one of the biggest challenges is the perception of being on demand constantly. So 24/7 being there for a student or a parent. And it's easy, since you are not visually, well not physically with this person, it's very easy to assume that they have nothing to do. That you're right by the phone waiting for their call, and that you should be there when you receive a phone call or text message, instant communication is expected.
(13) More rewarding due to student population	[11:30.4-12:33.3] ST7. the biggest for me as a teacher would probably be that it is much more rewarding for me. In terms of I feel better about being able to help a lot of students that wouldn't be able to get that help normally. And I think a lot of that teaching field is you want to get out there, you want to help, you want to change lives as they all say. And I feel like that happens a lot more in the online environment.
(14) Online course sizes are too large	[13:45.3-14:46.3] ST7. But right now I'm sitting at about 200. Which, it's high. It's the highest it's been in I'd say about 9 months. So I mean, it's, I love it, I love what I do, but when it gets that high, I don't feel like I'm able to reach each student as well. So the quality suffers because of the quantity a little bit.
(15) Difficult for students to collaborate due to asynchronous intake model	[04:36.8-07:53.8] ST10. We run an asynchronous program and it's continuous intake so we've really moved away from doing anything, from having a structure that fosters any type of collaboration and I feel like that's important because my face-to-face classes that's something that I really try and incorporate and is valuable for students.
(16) Safe space for students to learn	[18:37.5-18:59.5] ST11. I guess I'd like to add to that, with the bullying issues. So we get kids who come to us because, you know, it's just a negative experience in regular high school. So it's nice to see that they are comfortable and safe and they are getting a good education without having to be in such a terrible environment.
(17) Viewed as not really working	[01:00.7-02:07.9] ST7. It's interesting because usually when you tell people that they think, "oh, you work from home, you don't really work". That's what that translates to, you don't really work.
(18) Teachers miss physical presence of students	[17:15.8-18:44.0] ST10 Obviously when you're online you don't get that same energy back from your students, right. I

	mean yes, you can see them being engaged, but you don't get to see them sort of face-to-face. And so as a classroom teacher you feed off of that, you feed off the energy and you feed off their curiosity and their interest and their question. You don't get that online.
(19) Teachers prefer not to be in physical presence of students	[09:31.0-11:41.0] ST4. What I like is, when I talk to them on a one to one basis, I can focus on them without there's some kid doing something crazy, I can actually focus on the kid. So that really changes because I am able to do that and just work with the kid. You can't do that in mass teaching 40 kids and they're all in the range of different abilities and
(20) Online teachers require technology skills	[17:34.6-18:08.5] ST1. Yes, the whole use of the computer. When I was in the brick and mortar I only had to take attendance and input grades. This has been a very good experience for me in forcing me to research materials, find videos, learning how to use the BBC. In fact we just had another conference online on adding animations to our PowerPoints. You know kind of making them a little more exciting. I guess learning the tricks of the PowerPoints and what not.
(21) Understand how to help student collaborate online	[31:39.7-33:23.2] ST11. Maybe teach them how to design a lesson or activity where the kids actually use the whiteboard tools to move things around and do things like that. I've done things where, like matching games, like terms on one side and they actually have to click on it and match things up. Activities like that. But one of the challenges is too is teaching the kids how to use those whiteboard tools.
(22) Time management important for teachers	[37:52.9-43:05.0] ST8. But time management for my job is crucial. You have to spend your time and this is what I'm doing and I'm not doing anything else right now. Now I'm calling my kids... and some teachers are like "Oh I just let them call me any time of the day and I'll do the DBA whenever", and I'm like "I can't function that way"...And then all of a sudden the day is gone and I didn't get anything done today... You're not sitting there and letting the bell drive your day... You have to be your own bell maker.
(23) Time to teach	[29:53.9-31:01.3] ST2. And in an online classroom you teach about only an hour to an hour and half a day, and the

rest of the time is for you to catch up on everything. Your meetings. You don't have to use your prep period to go to a meeting. You don't have to use your prep period to either grade or lesson plan, "which one do I do?" So, or prepare a lab. So everything you really can't truly get to in a brick and mortar classroom you have the ability to do in an online classroom. So all that stuff you're supposed to do in a brick and mortar. So I have that time to chase after kids.

Appendix D

Structures of Awareness of the Themes

Table 13

The Structure of Awareness of Virtual Labs and Learning

DoV	Referential Aspect	Structural Aspect	
	Meaning	Internal Horizon	External Horizon
1	Positive conceptions of student learning in relation to virtual labs.	<ul style="list-style-type: none"> • Certain virtual labs more effective than real-life counterpart (flame lab). • Students report increased understanding, reflected in work submitted. • Students can tie labs to scientific argumentation, explain and justify results. • Student learning seems to improve when students allowed to collaborate on virtual labs. 	<ul style="list-style-type: none"> • Classroom management issues are non-existent for virtual labs. • Virtual labs are safer and accessible to students who do not have access to materials. • Virtual labs true to live experiences. • Students are more focused when conducting virtual labs, not “goofing” around as compared to face-to-face labs. • Student gaming culture results in increased student engagement with virtual labs.
2	Negative conceptions of student learning in relation to virtual labs.	<ul style="list-style-type: none"> • Lack of “hands-on” experiences limit student learning. • Virtual labs reduce students’ engagement, no “wow” factor. • Virtual labs as “cookie-cutter” leading to one answer, lack ability for student-designed labs to collect own data to answer own question. • Some labs not interactive, video observation only. 	<ul style="list-style-type: none"> • Students lack writing skills needed to write up lab reports. • Teachers tend to not use labs as they do not want students to struggle. • Some students lack social skills or the desire to interact. • Continuous entry format mean students are at different levels in course, making it difficult to collaborate on labs.

Table 14

The Structure of Awareness of Student Learning and Factors Involved

DoV	Referential Aspect		Structural Aspect	
	Meaning	Internal Horizon	External Horizon	
1	How online teachers experienced student learning.	<ul style="list-style-type: none">•The lack of physical cues and facial cues made it difficult for teachers to determine if students were “getting it”.•Student learning measured by their use of “thumbs up” or “thumbs down” in LMS.•Identifying student speech patterns when talking on the phone helped teachers identify if students had learned.•Identifying student writing helped teachers identify if students had learned.•Students learning judged based on pre, post-test scores.•Results on state-mandated tests.	<ul style="list-style-type: none">•Perceptions in educational community that online learning is not really learning.•Teachers held belief that students could learn science online.•Students need diploma for more jobs, GEDS no longer accepted.•Online students and f2f students struggle with same concepts.•Large class sizes (150+) made it difficult to assess every student.	
2	Student support, supports put in place to assist student learning	<ul style="list-style-type: none">•Teachers as tutors, provide support for concepts students do not understand.•Varying support structures: special education teachers, counselors, family support liaison, principal.	<ul style="list-style-type: none">•Parent coaches lack of student support, students not spending computer time on coursework.	
3	Student characteristics and demographics and effects on learning.	<ul style="list-style-type: none">•Teacher belief that students require certain characteristics to be successful learning	<ul style="list-style-type: none">•Students enrolled in courses taking extended time to complete the course.	

- online: self-motivated, organizational skills.
- Low level ESOL and language gap.
- School as “safe place”, home environment not a positive learning environment.
- Personal issues such as attending rehab and no internet at home make it difficult to participate.
- Student disappearing, “Baker acted”.
- Students need basic life and technology skills, not learning at home.
- Students have face-to-face school obligations, families (own children), after school commitments.

Table 15

The Structure of Awareness of Communication and Instruction

DoV	Referential Aspect		Structural Aspect	
	Meaning	Internal Horizon	External Horizon	
1	Communication and teaching science online.	<ul style="list-style-type: none">• Requires a greater amount of communication compared to face-to-face courses.• Teachers must be effective online communicators in both text and verbal formats.	<ul style="list-style-type: none">• Text and email messages coming in waves, experienced as multiple people talking to you at once.	
2	Teacher-Student communication for instruction	<ul style="list-style-type: none">• Difficulty communicating with ELL students, cannot use face-to-face strategies.• Instruction becomes more teacher driven due to students possessing low online communication skills.• Must have deep content knowledge to convey science concepts over phone with just words.• Able to have time to reflect before giving feedback.• Must develop communication skills so can convey emotion and engage students, remember audience.• Lots of feedback to keep students engaged.• Students communicate more fully and authentically since not concerned about peer pressure.	<ul style="list-style-type: none">• Adapting to environment, learning new ways to communicate concepts to students.• Students lack writing skills and online communication skills.• Monthly calls to students for tracking purposes.	
3	Teacher-Student communication to develop relationships	<ul style="list-style-type: none">• Awareness that text messages and email can	<ul style="list-style-type: none">• Students can end conversations by turning off computer.	

		<p>be interpreted differently from intent.</p> <ul style="list-style-type: none"> • Difficult for teachers to convey personality in text or to get to know student personality. • More opportunities to interact with students 1 on 1. • Get to know students through phone discussions, know students better due to having time to talk and communicate. 	<ul style="list-style-type: none"> • Students can be rude online, teachers must instruct on digital citizenship. • Need a quiet place to make calls which can be isolating. • Lack of internet at home preventing text messages or email communication.
4	Student-Student communication (live lessons)	<ul style="list-style-type: none"> • Students may be shy and not wish to talk or communicate during live lesson. • Students like to collaborate during live lessons, peer explanation of material and lab results. 	<ul style="list-style-type: none"> • Technology does not work or is not available – webcam, microphone, Internet. • Limited S-S interaction, students seem isolated.
5	Teacher-Parent communication	<ul style="list-style-type: none"> • Informing parents of student success, how child is doing in course. • Developing student pace plan via phone. • Discussing potential cheating allegations. • Discussing life issues and effect on student learning. 	<ul style="list-style-type: none"> • Language barrier between teachers and parents. • Lack of internet at home preventing text messages or email communication.

Table 16

The Structure of Awareness of Teaching as Collaboration/Social Aspect

DoV	Referential Aspect	Structural Aspect	
	Meaning	Internal Horizon	External Horizon
1	Collaboration on instruction, professional support.	<ul style="list-style-type: none"> • Co-teaching live lessons due to high student participation. • Instant messaging for support and meeting face-to-face to grade and develop lessons. • Online science teachers seen as more willing to share materials compared with teachers at traditional schools. • Lack of support on best approaches for teaching particular content areas. 	<ul style="list-style-type: none"> • Attending conferences. • Finding time to collaborate. • Only teacher at virtual school. • Teaching science subject outside content area. • Instant messaging software used by virtual schools provided quick access to other teachers.
2	Teaching online as professionally and socially isolating.	<ul style="list-style-type: none"> • Isolation due to lack of socializing with other educators or having educators to share experiences with. • Isolation due to desire to talk with adults during the day. • Feeling like they do not have coworkers. 	<ul style="list-style-type: none"> • Family members and friends out during week, want to be home on weekends; opposite is true for online teachers. • Online science teacher may be only one at virtual school teaching science.

Table 17

The Structure of Awareness of Teaching and Learning as Assessment

DoV	Referential Aspect		Structural Aspect	
	Meaning	Internal Horizon	External Horizon	
1	The use of assessments to inform teaching strategies.	<ul style="list-style-type: none">• Tracking student data, work for the week, how long on LMS, if behind in work, grades.• Use of webcam to access facial cues to assess student understanding.• Assessing for misconceptions in order to develop deeper sense of how students learn.	<ul style="list-style-type: none">• Teachers evaluated based on student grades.• Unable to perform continuous formative assessments (unlike face-to-face courses).• Unable to access student data; time spent on LMS, data on videos watched, etc.	
2	The use of assessments to affect student learning.	<ul style="list-style-type: none">• Snapshot of student learning based on assignments, exams, and labs.• Application versus memorization, applied knowledge assessed with open-ended questions.• Discussion based assessments via the phone to check for ability to apply knowledge.• LMS allows easy grading of assignments and assessments, allowing immediate feedback to students.• Online grading systems allows grading without knowing owner of work, unbiased grading.	<ul style="list-style-type: none">• Teacher content knowledge important to assess students' critical thinking skills.• Barriers such as not feeling competent or falling behind may cause students to cheat on assessments.• Parents and students become annoyed or angry that assessments are application based and not rote from course material.• Academic integrity and plagiarism. LMS features.	
3	Enable students to be in charge of own learning through self-assessment.	<ul style="list-style-type: none">• Students track own learning through interactives, must be able to assess own learning quickly or they disengage.	<ul style="list-style-type: none">• Teachers need to be guided on the process of connecting student learning and self-assessment.	

- Feedback replacing the lecture.
- Immediate feedback from teacher required, short assessments that are easy to grade quickly.

Table 18

The Structure of Awareness of Curriculum Effects on Teaching and Learning

DoV	Referential Aspect		Structural Aspect	
	Meaning	Internal Horizon	External Horizon	
1	How the curriculum structure guides online science teaching.	<ul style="list-style-type: none"> • Teaching as linear to follow preset curriculum. • Teaching experienced as limiting, lacking freedom to teach. • Not really teaching content, rather helping students during sections they do not understand. • Must know curriculum as it may vary from way the course was taught in face-to-face class, know learning goals and assessments. • Loss of creative energy due to using preset curriculum. • Able to focus on student communication since time is not needed to create materials. • Curriculum structure lacking, need to provide extra resources, particularly verbal explanations. 	<ul style="list-style-type: none"> • Ability to provide more resources online. • Volunteer at schools/community centers to have creative control over content, hands-on experiences. • Teachers cannot bring what they know into course as students are not tested on it. 	
2	How the curriculum structure affects student learning.	<ul style="list-style-type: none"> • Busy work for students, assignments at a low level and not challenging. • Limiting learning options for the students. • Students are just memorizing the material, not having to extend understanding. 	<ul style="list-style-type: none"> • Curriculum is module based with a predetermined order. • Inability to correct misinformation in set curriculum. 	

3

Curriculum structure and teaching motivation, professional learning.

- Poorly designed assessments only check for memorization, is student learning or parroting back information?
- Creating own curriculum, looking for content to keep students engaged, keeping up to date on latest methods, strategies.
- Online teachers discontinue learning as there is no incentive to learn, not designing own curriculum.
- Professional learning occurs as teachers search for resources.

Table 19

The Structure of Awareness of Online Structure Effects on Teaching and Learning

DoV	Referential Aspect		Structural Aspect	
	Meaning	Internal Horizon	External Horizon	
1	How the nature of the online environment impacts teaching and learning.	<ul style="list-style-type: none">• Teaching online does not feel as effective as in the traditional classroom.• Continuous intake model shifts focus to administrative issues rather than teaching.• More time to lesson plan, fewer meetings and committees.• Teaching is not confined by geography, the teacher just requires Internet access.• Able to help students who would not normally thrive in traditional classroom, changing lives happens more online.• Easier to teach every student, individualize instruction.• Asynchronous nature does not allow for real-time projects and teacher “live” formative assessment.• Students’ schedules mean teachers work weekends and in the evenings.	<ul style="list-style-type: none">• Program design, semester model versus continuous intake model.• Flexibility to work from home.• Flexibility to address family scheduling issues.• Perceived as “not really working” as a teacher due to online environment.• Use of computer for teaching.• Virtual school policy on availability.• Effect on home life when working weekends and evenings.	
2	The physical location of the students and the effect on teacher engagement.	<ul style="list-style-type: none">• Difficult to get used to not being in same physical location as students.• Teachers like being around the students.• Synergy between students and teacher in	<ul style="list-style-type: none">• The need to feel that a teacher is more than just a teacher.• Human interaction.	

<p>3 Teacher identity and characteristics and their development in relation to teaching science online.</p>	<p>the classroom is lost online, or much reduced.</p> <ul style="list-style-type: none"> • Similar characteristics as students, self-motivated, organized, time management crucial. • Teaching online as an art form that required patience, must be able to motivate students due to self-paced nature. • Teacher becomes more of a facilitator and “life coach”. • Just “the teacher”, no longer the coach or involved in extracurricular activities. • Teacher experience as missing modeling science and hands-on component, no demonstrations online. • Teaching as trouble-shooting and support, students are independent learners so no direct instruction. • Prefer working with individuals rather than whole-class model. 	<ul style="list-style-type: none"> • Online schools do not typically have clubs or sports teams. • Set curriculum used in many virtual schools. • Students are self-paced, access materials on own.
<p>4 Classroom management and effect on teaching.</p>	<ul style="list-style-type: none"> • More time to teach as time is not spent on class discipline issues. • Can spend more time with students individually. • Can focus on the needs of one student without other students disrupting. 	<ul style="list-style-type: none"> • Virtual schools have different methods of handling behavior issues. • LMS systems allow teachers to quickly banish misbehaving students from live lessons. • Use of webcams to check for on-task behavior.

- 5 The importance of developing basic technology skills outside of pedagogical considerations.
- Must have good basic technology skills.
 - Must be able to help students troubleshoot technology.
 - Technology skills must be at a level that allows the teacher to develop content and build course resources effectively.
 - Multiple operating systems to contend with.
 - Students have different levels of technology and technology knowledge.
 - Students may not have technology at home.

Appendix E

UNLV IRB Approval



Social/Behavioral IRB – Exempt Review Deemed Exempt

DATE: December 23, 2014

TO: **Dr. Kendall Hartley**, Graduate College

FROM: Office of Research Integrity – Human Subjects

RE: Notification of IRB Action
Protocol Title: The Experience of Online Secondary Science Education from the
Perspective of Teachers
Protocol # 1412-5033

This memorandum is notification that the project referenced above has been reviewed as indicated in Federal regulatory statutes 45CFR46 and deemed exempt under 45 CFR 46.101(b)2.

PLEASE NOTE:

Upon Approval, the research team is responsible for conducting the research as stated in the exempt application reviewed by the ORI – HS and/or the IRB which shall include using the most recently submitted Informed Consent/Assent Forms (Information Sheet) and recruitment materials. The official versions of these forms are indicated by footer which contains the date exempted.

Any changes to the application may cause this project to require a different level of IRB review. Should any changes need to be made, please submit a **Modification Form**. When the above-referenced project has been completed, please submit a **Continuing Review/Progress Completion report** to notify ORI – HS of its closure.

If you have questions or require any assistance, please contact the Office of Research Integrity - Human Subjects at IRB@unlv.edu or call 895-2794.

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- Yiotis, K. (2013). The open access initiative: A new paradigm for scholarly communications. *Information Technology and Libraries*, 24(4), 157-162.

Curriculum Vitae

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Education

- | | |
|-----------------|--|
| 2011 to Present | PhD Studies, University of Nevada, Las Vegas, Curriculum and Instruction.
Areas of emphasis in educational technology and science education.
Dissertation (anticipated graduation date: May 2016)
“The Experience of Teaching Online Secondary Science” <i>A phenomenographic study employing the Variation Theory of Learning to develop an understanding of what it is to teach in the online secondary science environment.</i>
Co-Chairs: Dr. Kendall Hartley, Dr. Hasan Deniz
Committee: Dr. Neal Strudler, Dr. Gregory Schraw |
| 2010 | M. A. Science Education (Physics 5 – 12), Western Governors University
Thesis: <i>The Effects of Guided Reading on Student Comprehension of Science Textbooks</i> |
| 2004 | Post Baccalaureate, Teaching Prep, Mathematics (5 – 12), Western Governors University |
| 1996 | B. S., Civil Engineering, University of Colorado at Denver
Member of Chi Epsilon (undergraduate engineering honor society)
President of the student section of American Society of Civil Engineers (ASCE) |
| 1984 | B. A., Environmental Conservation, University of Colorado at Boulder |

Affiliations

American Association of Physics Teachers (AAPT)
American Educational Research Association (AERA)
International Society for Technology in Education (ISTE)
Association for the Advancement of Computing in Education (AACE)
Society for Information Technology and Teacher Education (SITE)
National Association of Research in Science Education (NARST)
International Association for K-12 Online Learning (iNACOL)

Awards

- 2015 UNLV Graduate & Professional Student Association Grant (\$500)
- 2015 Patricia Sastaunik Scholarship (\$2500)
- 2015 UNLV Graduate & Professional Student Research Forum 2015 Outstanding Presentation Awards, 2nd place. Education Poster Session (\$125)
- 2015 AERA Division C Graduate Student Seminar (\$200)
- 2014 UNLV Outstanding Graduate Student Teaching Award, 2nd place (\$2000)
- 2014 UNLV Graduate & Professional Student Association Grant (\$225)
- 2013 John M. Vergiels Scholarship (\$1000)
- 2013 UNLV Graduate & Professional Student Association Grant (\$400)

Publications

Refereed Journals

- Clark, C.,** Zhang, S., & Strudler, N. (2015). Teacher candidate technology integration: For student learning or instruction? *Journal of Digital Learning in Teacher Education*, 31(3), 1-14. doi:10.1080/21532974.2014.967421.
- Clark, C.,** Strudler, N., & Grove, K. (2015). Comparing asynchronous and synchronous video versus text based discussions in an online teacher education course. *Online Learning: Official Journal Of The Online Learning Consortium*, 19(3).
- McCreery, M. P., Vallett, D., & **Clark, C.** (2015). Social interaction in a virtual environment: Examining socio-spatial interactivity and social presence using behavioral analysis. *Computers in Human Behavior*, 51, (Part A), 203-206. doi:10.1016/j.chb.2015.04.044
- Clark, C.,** Pearson, B. (revise and resubmit). Microblogging educators: Can meaningful learning and communities of practice develop in 140 characters or less? *Journal of Technology and Teacher Education*.

Conference Proceedings

- Clark, C.** (2013). Science Instruction at a Distance: What can we see? In T. Bastiaens & G. Marks (Eds.), *Proceedings of World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education 2013* (pp. 1092-1101). Chesapeake, VA: AACE.

Book Reviews

- Hartley, K., & **Clark, C.** (2015). Review of Performance-based assessment for 21st-century skills. *Teachers College Record*, July 2, 2015. <http://www.tcrecord.org> ID Number: 18009.

In Progress

Clark, C., McCreery, M.P., Kuch, F. (in progress). Digital native versus personality and online discussion design: Which construct provides the best guidance?

Research Experience and Faculty Development

- 2015 *Research Assistant:* Teacher use of Class Dojo, recording student behavior . Data entry and statistical analysis (descriptive data).
- 2014 *Research Assistant:* Decision making aspects of World of Warcraft gamers. Coded actions of players in asynchronous play. Contributed social presence discussion in journal article.
- 2014 *Teaching & Learning Faculty Technology Mini-Grant Workshops.* Developed and led faculty workshops on uses of educational technology.
- 2013 *Teaching & Learning Faculty Technology Mini-Grant Workshops.* Led three faculty workshops on uses of various technologies; Google+, Edmodo, Prezi and Google Presentation
- 2012 *NeCoTIP Grant:* Developed training methods and materials for secondary science**
- 2013 teachers within a prototype of an online community of practice.

Grants

Funded

- 2014 Platt, S., Tomiyasu, B., **Clark, C.**, and Mason, M. (2014). Henderson Library: Generation STEAM. Submitted to Library Services and Technology Act (LSTA) 2014 Competitive Grant Cycle. (\$85,000/\$19,000).

Non-Funded

- 2012 Hartley, K., **Clark, C.**, Zhang, S. (2012). TeachCraft: An Online Community of
-2013 Practice. Submitted to Nevada System of Higher Education *NeCoTIP* Professional Development Program. (\$92,000)

Conference Presentations

National/ International Refereed Conference Presentations:

Clark, C., & Pearson, B. (2015, April). *Educators Forming a Virtual Community of Practice: Who is Microblogging and Why?* Paper presented at the annual meeting of the International Society for Technology in Education, Philadelphia, PA.

- Clark, C.** (2015, February). *Creating community in an online course using asynchronous and synchronous video communication*. Poster presented at the annual meeting of the Educause Learning Initiative, Anaheim, CA.
- Clark, C.,** Zhang, S., and Strudler, N. (2014, April). *Student learning or instruction? How preservice teachers integrate technology in the classroom*. Paper presented at the annual meeting of the American Educational Research Association, Philadelphia, PA.
- Clark, C.** (2013, October). *Science Instruction at a distance: What can we see?* Paper presented at the annual E-Learn – World Conference on E-Learning organized by the Association for the Advancement of Computing in Education, Las Vegas, NV.
- Clark, C.,** Strudler, N., and Grove, K. (2013, June). *I see you: Using the affordances of Google+ to increase social and teaching presence in an online undergraduate teacher education course*. Paper presented at the annual meeting of the International Society for Technology in Education, San Antonio, TX.
- Clark, C.** (2013, June). *Online collaboration with Google+ and Hangout*. Poster presented at the Poster Session at the annual meeting of the International Society for Technology in Education, San Antonio, TX.
- Clark, C.** (2013, April). *Gamifying the wiki experience of a science teacher community of practice*. Paper presented at the GSC In-Progress Session at the annual meeting of the American Educational Research Association, San Francisco, CA.
- Local Conference Presentations:**
- Clark, C.,** McCreery, M. P., & Vallett, D. (2015, April). *Exploring the role of social presence in socio-spacial interactivity*. Poster presented at the annual Western Psychological Association conference, Las Vegas, NV.
- Clark, C.,** Zhang, S., Strudler, N. (2015, March). *Teacher candidate technology integration: For student learning or instruction?* Poster presented at the annual University of Nevada, Las Vegas GPSA Research Forum, Las Vegas, NV.
- King, J., Vartouhi, A., Webb, N., McCool, S., and **Clark, C.** (2014, April). *Connecting to students and the world with online synchronous tools*. Panel discussion at the Nevada Conference on Digital Learning, Las Vegas, NV.
- Clark, C.** (2014, March). *Online collaboration with Google+ and Hangout*. Poster presented at the annual University of Nevada, Las Vegas GPSA Research Forum, Las Vegas, NV.

Teaching Experience

UNLV Instructor

2012 – 2015 *Preparing Teachers to Use Technology* (online secondary)
2014 *Teaching Elementary Science*
2013 *Integrating Technology in Teaching and Learning* (Masters level course, online)
 Teaching Secondary Science

UNLV Teaching Assistant

2012 *Preparing Teachers to Use Technology* (elementary)

K-12 Teacher

2005 – 2006 *Shadow Ridge High School, Clark County School District, Las Vegas, Nevada.*
2009 – 2011 Courses Taught: Math Applications, Consumer Mathematics, Physics I Honors, Physics I, and Chemistry I. Coached science bowl team.

2004 *Bonanza High School, Clark County School District, Las Vegas, Nevada*
Student Teacher. Courses Taught: Algebra IA and Geometry Honors.

Professional Service

National

2015 *Reviewer, The Internet and Higher Education* (Elsevier)
2015 *Editorial Review Board, Journal of Technology and Teacher Education* (JTATE,
-present AACE)
2015 *Editorial Review Board, Journal of Online Learning Research* (JOLR, AACE)
-present
2014 *Panel Reviewer, International Society for Technology in Education* (ISTE)
annual 2015 conference.

College and Local

2014 - 2015 *Graduate/Professional Student Association (GPSA): Teaching and Learning*
GPSA Representative
2014 - 2015 *Doctoral Studies Graduate Student Representative: Teaching and Learning*
Department

- 2014 – 2015 *UNLV Teaching Awards Committee*
- 2014 *UNLV Teacher Education Faculty Search Committee*, Doctoral Student Representative
- 2013 - 2015 *NSHE E-Learning Task Force*. Student member. This Task Force has been charged with utilizing e-learning in the support of remediation of students in Mathematics and English curriculum, and to develop an education and business model for the implementation of e-Ncore on-line gateway course offerings that will be transferable to all NSHE institutions.
- 2013 - 2015 *UNLV Disruptive and Adaptive Technologies (DAT) study group*. Student member. The group's mission is to facilitate UNLV faculty leaders and academic policy makers on campus on how DAT might be integrated into the University.
- 2013 - 2015 *Southern Nevada American Association of Physics Teachers (SNAAPT)* – Vice President. Provide quarterly professional development for Las Vegas physics teachers.
- 2013 – 2015 *Education Board, SYN Shop* (Las Vegas hackerspace)

STEM Related Professional Experience

RMH Group: Developed pricing for HVAC components for commercial clients. Provided design documentation to architects and other consultants. Assisted CAD department during peak times.

MK Centennial: Analyzed traffic frequency data and developed highway graphics based on optimum corridor improvements for the Roaring Forks Transportation Authority. Attended community meetings to inform citizens of proposed highway designs and improvements planned for their communities.

ACZ Laboratories: Performed water chemistry studies, radiochemistry studies, and soil studies for various clients. The reports included analysis of trace level contaminants in waters, soils, biota, waste, and plant tissue.

Quanterra Environmental Services Laboratory: Lab technician. Conducted environmental analysis including organic, inorganic, metals and wet chemistry in a variety of matrices including water, soil, waste, biota, and sludge. Utilized mass spectrometry to analyze prepared samples.