School of Education

An Investigation of the Quality of Online Science Education at the Tertiary Level from the Perspectives of Students, Instructors and University Administrators

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Declaration

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

Human Ethics The research presented and reported in this thesis was conducted in accordance with the National Health and Medical Research Council National Statement on Ethical Conduct in Human Research (2007) – updated March 2014. The proposed research study received human research ethics approval from the Curtin University Human Research Ethics Committee (EC00262), Approval Number # SMEC-11-14

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Date: ....

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Abstract

Online education has become an indispensable component of higher education in the wake of the COVID-19 pandemic. Many universities decided to offer all courses online for several semesters. This was preceded over the last several years with universities increasing their offerings of undergraduate online courses across all disciplines, including the sciences. Recent studies on online education support its effectiveness, yet skepticism remains regarding the quality of *science* online education. Consequently, a crucial challenge is to determine and understand the essential elements of quality in science online education and address this skepticism to present the path forward.

Perceptions of quality in online science courses among three stakeholder groups – administrators, instructors and students – was investigated by a qualitative interview study. A focused review of the literature established an initial database of quality indicators specific to online science education. Stakeholder analysis confirmed the importance of these quality indicators. Stakeholder perceptions diverged specifically with regard to learning outcomes in science laboratories. The effectiveness of online science laboratories proved to be highly dependent on context, such as the specific science discipline, whether the course is designed for science majors or non-majors, and the purpose of any laboratory component. This study showed that the educational context is frequently overlooked in discussion despite being a vital part of the holistic evaluation of quality and thus contributes to much of the skepticism. The context needs to be clearly identified first in order for universities to have productive discussion of how to provide quality online science courses in the foreseeable future.

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Chapter 1.
Introduction

1.1 Personal Drive for Research

Online education, particularly in the sciences, has been a pivotal part of my life for the last ten years through my teaching as well as through my own educational endeavors. My teaching career began in 2008 as a full-time instructor in the Division of Mathematics and Science at a small liberal arts university in Southern Illinois. Moving around the world with my family pulled me away physically from this wonderful learning community but through the use of online education I have been able to continue teaching to this present day. In addition, online education has allowed me to continue to pursue my own education through Curtin University's online program, beginning my PhD study as a part-time student in February 2013. Through my direct experience in the field of online education, both personally and professionally, I have become aware of the discrepancies of perceptions of online education and the overall lack of understanding of quality in online science education. This personal experience is what drives my passion for this research study.

Over the last decade, universities in the United States began to implement more online science courses into their undergraduate curricula. Even at my small liberal arts university, online science courses were continuing to be offered each semester. However, general perceptions told a very different story. Skepticism of the quality of online science education was and still remains quite high. Whenever I discussed my teaching of science online, academic colleagues and friends were quick to voice their uncertainty of teaching science online. *"How on earth are you making that work?" "How can you teach science online when it has to be hands-on?"* Many similar questions such as these, combined with raised eyebrows and looks of concern, indicated science courses could not be of quality if taught online. In addition, much of the mainstream news concerning online education spoke of how effective online education had become, showing student learning outcomes equivalent to face-to-face learning, but at the same time voiced uncertainty of online education for certain disciplines such as the sciences. These reactions puzzled me, especially in light of the success in online science education I was experiencing personally and among colleagues at the university.

Informal analysis of final grades and student course evaluations appeared to indicate that my online courses were as effective as my face-to-face courses in terms of cognitive and affective student learning outcomes. These personal experiences and findings of “no significant difference” in learning outcomes from some educational studies were in stark contrast to the skepticism being heard. Where was this skepticism coming from? What elements of science are viewed to be unsuitable online and why? I began to question myself whether the online courses I was teaching were truly of quality and what actually makes quality online science education. Would those directly involved in online education also ask similar questions as I? These questions ignited my interest in conducting research into the perception of those directly involved in online science courses.

Much of the research on the quality of online education was conducted by surveying students and instructors. However, in my experience teaching online courses, university administrators were the ones pushing for the sciences to develop online courses. The whole university perspective of online science education must be considered, not the view of just one or two groups of people, but all of the primary stakeholders. My intention in pursuing this research is to provide a better understanding of common concerns and challenges in designing and offering quality online science courses so that educators can establish a realistic understanding of the quality of online science courses.

Today, in the time of the Coronavirus disease (COVID-19) pandemic, online education has become an indispensable component of higher education. Many colleges and universities across the United States have decided to offer all courses online for the most recent semesters (Fall 2020 / Spring 2021). Having a clear understanding and framework of how to provide quality online courses, especially in the sciences, has never been more necessary. Since the sciences have been slower than other disciplines in embracing the online learning environment, the transition to online is a major endeavor. The intention is that the results from this research study can guide educators in designing their online science courses and laboratories with the confidence that what they provide is of quality. Additionally, the findings this research provides regarding skepticism of online science education can guide institutional decisions of which courses or laboratories may still require a physical learning experience.

1.2 Rationale for the Research

Online education has prompted a rapidly growing shift in learning environments, pedagogy, curriculum development and determination of educational quality. Advances in technology and evolution in our conceptions of learning and society have driven the advancement in online education over the past few decades (Bates, 2005, 2019; Major, 2015). Universities around the world have been an integral part of this rapid growth. In the United States alone, over six million students at the tertiary level are taking at least one online course (Seaman et al., 2018). The Online Learning Consortium defines a course as ‘online’ when at least 80% of the course content is delivered online (Allen et al., 2016). Out of all student enrollment in higher education in the United States in 2016, 31.6% of students were enrolled in some online education, a proportion that continues to rise (Seaman et al., 2018). Between spring 2017 and 2018, a 10% median growth rate of student enrollment in fully online courses was reported in the 2019 CHLOE report, which sampled 280 higher education institutions in the United States (Legon et al., 2019). With the growing student enrollment in online courses, university administrators acknowledge the addition of online courses as an important factor for the future growth of their universities (Allen et al., 2016; Xu & Xu, 2019).

As online learning has become an essential component of higher education, an abundant amount of research has been devoted to evaluating its effectiveness. Policy-makers and practitioners are recognizing a need for research concerning the quality of online education and information on the effectiveness of online learning environments, specifically at the tertiary level (Arias et al., 2018; Bolton et al., 2019; Cavanaugh & Jacquemin, 2015; Smidt & Li, 2019; Xu & Jaggars, 2014). A common way for educators to explore the effectiveness of a new mode of teaching is to compare it to the common mode of teaching (face-to-face) in terms of student learning outcomes so that the educational community can evaluate and accept this new mode of teaching (Mitchell, 2010). In this context, student outcomes typically refer to cognitive outcomes measured by final course grades or test scores.

Studies comparing traditional, face-to-face classrooms to online learning environments in higher education have reported mixed and complex findings (Nortvig et al., 2018). An academic performance comparison study reported that students found it difficult to persist and succeed in online courses compared to face-to-face courses across various subject areas and student subgroups (Xu & Jaggars, 2014). On the other hand, a large-scale multi-year survey study reported that a majority of university administrators perceive the effectiveness of online learning to be equivalent or superior to face-to-face instruction, while less than one third of administrators report that their instructors accept the value and legitimacy of online education (Allen et al., 2016). Another meta-analysis found online learning to be as effective as face-to-face learning in terms of learning outcomes (including grades, assignment scores and test scores), but cautioned against simple comparisons considering the differences in the two modes including the amount of time students spent on completing the learning tasks (U.S. Department of Education, 2010).

The integration of online education into universities presents both opportunities and challenges. There is great enthusiasm in the potential of affordable and flexible education opportunities, but also concern about the level of educational quality in terms of academic rigor, accountability and constructive interactions. Even after a decade of considerable growth in the number of universities offering online education, the level of skepticism among university instructors has remained high (Allen et al., 2016; Bagasra & Mackinem, 2019). While no longer considered a 'new' mode of delivery, online education continues to generate debate and controversy concerning whether online courses provide quality educational experiences, and if they are designed to meet instructors' and students' needs (Davis & Snyder, 2012; Saltmarsh & Sutherland-Smith, 2010). With the growing number of online higher education courses, the demand for more rigorous evaluation of quality for online learning has also increased (Cheawjindakarn et al., 2012).

Comparison research of learning outcomes between face-to-face and online instruction defines online learning quality in terms of traditional learning settings

(McGorry, 2003). Current research has noted that in an effort to make online learning “as good as face-to-face,” we may be overlooking, even sacrificing, its distinct potential (McDonald, 2002). Online learning environments are distinctly different from traditional classroom settings and they have evolved beyond simple comparisons with classroom instruction (Abrami et al., 2011; Martz et al., 2004; Nortvig et al., 2018; Swan, 2004). Thus, researchers in online education have begun moving beyond direct comparisons between online and face-face education, and are moving towards “approaches that go beyond no significant difference” (Twigg, 2001a, p. 4).

A few nationally recognized organizations, such as the Quality Matters Rubric and the OLC 5-Pillars Quality Framework, provide university-wide rubrics for measuring and defining quality of online courses (Online Learning Consortium, 2019; Quality Matters, 2018). Frameworks such as these are becoming more frequently implemented into universities as they increase the number of online courses and fully online degree programs. In addition to investigating quality indicators specific to online education, it is pertinent to consider discipline specific factors. Each discipline includes unique learning objectives and curricula design which determine quality factors. In the sciences, for example, the laboratory component creates a unique challenge in the online environment (Jeschofnig & Jeschofnig, 2011; Mosse & Wright, 2010), which some believe make online science courses inherently inadequate or inferior to face-to-face courses (Casanova et al., 2006; Mawn et al., 2011). Science education also advocates strongly for collaboration, as it is considered a ‘best practice’ in science education by the National Research Council (2005).

Compared with other disciplines, there are fewer online course offerings and fully online degree programs in the sciences (Flowers, 2011; Varty, 2016; Xu & Xu, 2019). As such, relatively few studies have focused on the identification and application of online quality indicators to the core sciences such as physics, chemistry, biology and earth sciences. The literature addressing online science courses is widely scattered. Much of the research literature focuses on online laboratories, specific individual courses or sub-topics within a course. Few address the status or quality of online science education as a whole. A strong laboratory is at the heart of science education and the most scrutinized component of online science education. Extensive literature reviews have compiled studies that focused solely on the science laboratory in the online environment (Brinson, 2015; Faulconer & Gruss, 2018; Ma & Nickerson, 2006). Other online science literature has focused on the necessities of interaction in online science learning, as social constructivism is a central component of current science education research and practice (DeHaan, 2005; Flener-Lovitt et al., 2020; National Academies of Sciences Engineering and Medicine, 2016). Similar to online learning overall, much of online science literature is focused on comparisons with face-to-face science learning environments in student learning outcomes (Bergeler & Read, 2021; Brinson, 2015; Lee et al., 2011). Science educators remain concerned about the effects of online education in reconfiguring the nature, process and practices that are fundamental to science teaching and learning. A more thorough investigation is needed considering the unique quality indicators considering online science courses in particular.

1.2.1 Defining Quality

The evaluation of online education is moving beyond comparisons with face-to-face learning, recognizing online as a unique modality and requiring a reconsideration of quality standards. Online courses are determined to be effective if they meet an established set of quality standards unique to the online environment. Defining quality in any field is a challenge but educators continue to attempt to define quality for online education, particularly due to its important role in evaluation.

There are different approaches to establishing the quality of an online course (Bagasra & Mackinem, 2019). The evaluation of student cognitive outcomes is readily used as a measurement of quality, but it is not the only standard by which online education can be evaluated. Some researchers claim the comparison of academic performance alone does not and cannot give a complete picture of the educational process, and the experience of the people involved needs to be considered to provide a fuller understanding of quality (Fraser, 2012). Understanding the perceptions of stakeholders is particularly important for the development and implementation of online science courses, considering the persistent skepticism on its value and legitimacy.

Mitchell (2010) explains that current measures of the quality of online courses can be organized into four categories: stakeholder perceptions (e.g., perceived effectiveness), course design elements (e.g., collaborative interactions) and external standards (e.g., Quality Matters and OLC 5 Pillars) in addition to quantifiable elements (e.g., student outcomes and retention rates). Cleary (2001) conveys quality as a relative, subjective construct, dependent on an individual's experiences, making it a challenge to define. As the meaning of quality is dependent on the unique perspectives of different stakeholder groups, namely students, instructors and university administrators, it is important to understand the perceptions and experiences of stakeholders to define quality of online science courses (Esfijani, 2018; Parker, 2008).

Studies based on perceptions of online courses tend to focus on one stakeholder group alone (Clary & Wandersee, 2010; Flowers, 2011; Khoo et al., 2010; Koenig, 2010), rather than representing perspectives from multiple stakeholder groups, including administrators, instructors and students. Determination of quality in online science learning is most accurately represented if analyzed from many different perspectives in an attempt to represent the university as a whole. Thus, a more thorough investigation of the quality of online courses should consider perspectives of university instructors and administrators in addition to student perceptions.

This study combines the views of Mitchell (2010), Cleary (2001) and Esfijani (2018) by investigating the quality of online science courses through the perceptions of primary stakeholders. Through a collective agreement among stakeholders, the quality of online science courses is defined by aspects shown to produce acceptable, agreed upon, experiences and outcomes. This thesis acknowledges that quality evolves and changes over time. Thus, any agreed upon definition of quality, or identified quality factors, would require constant revision and consideration (Esfijani, 2018).

1.3 Aims and Research Questions

The primary aim of this research is to establish a clear and comprehensive understanding of what is considered quality in online science courses at the tertiary level from the perspectives of three primary stakeholder groups: university students, instructors and administrators. In addition, this research aims to identify and understand the sources of skepticism and discrepancy of perceptions regarding online science education effectiveness. This in-depth evaluation of different perceptions regarding the quality of online science courses adds insight to the current state of online science education and can guide decisions of how online science education can proceed in the future.

Research about online science education naturally incorporates aspects of online education more broadly in addition to the unique aspects of science learning. Thus, this investigation of online science courses encompasses analysis of perceptions regarding online education combined with perceptions of the unique aspects of science learning, providing a comprehensive analysis of science in the online environment. Consequently, the following research questions guiding this study address both online education and science online education:

Online education:

1. What does the literature identify as quality indicators for online education?

2. What indicators do the university stakeholders use to evaluate the quality of online education in the context of university science courses?

Science online education:

3. What does the literature identify as science learning objectives, especially for science laboratories?

4. How do the university stakeholder groups evaluate online science courses in relation to the science learning objectives?

1.4 Research Methods Overview

1.4.1 Establishing Literature Identified Quality Indicators

Quality indicators for online science education were established through focused reviews of the literature and used to guide the data collection and analysis of this qualitative interview study. Investigating the quality of online science education incorporates online education more broadly, with the specifics of science learning. Identifying previously established quality indicators was best achieved through two focused reviews of the literature. The first focused literature review dealt with quality indicators for online education generally while the second determined science laboratory learning objectives as representative of the unique aspects of science learning. The results of these literature reviews provided a framework used to guide the data collection and analysis of the interviews with participants.

1.4.2 Interviews and Analysis

This research study investigated the quality of online science education at the tertiary level from the combined perspectives of university administrators, instructors, and students. In order to acutely investigate the unique perceptions of stakeholders, a qualitative interview study was used. One-on-one interviews served as the primary data source and document analysis and non-participant observation allowed for added depth in understanding participant perceptions of quality indicators of online science. Interviews were conducted at the university campuses in October 2014, using semi-structured, open-ended, interview questions. Interview data were coded for comparison to the quality indicators established from the literature and analyzed for overarching themes. Several themes emerged regarding the skepticism of online science education, as well as the identification of significant quality indicators identified by participants.

1.5 Universities and Stakeholder Participants

This study includes five universities from the Midwestern United States located in the states of Kansas, Illinois, and Missouri. The universities are 4-year institutions that offer Bachelor Degrees in the core sciences. Core sciences refers to disciplines of physics, chemistry, biology, astronomy, and earth sciences. The universities were selected based on the requirement of offering a minimum of two online undergraduate science courses between Spring 2013 and Fall 2015, and were intentionally chosen to maximize the variability in the university size. Each university is comprised of three participant groups: university administrators, online science instructors, and online science students.

Participants ranged in their experience with online science education, some experiencing online teaching or learning for the first time, others having several years of experience. Spanning all universities, each participant group was studied as a unique group as well as collectively representing the university population as a whole. Interview data were collected from 50 participants across the five universities: 16 administrators, 14 instructors and 20 students.

1.6 Significance

This study has both theoretical and practical implications for tertiary level online science education. The results and discussion from this research may benefit researchers, policy makers, online curriculum developers, and administrators and instructors implementing online science courses into their university curriculum.

As the demand for online education in science increases, a clear understanding of what quality online science courses entail becomes important. Identification of quality indicators gives all stakeholders in higher education insight into what is necessary for the effective implementation of science in higher education online learning environments. This study helps to fill the gap in knowledge of quality perspectives of online science courses at the tertiary level. The insight gained from multiple perspectives is beneficial for future research regarding all aspects of online science education. This representation of the aspects considered essential for providing quality online science courses through the combination of literature and perceptions from three primary stakeholder groups provides a theoretical foundation upon which further research can build and expand. This research provides a unique understanding of the perceptions of three stakeholder groups, giving insight and rationales into the continued skepticism of online science education. These findings can help to bridge the gap between the differing results of educational research and general perceptions of quality in online science education.

1.7 Thesis Overview and Organization

This thesis investigates the quality of online science education at the tertiary level through identification of salient indicators of quality and perceptions of three primary stakeholder groups: university administrators, instructors and students.

Chapter 2 provides a review of the current status of online science education in higher education, addressing the history of online science education, discussing the "no significant difference" phenomenon of online compared to face-to-face education and current research on perceptions from the three stakeholder groups. Chapter 3 details the research methods and procedures of this thesis, outlining the research paradigm and presents the research design, demographics and criteria, as well as participant descriptions, recruitment and data collection procedures.

Chapters 4 and 5 present the results pertaining to the quality of online education more broadly. Chapter 4 responds to Research Question 1, identifying the quality indicators for online education. Chapter 5 responds to Research Question 2, presenting the results of the stakeholder perceptions regarding online education quality and a comparative analysis of these results with those established from the literature.

Chapters 6 focus on the quality of science specific aspects of online education. Chapter 6 presents both the literature established quality indicators and stakeholder perceptions of quality unique to online science courses, responding to Research Questions 3 and 4. Additionally, this chapter presents themes which frame how stakeholders evaluate the realization of online science education in relation to science learning objectives.

Chapter 7 provides a discussion of the major challenges identified by the stakeholder groups in providing effective online science education in relation to the current literature. The thesis concludes in Chapter 8 with a final summary of the entire thesis presenting limitations of the study, the significance and suggestions for further research.

Chapter 2.
Review of the Current Status of Online Science Courses in Higher Education

There is substantial research about online education because universities around the world are offering more online courses and fully online degree programs as part of their regular curriculum. The majority of published work focus on comparisons of online learning environments to face-to-face learning in an effort to ensure universities are offering equitable education across modalities. While these studies have helped to solidify online education in the mainstream higher education market, the influence of online education is not uniform across all disciplines. Course offerings and literature regarding online science education remains lacking compared to other online disciplines. Further, a limited body of knowledge exists regarding perceptions of online science effectiveness and what factors specifically contribute to quality in online science courses.

The goal of this literature review is to summarize the current status of online science education in the higher education marketplace. A review of the results of over a decade of comparative studies of online and face-to-face learning is presented, including a discussion of the well-known 'no significant difference' phenomenon. A discussion of science learning specific attributes set the stage for understanding the general hesitation towards learning science online. Finally, as this study seeks to develop a firmer understanding of quality factors pertinent to online science courses from those directly involved, the literature on perceptions from primary stakeholder groups is discussed.

2.1 Understanding Online Higher Education

Distance education has provided learning opportunities for students studying away from a traditional university campus for many years. Being able to take university courses and complete full degree programs remotely has provided students with educational opportunities that may otherwise not have been available (Bruce, 2004; Gray, 2013; Jeschofnig & Jeschofnig, 2011). Online education has rapidly replaced other distance delivery methods and is now the leading method of delivering distance education. This development has created a new higher education market in which universities are competing for success.

2.1.1 Terminology History: Distance Education to Online Education

Distance education was used long before the establishment of online technologies (Bates, 2005). Historically, distance education or distance learning utilized correspondence study, video conferencing and educational television. Computers, email and the Internet have supplemented these delivery methods (Belanger & Jordan, 2000; Haughey et al., 2008; Jegede et al., 1995; Moore, 2011). Although the term ‘distance education’ generally encompasses online education, there remains a discrepancy among the literature and research community concerning the use of online education terminology and its relation to distance education. Some argue that online education is a “relatively new phenomenon associated with the development of the Internet in the 1990s” (Guri-Rosenblit & Gros, 2011, p. 3), separate from distance education. However, others argue that online learning is not new, but is an evolution of distance education that occurred with the development of computer networking (Harasim, 2000). This evolution, or generational shift, supports thinking of online education as a new subset of distance education.

Distance education generations are defined by the primary way education is conducted or delivered, from correspondence, multi-media, telelearning, and finally online education (Bates, 2005; Parchoma, 2010). In 2009, Moore et al. (2011) conducted a study on the use and understanding of terminology for distance and online learning environments. They found that participants were more familiar with the term online learning, whereas the term distance learning was viewed as outdated and less familiar. Online education incorporates online delivery of course materials, interactive learning activities, avenues of communication, and assessment delivered remotely via the Internet (Cavanaugh, 2001; Guri-Rosenblit & Gros, 2011; Harasim, 2012; Maddux et al., 2010). Branching both sides of the argument, in the current higher education climate, it is acceptable to refer to online learning as a modern version of distance education (Harasim, 2000).

Beyond delivery methods, distance education is traditionally described as education delivered to individuals who are “geographically dispersed or separate by physical distance from the instructor" (Belanger & Jordan, 2000). Online learning no longer necessarily implies learning at a distance (Bates, 2005). Online learners are found both on and off university campuses, making distance less of a defining factor in online learning. Bates eloquently concludes that "distance learning can exist without online learning, and online learning is not necessarily distance learning" (Bates, 2005, pp. 14-15). Guri-Rosenblit and Gros (2011) agree that online learning is no longer exclusively meant for learners at a distance. Online learning allows for students as well as instructors to be located on or off the university campus. In fact, both distant students and residential students are utilizing online learning opportunities, adding to the growing number of participants in online higher education (Haythornthwaite & Kazmer, 2004; Jeschofnig & Jeschofnig, 2011). Educational tools and technology available for all types of learning environments has caused the physical location of student and instructor to become less of the defining factor for distance learning (Bruce, 2004).

Although the mode of delivery has evolved over time, the purpose and objectives of distance learning have remained somewhat the same in the online world, providing education to those not able to attend class at a designated time and place. The foundations of distance education are congruent with those of today's online education showing the connection between the two terms foundationally. A clear understanding and definition of these terms helps to clarify the aspects unique to current online education and how they have developed with the changing technology. This study uses the terms online education and online learning focusing on the delivery method and use of technology as a new educational paradigm built upon the existing paradigm of distance learning (Sangra et al., 2012).

Definitions:

Distance Education/Learning – describes an educational environment in which learners are distant or displaced from the physical university campus. Distance education can be online, but not synonymous with online education.

Online Education/Learning – describes an educational environment delivered via the Internet that excludes the traditional face-to-face classroom environment.

> When the term ‘learning’ is used, instead of education, it often suggests pedagogy and curriculum.

The types of online education and the tools needed to provide this type of educational environment are in constant growth and flux. Currently, universities utilize a few basic delivery methods and tools for providing online learning environments, setting the foundation of online education in the current digital age.

2.1.2 Online Higher Education Growth

Online education has allowed local universities to become global institutions, allowing students to study at universities beyond their physical geographical location (Gray, 2013; Turoff et al., 2004). This expansion of higher education provides economic opportunities for the universities and education opportunities for students, but it requires additional accommodations and policy changes. Universities work to satisfy the student demand, so as the population of students changes, so must the policies and accommodations that are provided by universities (Chau, 2010; Jeschofnig & Jeschofnig, 2011; Kennepohl & Shaw, 2010).

The number of students participating in online education is continuing to increase. In the Fall of 2016, it was reported that 6.3 million students were enrolled in at least one online course, which is a 5.6% increase from the year 2015 to 2016 (Seaman et al., 2018). The most recent data from the Integrated Postsecondary Education Data System (IPEDS), reports that just two years later, in the Fall of 2018, 6.9 million students were enrolled in online courses, which accounts for 35.3% of all students enrolled in postsecondary education at the time (U.S. Department of Education, 2019b). The demand for online courses continues to rise, as the growth of online education accelerates past other segments of higher education in the United States (Gallagher, 2019). As Bonvillian and Singer (2013) state, “the online education revolution is here” (p. 26). Educators understand and are embracing the fact that online instruction has become a lasting component of higher education (Buckley & Narang, 2014; Haythornthwaite & Kazmer, 2004; Young & Norgard, 2006). Over the last decade, student enrollment in online education has been increasing even though enrollment in higher education overall has been decreasing (Seaman et al., 2018).

Student’s increasing interest in online higher education is mainly attributed to the flexibility and convenience that online education provides (Du et al., 2019; Young & Norgard, 2006). For asynchronous online education, this flexibility in learning overcomes the limitations of the physical space and time restrictions of traditional education settings (Arbaugh, 2004; Bates, 2005; Du et al., 2019). Online education is therefore well suited for both traditional and non-traditional students balancing school, family, work, and other obligations (Jaggars, 2014; Shea, 2007). As online education has become a mainstay in higher education across the United States, universities are no longer asking whether they should offer online courses, but how they will offer online courses, at what level, and in what disciplines.

2.1.3 Types of Online Delivery

Tertiary level online education is delivered in three distinct forms: Open learning, Massive Open Online Courses (MOOCs), and university credit based online courses and programs. MOOCs and Open Universities focus on the concept of open learning policy, whereas online education is administered as part of a university’s regular educational courses and programs offered (Bates, 2005; Rumble, 1989).

Open learning has been implemented outside the United States for decades, with the British Open University (OU UK), established in 1967, being at the forefront of open learning in higher education (Bates, 2005; Harasim, 2000). Other countries with long standing open learning offered by universities include Australia (Open Universities Australia established in 1993), South Africa (University of South Africa (UNISA) established correspondence courses in 1946), and Germany (the University of Hagen, Germany established in 1974). However, open universities have yet to be very successful, or as well understood, in the United States higher education sector (Allen et al., 2016; Meyer, 2006). In current education culture, open learning is known for removing barriers such as admission standards and access for learning (Bates, 2005; MacKenzie et al., 1975; Ross & Scanlon, 1995). Open learning does not define the delivery method for courses as these can be conducted face-to-face or at a distance (Harasim, 2000; Keegan, 1996).

MOOCs are a form of open learning that relies solely on online delivery typically offered by, or in association with, universities and provided by private companies and consortium such as edX, Coursera, and Udacity (Buckley & Narang, 2014; O'Connor, 2014). MOOCs have become prevalent worldwide, attracting tens of thousands of student users enrolled in a single course, creating open online education on a massive scale (Lombardi, 2013). Although MOOCs have received a lot of attention in the last few years in the United States (Park & Shea, 2020), only about 11% of universities were experimenting with, or involved in MOOCs in 2015 (Allen et al., 2016). More recently, universities are reporting little major investment in MOOCs, but report continued interest and experimentation with such courses and programs (Legon et al., 2019). Interest in enrolling in individual MOOCs appears to be declining among students. In a recent survey of online college students, just 13% have ever enrolled in MOOCs, with only 4% reporting that they plan to enroll (Magda et al., 2020). MOOCs are considered a separate form of online learning from the traditional online education offered by universities (Allen & Seaman, 2013, 2014; Buckley & Narang, 2014; O'Connor, 2014; Sauter et al., 2013; Scanlon, 2012). However, the two types of online offerings are currently starting to merge with some traditional universities accepting credit earned from MOOCs (completed with a passing grade and paid certificate of proof) toward degree completion at their university. Arizona State University partnered with edX and Georgia Institute of Technology (Georgia Tech) partnered with Udacity are just two examples of such mergers.

Online education, within higher education in the United States, implies online education administered by a university where students receive academic credit and pay tuition. Comparatively, there are few universities that are exclusively online. The vast majority (87%) of student enrollment in online courses is at traditional universities that also offer on-campus courses (Ginder et al., 2019). Most of this online enrollment is in individual online courses. However, universities are also developing fully online degree programs which allows students to earn bachelor’s degrees online. Completion of a fully online degree program requires all the same courses required for the major as well as general education courses.

At traditional universities, online courses can be delivered fully online or in a blended (or hybrid) format. Blended courses include some traditional, face-to-face learning combined with online learning (Bonk & Graham, 2006; Bonvillian & Singer, 2013; Lombardi, 2013). Allen et al. (2016) have stratified blended education based on the proportion of content delivered online as outlined in Table 2.1. The final designation, "online", is often addressed as fully online (Bates, 2005), completely online, or as Harasim (2000) says, totally online, when specifying the mode of online education delivery.

Table 2.1

The Prototypical Course Classifications Used in This Study

Proportion of Content Delivered Online	Type of Course	Typical Description
0%	Traditional	Course where no online technology is used – content is delivered in writing or orally
1 – 29%	Web Facilitated	Course that uses web-based technology to facilitate what is essentially a face-to-face course. May use a learning management system (LMS) or web pages to post the syllabus and assignments.
30 – 79%	Blended/Hybrid	Course that blends online and face-to-face delivery. Substantial proportion of the content is delivered online, typically uses online discussions, and typically has a reduced number of face-to-face meetings.
80+%	Online	A course where most or all of the content is delivered online. Typically have no face-to-face meetings.

Note. Reprinted from "Online Report Card: Tracking Online Education in the United States" by Allen et al., 2016, Babson Survey Research Group and Quahog Research Group, LLC., p. 7.

The type of fully online education can be further divided into synchronous and asynchronous delivery modes. Synchronous online learning can take place anywhere via the Internet, but requires the instructor and all students to be online and communicating at the same time (Tallent-Runnels et al., 2006). Asynchronous online learning is free from time and space constraints, allowing the learner to access the course materials any time and from anyplace as long as an Internet connection can be accessed (Bates, 2005). Fully online, asynchronous courses at traditional universities is the chosen focus of this study as it continues to be the most widely used type of online higher education in the United States (Legon et al., 2019; Oztok et al., 2013).

2.1.4 Tools for Online Delivery

Online education was made possible and is frequently defined by technological advancement. "In the 21st century we simply have more technology and more choices" (Boettcher, 2004, p. 33; Mawn et al., 2011). There are numerous ways to deliver asynchronous online courses using a variety of tools and software, but the most widely accepted avenue is through the utilization of commercialized course and learning management systems such as Blackboard, Moodle, Sakai, Canvas, Desire2Learn and eCollege. These course management systems provide a complete framework for designing and implementing a class beyond the delivery of just lecture materials. They also provide avenues to foster online communication among students and between instructors and students. Harasim (2000) highlights that while email remains the major networking application, computer conferencing (text-based, audio and video) establishes the core of collaborative online learning environments. Popular programs used for such real-time collaborations include Blackboard Collaborate, Zoom, and Skype. The growth of available online educational tools has allowed online courses to become a viable addition to higher education programs.

It is inevitable that online education will continue to evolve as technology advances and as students and educators become more proficient and comfortable with technology used for learning. It is clear that "online learning is anything but static" as universities continue to provide online education across various disciplines (Bowen, 2013).

In this section, the historical development of online education in higher education was discussed. Derived from distance education, online education is no longer only serving learners at a distance, but serving a wider audience as an integrated part of regular university courses. The majority of online courses are now taking place in an asynchronous format.

2.2 Online Science in Higher Education

As universities embrace the addition of online education as part of their programs, each discipline is faced with the decision of whether to implement online courses. In 2008, Allen and Seaman reported that the consistently steady growth of online education enrollment is not concentrated to just a few disciplines, but is seen across almost all disciplines. The disciplines categorized as ‘liberal arts and sciences, general studies and humanities’ are among the fastest growing disciplines to provide full online degree programs (Allen & Seaman, 2008). The core science disciplines however, are not easily extracted among this generalized discipline category. The core sciences refer to the disciplines of physics, chemistry, biology, earth sciences, and astronomy. The number of online science courses, as well as research efforts in online science, are not as common as in many other disciplines, particularly when considering fully online degree programs (Downing & Holtz, 2008; Flowers, 2011; Kennepohl & Shaw, 2010; Xu & Jaggars, 2013). According to IPEDS, in the academic year 2016-2017, more than one half of degree-granting postsecondary institutions offered at least one fully online degree program; however, there is substantial variation among the disciplines offering these fully online degree programs (Xu & Xu, 2019).

IPEDS data from 2016 report that the disciplines of business and marketing, health and education provide the highest number of fully online programs, offering upwards of 26% of all their degree programs fully online. The biological and physical sciences on the other hand, offer only 1% of their degree programs fully online and rank in the lower tenth percentile of disciplines offering online programs (Xu & Xu, 2019). While disciplines in the core sciences are not offering many fully online degree programs, the pursuit of science online in higher education at the course level is undoubtedly growing along with online education growth overall (Scanlon, 2011). Fully online degree programs often require general education courses, making online science and laboratories a necessary component for degree completion.

2.2.1 The Demand for Online Science in Higher Education

There is an increased awareness of the importance of science education and science literacy among the United States public at large (Kennepohl & Shaw, 2010; Scanlon, 2012). An understanding and use of scientific inquiry has become important for everyone, especially as scientific information becomes necessary for making everyday life choices such as what food to eat, products to use and the tools required for business and pleasure (Allum et al., 2018; National Research Council, 1996). Science education methodology, such as the use of inquiry learning, can help prepare students for life after graduation, fostering more scientifically literate citizens who have a grasp of how scientific information is obtained and used in society (de Jong, 2006; DeHaan, 2005). The level of science knowledge among Americans remain strongly linked to education, with more educated Americans showing higher scientific literacy (Pew Research Center, 2019). As more students pursue their undergraduate education through online learning, the need to foster scientific literacy online is indeed necessary. As Jeschofnig and Jeschofnig (2011) explain, "because science education is vitally important to individuals and society, it must be supported and offered in all instructional modes" (p. 12). With the increased demand for more online university education, an opportunity to reach more undergraduate students and prepare them as scientifically literate citizens can be fostered by offering more undergraduate online science courses (Varty, 2016).

The increase in student interest in using the online environment is attributed largely to the flexibility of time and place for learning (Arbaugh, 2004; Paechter & Maier, 2010). There is a growing demand from students for the same flexibility in science education at the undergraduate level (Kennepohl & Shaw, 2010; Scanlon, 2011). In response to the increased demand from students for online education, universities are adding more fully online degree programs but sometimes find it difficult to provide all of the general education courses needed as part of a fully online undergraduate program (Allen et al., 2016). Core science disciplines are typically part of these general education requirements and therefore universities are beginning to push for more online science courses within their universities. Therefore, the requirement for a more scientifically literate society, combined with the popularity of online education and a need for general education courses, creates a demand for online science at universities across the United States.

2.2.2 Unique Aspects of Science Learning in an Online Environment

The majority of literature sources concerning online science education shows that the characteristic aspects of learning science can be effectively administered in an online learning environment. Ross and Scanlon (1995) explain that science courses should aim to provide meaningful and useful content to learners using a diversified range of opportunities, while also sharing the awe and excitement of science. Science education is also generally agreed to embody unique aspects such as the addition of laboratory or hands-on type environments (Hegarty-Hazel, 1990; Mawn et al., 2011; Ross & Scanlon, 1995), constructivist and inquiry based learning approaches (Davis & Snyder, 2012; Mintzes, 2020) and a need for interaction and collaboration (Anderson, 2010; U. S. National Research Council, 2005; Scager et al., 2020). Such criteria, inherent in science learning today, can be accomplished in an online learning environment (Kennepohl, 2016).

Laboratories are probably one of the most widely accepted, fundamental components of science education and have been the largest deterrent to the acceptance of online science education (Jeschofnig & Jeschofnig, 2011; Kennepohl, 2010, 2016). Introductory science courses often employ methods of experimental inquiry which are frequently conducted as part of a science laboratory or hands-on learning activity (Kam & Hoop, 2013). Laboratory work is typically viewed as the primary hands-on application of science concepts, where a learner tactically interacts with substances in a laboratory setting. Although this is just one type of laboratory, science laboratories can be conducted in a wide variety of ways including traditional laboratory experiments, home laboratory work, fieldwork, remote laboratories, and virtual simulations. Take-home laboratory kits, remote laboratories and virtual laboratory simulations have been shown to be effective methods of providing science laboratory experiences for online students (Edwards et al., 2021; Faulconer & Gruss, 2018; Finkelstein et al., 2005; Flowers, 2011; Miller et al., 2018; Rowe et al., 2018).

Contemporary perceptions of science education view constructivism to be at the heart of how students learn science (Driver et al., 1994; Mintzes, 2020).

Constructivist theory of knowledge views knowledge as something that must be actively constructed mentally by the learner instead of simply transmitted directly from instructor to student (Blais, 1988; Von Glasersfeld, 1995). Under the foundation of constructivism, science higher education often utilizes a guided inquiry-based learning approach where students are actively engaged in their own learning involving exploration, discovery, testing of ideas, and asking questions in the pursuit of understanding (de Jong, 2006; DeHaan, 2005; Scanlon, 2012). Literature on the use of constructivist learning theory and inquiry-based learning in online education find that this type of teaching and learning can be successfully accomplished in an online environment (Cotta Natale et al., 2021; Davis & Snyder, 2012; Jordan, 2013; Miller, 2008).

Learning science involves both individual and social processes making interaction and collaboration an essential part of science education (Anderson, 2010; Driver et al., 1994). Within the foundations of a constructivist theory of knowledge, much of science learning emphasizes a social constructivist approach in which learning is a collaborative method. Collaboration is even considered to be a best practice in science education by the U. S. National Research Council (2005). The foundations of social constructivism in science learning often build upon Lev Vygotsky's constructivist models which emphasize the role of interaction between individuals within a constructivist framework (Agarkar & Brock, 2017). Interaction includes interaction between instructors and students, interaction among students, and student interaction with the content (Abrami et al., 2011; Moore, 1989). These forms of interaction are possible and have been shown to be effectively conducted in online learning environments through the use of technological tools (Anderson, 2010). Interaction in asynchronous online education takes place primarily through the use of learning management systems, email, discussion board forums, and computer audio or video conferencing (Asbell-Clarke & Rowe, 2007; Downing & Holtz, 2008; Revere & Kovach, 2011; Vonderwell, 2003).

Situated within social constructivism, much of research and practice in online learning refers to the Community of Inquiry (CoI) framework which proposes that genuine collaboration among students and with instructors is a catalyst for authentic knowledge creation and is crucial for quality online education (Garrison et al., 2000, 2001). The framework focuses on the theory that knowledge can be constructed through the process of critical inquiry within collaborations in an online learning community (Shea & Bidjerano, 2008). The framework identifies three interrelated components that lead to genuine collaboration in online learning: cognitive presence, social presence, and teaching presence (Garrison et al., 2000, 2001). As this framework is foundational and used widely among the online learning community, research continues to verify the validity and reliability of these elements (Garrison & Arbaugh, 2007; Geraldine & Lakhal, 2020).

2.2.3 Level and Disciplines of Science Online

The amount of research concerning level and disciplines offered in online science education is relatively limited. In an attempt to gain a better understanding of the status of online undergraduate science education, Downing and Holtz (2008) conducted a small study surveying university science education in nine Midwest states and found that online courses in the sciences tend to be at the undergraduate lower-level, asynchronous and in the physical sciences. This study found that more online courses in biology, earth science, and chemistry were offered than in physics and astronomy (Downing & Holtz, 2008). A study of community colleges in Washington state found that 10% of all enrolled courses were online at the undergraduate lower-level, with 8.42% of those in the natural sciences. Astronomy and geology courses were the most common at 33% and 19%, respectively, followed by biology (7%), chemistry (4%) and finally physics (2%) (Xu & Jaggars, 2013). Much of the literature concerning online science education, including several large meta-analyses, focus on the laboratory component, as it is a unique aspect of science education at the undergraduate level (Brinson, 2015; Ma & Nickerson, 2006). A review of the current literature reveals that much of the literature concerning laboratories online focus on the disciplines of chemistry, biology and physics. These disciplines typically have a required concurrent laboratory component, whereas the disciplines of earth science and astronomy, the laboratory component can often be taken as a separate course.

This section discussed the role of science courses as a necessary part of the growth of online education. Online science courses fulfill a general education requirement for fully online degree programs and fosters scientific literacy among undergraduate students. The literature shows success in maintaining the unique aspects of science online, including laboratories and following a social constructivist approach to learning. Most undergraduate online courses in the sciences are lower-level and in the physical sciences.

2.3 Comparisons between Online and Face-to-Face Science Education

Online learning has become an essential component of higher education resulting in a copious amount of research. The bulk of this research are studies comparing traditional face-to-face classroom education to online education, with the goal of determining whether online courses are as effective as face-to-face courses. Student learning outcomes and retention rates are the most common measures used to compare the effectiveness of online and face-to-face courses (Lack, 2013; Wu, 2015). Reported results on the effectiveness of online education are mixed.

Some studies indicate that student performance in online courses is worse than in similar face-to-face courses, especially for community college students. Francis et al. (2019) found that the academic outcomes (course grades and pass rates) of students in online community college mathematics courses were lower than in face-to-face courses. Furthermore, in a large study examining performance gaps between almost 500,000 online and face-to-face courses, Xu and Jaggars (2014) found that community colleges students in online courses had more difficulty succeeding in their courses than students in face-to-face courses, receiving lower course grades and showing lower persistence online. One study reported that whilst online students struggled to persist with the course, the students who stayed on outperformed their face-to-face class counterparts in computer science courses (Dutton et al., 2001). On the other hand, Schoenfeld-Tacher et al. (2001) found that students in an upper-level, online histology course showed significantly higher academic performance on a content post-test compared to students in a similar face-to-face course.

Much of the research comparing online and face-to-face learning report little difference in student outcomes between the modalities. Highly cited reports including large-scale analyses from the Babson Survey Research Group and the US Department of Education determined the effectiveness of online learning to be at least equivalent to traditional face-to-face, classroom-based instruction (Allen et al., 2016; U.S. Department of Education, 2010). Allen et al. (2016) report 71.4% of academic leaders in their study rate the learning outcomes in online education as the same or greater to those in face-to-face education. Although findings vary in regard to the effectiveness of online courses compared to face-to-face courses, much of the discussion over the last two decades has centered upon results indicating no significant differences in effectiveness between the types of learning environments across disciplines in higher education (Paul & Jefferson, 2019; Russell, 1999; U.S. Department of Education, 2010).

2.3.1 Foundations of the No Significant Difference Phenomenon

Most comparative studies of online learning have shown little difference in effectiveness based on student learning outcomes, resulting in the literature addressing this as 'the no significant difference phenomenon' (Russell, 1999; Twigg, 2001a). This phrase was first noted when Thomas Russell published a compendium of 355 research reports, summaries and papers from 1928 to 1998, indicating inconsiderable differences in student learning outcomes between technology-based distance learning and traditional face-to-face learning (Russell, 1999). Comparative research has continued, including several meta-analyses, which indicate that online learning is just as effective as traditional classroom-based instruction (Bell & Federman, 2013; Cavanaugh & Jacquemin, 2015; Paul & Jefferson, 2019; U.S. Department of Education, 2010). Most comparative research reporting no significant difference between online and face-to-face learning analyzes student achievement or learning outcomes (Colorado Department of Higher Education, 2012; U.S. Department of Education, 2010; Wu, 2015). Measures of learning outcomes typically include performance measures such as examination and assignment scores, overall course grades, and student satisfaction of learning (Swan, 2004). When appropriately designed, constructed, and taught, online courses have the ability to provide an engaging learning environment with improved student outcomes appropriate for delivery of education in all disciplines, including the sciences (Bourne & Moore, 2005).

2.3.2 Online Science and 'No Significant Difference'

Similar to online education research, many studies investigating online education in the sciences have focused on comparisons of online and face-to-face science education for specific science disciplines (Flowers, 2011). Much of the research focusing on science online education are also concluding no significant difference in learning outcomes in science courses and laboratories for various science disciplines (Brinson, 2015; Lee et al., 2011).

In the earth sciences, there appears to be few studies that critically assess learning outcomes in online courses compared to classroom instruction (Cloutis, 2010). However, the few that do, find that earth science courses and earth science laboratories can be effectively delivered online as long as they are well designed and take student needs into account (Cloutis, 2010; Paul & Jefferson, 2019; Reuter, 2007; Veal et al., 2004). For example, in 2010 a direct comparison study of student outcomes based on exam scores from an online and face-to-face earth science community college course found that students performed equally well in both environments (Werhner, 2010). Another study which investigated the development and implementation of an online undergraduate introductory geology laboratory also found no significant difference in assessment outcomes, namely, for grades between a traditional on-campus laboratory and the new online laboratory (Feig, 2010). More recently, Paul and Jefferson (2019) conducted a study with over 500 students in an undergraduate environmental science course offered both online and face-to-face between 2009 and 2016. They reported no significant difference in student performance (course grade received) between the two modalities with respect to gender and class rank.

Literature concerning online astronomy education appears lacking compared to other sciences. One study, focused on student conceptual understating learning gains using pre- and post-tests, found that students in an online astronomy course showed comparable learning gains to students in similar face-to-face astronomy course (Margoniner, 2014). However, Margoniner (2014) also noted that the retention rate for freshmen and sophomore students in the online course was much higher, resulting in a self- imposed segregation of student type between the modalities.

Much of the literature concerning online astronomy education focuses on course design techniques rather than comparison of learning outcomes, but advise that with careful preparation and purposeful design, introductory astronomy courses can be effectively conducted online (Miller & Redman, 2010; Radnofsky & Bobrowsky, 2005).

In physics online education, many studies focused on comparing web-based versus paper-based homework systems within traditional physics courses (Lee et al., 2011). The few studies that do investigate full online introductory level physics courses and laboratories find them to be effective. In 2009, the Colorado School of Mines developed an online version of their calculus-based introductory level physics course, geared towards science and engineering majors. This course was run parallel to the traditional, on-campus versions of the course for comparative analysis of effectiveness. The study found that student's conceptual understanding of energy increased significantly in both the online and on-campus versions of the course. Comparing pre to post-test scores for each group, the students enrolled in the online version showed a higher gain, but not significantly. These results indicate that offering an online version of a university level introductory physics course "does no harm" to student learning (Dunlap et al., 2009, p. 72). A recent study comparing student outcomes using examination scores and course grades for online and face-to-face versions of an algebra-based physics course for non-majors found no significant difference between the modalities (Bergeler & Read, 2021). In addition, the study examined student satisfaction and found that the online students reported a higher rate of satisfaction of the course than the face-to-face students.

Majority of comparative studies in biology online education also report no significant differences in student learning outcomes. Johnson (2002) conducted a direct comparison study of two non-introductory biology courses with laboratory, one taught online with home laboratory kits, and the other taught on-campus and in a traditional laboratory setting. Online students were found to be as successful as on-campus students in their conceptual knowledge, graphing skills, reasoning ability and attitudes towards science. In addition, no significant difference was found between final examinations mean scores for the two groups of students (Johnson, 2002). Analyzing knowledge outcomes of community college students in online and face-to-face general biology courses with a laboratory, Riggins (2014) also found that student learning outcomes based on pre- and post-tests were similar. This study also found that biology students in both the online and face-to-face courses were prepared for the next level science course (Riggins, 2014). Biel and Brame (2016) conducted a review of the literature which compared student performance in online and face-to-face undergraduate biology courses, identifying 13 studies: 5 large-scale studies comparing multiple sections of courses, and 8 smaller studies examining singular courses. Majority of the studies in their review found no significant difference in student learning outcomes between the two modalities (which include the studies by Johnson (2002) and Riggins (2014) presented here). However, the remaining studies in the review report differing results. Two studies found that students in face-to-face courses outperformed students in online courses when considering final course grades across multiple sections, however these studies did not consider course design elements in their comparisons. Biel and Brame (2016) conclude that, considering results for all the studies reviewed, well-designed online biology courses can be at least as effective as face-to-face courses in regards to student learning outcomes.

Literature investigating aspects of chemistry online education appears to be more abundant than for any other core science discipline, but often focus on particular course components, individual topics or the laboratory, as opposed to an entire course (Faulconer et al., 2018; Lee et al., 2011). Generally, studies focusing on fully online chemistry courses in higher education once again confirm little difference in learning outcomes between online and on-campus students taking chemistry (Phipps, 2013). In line with the results of previous studies, a recent study examining student performance between an online and face-to-face version of an introduction to inorganic chemistry course, found a negligible difference in student's learning of core concepts (Nennig et al., 2020). However, a study exploring difference in student outcomes, including pass rate, grade distribution and withdraw rate, between online and face-to -face versions of a first-year general chemistry course with laboratory using data from 823 students from 2015-2017 reports differing results (Faulconer et al., 2018). The study reports that little difference was found in withdraw rates and pass rates between the modalities. However, a disparity between grade distributions were reported, with students in the online courses earning higher final course grades than those in the face-to-face courses, but the authors note that the courses and assessments were not standardized between the modalities.

The core science disciplines, although relatively lacking in abundance in the online learning world compared to disciplines such as education and business, have been shown to be effective online compared to traditional face-to-face science learning (Flowers, 2011; Kennepohl, 2009).

2.3.3 The Online Science Laboratory and 'No Significant Difference'

In teaching science, the laboratory is an essential component of science learning, as it is what makes science ultimately unique from other disciplines. Because of the importance of science laboratories in science education and the perceived difficultly of accomplishing hands-on work in an online environment, many people question the effectiveness of conducting science laboratories online (Corter et al., 2011; Flowers, 2011; Jeschofnig & Jeschofnig, 2011). Many science educators believe that it is one thing to put science content online; putting science laboratories online is quite another, thinking it sounds impossible to conduct science laboratories online that are comparable to a face-to-face physical laboratory (Scheckler, 2003).

While the general perception by many science educators of online science laboratory is particularly negative, research studies report quite a different story in terms of students' learning outcomes. Much of the literature suggest that well-designed online laboratories can be as effective as traditional face-to-face laboratories, particularly when considering student content knowledge and student attitudes (Faulconer & Gruss, 2018). The level of students' conceptual and procedural understanding is not considerably different between online science laboratories (mostly simulation based) and face-to-face laboratories (Brinson, 2015; de Jong et al., 2013; Tatli & Ayas, 2013). A study of an introductory undergraduate biology course revealed no significant difference in learning gains on content tests and final course grades between students participating in face-to-face and virtual laboratories (Reece, 2017). Many other studies investigating online biology laboratories, using virtual or simulation-based laboratories, found that online laboratories educate students as effectively as hands-on laboratories (Dobson, 2009; Flowers, 2011; Swan & O'Donnell, 2009). In addition, studies comparing virtual chemistry laboratories to traditional hands-on laboratories are finding student-learning outcomes to be similar (Dalgarno et al., 2009; Faulconer et al., 2018; Hawkins & Phelps, 2013).

Another study of physics laboratories at two large universities, in the United States, found that virtual and hands-on laboratories were similar in imparting the concepts of the laboratories to students (Darrah et al., 2014). A study conducted by Finkelstein et al. (2005) at the University of Colorado Boulder, on online inquiry-based physics laboratories, suggests that it is possible, and sometimes preferable to use virtual laboratory equipment instead of real equipment. In this study, one group of introductory level physics students used computer simulations of electric circuits where another group of students, within the same physics class, used real equipment in the laboratory. After completion of the laboratory, both groups were tested on their conceptual understanding as well as their ability to manipulate a real electrical circuit. The study found that the students who used the computer simulation laboratory performed better on the conceptual questions and appeared to excel more at the manipulation of the real circuits than the students who initially participated in experimentation with physical laboratory equipment (Finkelstein et al., 2005). This finding indicates that computer simulations can provide effective learning in some physics laboratories. Similar results were found in a study comparing student learning outcomes in an online virtual laboratory with a face-to-face laboratory for a physical science laboratory course, concluding that virtual laboratories can be effective. The study reported no significant difference in student knowledge gains (determined using pre- and post-tests) and student attitudes/preferences between physical science virtual laboratories and face-to face laboratories (Miller et al., 2018). The study did note that students self-selected the laboratory modality and found that the students chose the online laboratory based on the benefits of flexibility and time savings, but those choosing the face-to-face version based their decision on the desire for hands-on activities and in-person interactions.

In addition to virtual laboratory simulations, take-home laboratory kits and remote laboratories have been shown to be effective in providing science laboratory experiences for online students (Jeschofnig & Jeschofnig, 2011; Nguyen & Keuseman, 2020; Scanlon et al., 2004). Casanova et al. (2006) conducted a study investigating the effective use of “kitchen chemistry” home laboratory kits within a fully online general chemistry course for university science majors. Evaluation of the online chemistry students, using comparative assessments measures, found that students performed equally to on-campus chemistry students in a parallel course. The home laboratory approach appeared to be a rigorous and effective laboratory technique for online students (Casanova et al., 2006). However, another study evaluating an online introductory chemistry course that also implemented at home laboratories found that online students did not perform as well in the take-home labs compared to the traditional hands-on laboratory (Phipps, 2013). The laboratory components to undergraduate introductory chemistry are the largest challenge in online chemistry (Boschmann, 2003). The use of virtual laboratories in online chemistry appears to be an additional viable option (Kennepohl et al., 2005). While the research literature continues to suggest online science laboratories can be effective, national science organizations, such as the American Chemical Society (ACS), the American Association of Physics Teachers (AAPT) and the National Science Teachers Association (NSTA), remain strong proponents of traditional laboratory learning environments rather than online laboratories (Brinson, 2017). The National Association of Biology Teachers (NABT), while primarily geared towards secondary education and not higher education, holds a similar position.

The fact that educators continue to express ambiguous concern over the quality of science learning experiences in the online environment, despite studies showing student learning gains, raises questions (Rivera, 2016). Why have not perceptions of online laboratories changed in light of the comparative studies on students' science learning outcomes? What are the inherent sources of the concern and general negativity that remains regarding the effectiveness of online science courses and laboratories? In a partial answer to these questions, large meta-analyses investigating online and face-to-face science laboratories conclude that there is a wide variation in the outcomes and objectives used to measure online laboratory effectiveness (Brinson, 2015; Ma & Nickerson, 2006). Large variations in how student learning outcomes are measured in studies of online science courses are also seen. Effectively, studies comparing online and face-to-face courses and laboratories are using different measures of comparison, leading to discrepancy in results which may explain the continued unsettled debate and skepticism of the effectiveness of online science courses and laboratories (Arias et al., 2018; Faulconer & Gruss, 2018).

2.3.4 Moving Beyond 'No Significant Difference'

Even at the early stages of online learning research, Clark (1994) argued that the research findings presented above are not unexpected and that we should not expect any differences in student achievement between technology delivered education and traditional education. Some authors reason that the type of delivery is not the imperative evaluative aspect but rather it is how instruction is conducted that will influence learning (Clark, 1994; Rovai, 2003). Twigg (2001a) reflects the same sentiment, explaining that attempting to transfer traditional face-to-face courses into online delivery methods, frequently produces results that are "as good as" what we have done before. Current research suggests that in an effort to make online learning "as good as face-to-face" we may be overlooking the how the modalities differ and thus miss the unique aspects of online learning (McDonald, 2002; Nortvig et al., 2018).

With over two decades of research showing "no significant difference", researchers have begun moving beyond comparing online education to traditional standards and are moving towards "approaches that go beyond no significant difference" (Twigg, 2001a, p. 4). Researchers are recognizing that online learning environments are distinctly different from traditional classroom settings and they have evolved beyond simple comparisons with face-to-face instruction (Abrami et al., 2011; Oncu & Cakir, 2011). While studies reporting little difference in student learning outcomes between online and face-to-face science courses are insightful, learning outcomes, retention rates and student satisfaction are often influenced by more than just the learning environment modality (Nortvig et al., 2018). Thus, research has begun to focus on identifying and analyzing unique factors of online learning (Cohen & Ellis, 2004; Martz et al., 2004; Swan, 2004). When this approach is used an online course is designed expressly for the online learning environment and students, instead of being a simple conversion of a face-to-face course, the quality of the online course is often found to be improved (Northcote, 2019).

Evaluation of online education as a new paradigm can help build a clearer understanding of appropriate boundaries for behavior, guidelines for action, and rules for success within this form of education (Twigg, 2001a). This paradigm provides practitioners with the tools to effectively use and evolve online education. Along this avenue, an abundance of research in online education at the tertiary level has branched into studies aiming to understand the unique learning environment of online education to include the evaluation of aspects of learning effectiveness, practical use of tools and teaching pedagogies appropriate for online learning and investigations into the impact of online education on the higher education systems as a whole (Clayton, 2007; Oncu & Cakir, 2011; Trinidad et al., 2005; Walker & Fraser, 2005).

2.3.5 Quality of Science Online Education

In spite of findings of no significant difference between the effectiveness of online and face-to-face science education and an encouraging outlook for the use of online courses and laboratories in science, skepticism remains regarding the quality of online science education in the United States (Downing, 2016; U.S. Department of Education, 2010; Werhner, 2010). Although many authors are optimistic that the skepticism of online learning in science is behind us (Jeschofnig & Jeschofnig, 2011; Scanlon, 2011), there are still those that continue to question whether online courses provide high-quality educational experiences and if they are designed to meet the needs of the learner (Davis & Snyder, 2012).

As a result, several studies over the past decade have focused on determining quality indicators specific to online education in an effort to cohesively display what is necessary for effective online education. The effectiveness of online education is determined by indicators including, but not limited to, student satisfaction (Borg et al., 2021; Iyer, 2011; Martz et al., 2004), interactivity (Clayton, 2011; Davis & Snyder, 2012; Nandi et al., 2012), social connections, a sense of community and collaboration (Khoo et al., 2010; Rovai, 2002; Slagter van Tryon & Bishop, 2012), teaching presence (Swan, 2004; Wilson et al., 2018) and course structure (Soffer & Nachmias, 2018; Tamim et al., 2011). No formal set standards for quality in online education exist across universities. However, indicators such as those above have been compiled into several frameworks to assess quality in online education. Universities are beginning to utilize these quality frameworks, which are frequently referenced in the literature, to monitor the quality of their online programs. A few of the most commonly used quality frameworks include: *Quality on the Line* (The

Institute for Higher Education Policy, 2000), *Quality Matters* (Quality Matters, 2018), and *Online Learning Consortium (OLC) Quality Scorecard* (Online Learning Consortium, 2014). There is a high degree of congruency among such published quality standards, which is presented in more detail in Chapter 4 of this Thesis.

In this section, the results of online education research, focused on comparisons of student learning outcomes to face-to-face courses, were discussed. While results of comparative studies show mixed results, the majority of research report no significant difference in student learning outcomes between online and face-to-face courses across disciplines, including science online courses and laboratories. Measuring the quality of online courses goes beyond comparisons of student learning outcomes and considers quality indicators unique to online learning. No set standards exist for science online education, perhaps fueling continued skepticism of science online education

2.4 Perceptions of Online Education

In an effort to obtain a deeper understanding of the effectiveness of online higher education, researchers are considering the perceptions of the stakeholders directly involved: university students, instructors, and administrators. The meaning of quality in online education can vary among different stakeholders, as it is relative to the experiences and expectations of the individual (Cleary, 2001; Parker, 2008). Research of perceptions, as a way to understand quality in online education, are imperative as they elucidate online education from the eyes of those directly involved. Thus, investigation into quality without considering the perceptions of the stakeholders involved would lack depth of inquiry. The quality of online education is best measured by a collective agreement of stakeholders' perceptions of aspects shown to aid in producing acceptable, agreed upon experiences and outcomes (Cleary, 2001; Esfijani, 2018; Mitchell, 2010). As such, any discussion about quality in online education must consider the source from which quality is considered (Twigg, 2001b). Regarding online education in general, most studies focus on the student and instructor view, while fewer studies analyze administrators' perceptions. "The lack of an integrated view of quality of online education is a key issue" in understanding quality factors of online education (Esfijani, 2018). A more thorough investigation of the effectiveness of online education would consider perspectives of university instructors and administrators combined with student perceptions.

Quality indicators of learning environments are a perceived aspect of education. Many of the quality rubrics used by universities, such as Quality Matters and the OLC Quality Scorecard, show consistency in quality indicators for online courses and programs, including student support, course design and interaction (Online Learning Consortium, 2014; Stewart et al., 2013; Twigg, 2001b). However, in analyzing perceptions from primary stakeholders, it appears that the importance of such factors varies among stakeholders (Smidt et al., 2019). Benson (2003) argues that differing perceptions of quality may unexpectedly influence the establishment of online courses and fully online degree programs at universities. She suggests that exposing and discussing these differences will allow for agreement on how quality can be achieved, which can help universities plan for the development and implementation of future online courses and programs (Benson, 2003). Stakeholder perceptions regarding science online are less prominent throughout the literature of online education effectiveness. Thus, additional research investigating overall quality indicators from a variety of perspectives in online science education is needed.

2.4.1 Student Perceptions

Overall, students express positive perceptions regarding the effectiveness of online education. Students express appreciation for the availability of learning options from their universities. Online learning allows students to fit classes into their life more easily while also being able to successfully complete their educational goals (Young & Norgard, 2006). In investigating student perceptions of online education, several indicators of quality have emerged. A few of the most highly ranked indicators of quality, according to students, include instructor accessibility and timely feedback (Drouin et al., 2013; Ortiz-Rodríguez et al., 2005; Paechter & Maier, 2010; Smidt et al., 2019), course organization and clarity (Bolton et al., 2019; Cohen & Ellis, 2004) and a sense of community and interaction (Bagasra & Mackinem, 2019; Bolliger & Wasilik, 2012; Martz et al., 2004; Palloff & Pratt, 2007).

Students have high expectations regarding the instructor’s responsibility in online courses, including feedback and communication (Bagasra & Mackinem, 2019). One study reported students' rating of online instructors lower than face-to-face instructors in this regard (Lowenthal et al., 2015). Students respond favorably to instructor immediacy which includes forms of interaction immediacy and prompt feedback from instructors (Drouin et al., 2013). How an instructor designs the course can influence the extent of interaction and feedback in the class (Bolton et al., 2019). Because of the asynchronous nature of most online courses in higher education, course organization becomes essential. Students highlight quality online courses as those with consistent, clearly defined objectives and expectations for learners throughout the course (Dykman & Davis, 2008; Smidt et al., 2019; Swan et al., 2000; Young & Norgard, 2006). Student satisfaction is also commonly studied as part of student perceptions of quality in online education (Bolliger & Halupa, 2012). Aiding in student satisfaction, students highlight a desire for support services (Ortiz-Rodríguez et al., 2005; Stewart et al., 2013), including technical support (Lee, 2010; Young & Norgard, 2006). Research has also found that there is a statistically significant relationship between online interactions and student satisfaction and persistence (Asoodar et al., 2016; Shin, 2003).

Research suggests that previous experience in online education influences students' preferences and perceptions regarding quality elements in online courses (Arbaugh, 2004; Bailey et al., 2015; Drouin et al., 2013). Students with little experience in online courses may hold inaccurate and conflicting views concerning online learning overall (Bolton et al., 2019). Some research finds that students with more online learning experience hold more positive views and believe that more learning occurred in online courses compared to face-to-face courses (Barnes, 2017). Also, student satisfaction is found to be greater with more experience taking online courses, as students feel more comfortable with learning online (Barnes, 2017; Young & Norgard, 2006).

2.4.2 Instructor Perceptions

Many studies have investigated instructor perceptions of quality in online education (Boling et al., 2012; Cohen & Ellis, 2004; Khoo et al., 2010; Perry, 2003; Regan et al., 2012). However, instructor perceptions mostly contradict students' and university administrators' views. Instructors generally continue to be concerned about online course rigor and meeting the same course objectives and learning outcomes as face-to-face courses (Downing, 2016; Palmer et al., 2014; Smidt et al., 2019). Allen et al. (2012) reported that online instructors are overall more pessimistic than optimistic about online learning, voicing concern about the quality and the overall success of students in online courses. Instructors also report being concerned with their own abilities to design and build online courses and the significant time required for feedback and grading in online courses (Bagasra & Mackinem, 2019; Bolton et al., 2019). However, instructor perceptions of online learning have been found to differ based on prior online teaching experience, with those having more experience holding more positive views towards online course quality than those with no online teaching experience (Allen et al., 2012).

Li et al. (2019) and Garcell et al. (2007) argue that gaining instructor support is an important factor for online course and program success. Instructors can be a sort of gatekeeper. Without their genuine interest and participation, a university may be unable to develop and sustain viable online learning programs. This is especially true in the sciences. While literature directly concerning instructor perceptions of online science education quality is minimal, the general understanding is that science instructors remain hesitant to fully embrace teaching undergraduate science courses online (DeHaan, 2005).

2.4.3 Administrator Perceptions

The literature regarding quality of online education focuses more on student and instructor perceptions, leaving administrator perceptions to just a handful of studies (Allen et al., 2016; Garcell et al., 2007; Smidt et al., 2019). The Online Learning Consortium has been dedicated to reporting on the status of online education delivered by higher education institutions in the United States for over a decade (Seaman et al., 2018). In conjunction with Pearson, the College Board and various other partners, this consortium has reported yearly data from a sampling of over 2,500 colleges and universities across the United States in order to investigate the overall status of online education. Up to the year 2016, the reports have considered perceptions of university administrators, such as chief academic officers, provosts and university presidents (Allen et al., 2016). Over 60% of university administrators around the country agreed that online education was critical to their long-term plan with only a small group of administrators (14%) who have disagreed (Allen et al., 2016). Administrators’ position regarding online education continues along this trend, with more recent national surveys reporting strong support for online education from administrators, including the continued expansion of online learning a as component of long-terms strategic plans (Legon et al., 2019; Xu & Xu, 2019).

Administrators have a large role in setting the academic strategy for their universities which makes their perceptions influential. Overall, administrators report optimism concerning the growth of online education. In a study surveying perceptions of quality in online education from administrators, instructors and students from two mid-sized public universities in the United States, Smidt et al. (2019) found that university administrators view quality factors such as meeting objectives and learning outcomes, achieving comparable rigor to face-to-face courses and interaction to be of particular importance.

There appears to be some discontinuity in perceptions of quality in online education across the three main groups in higher education: students, instructors, and university administrators. It is prudent for institutions aiming for quality online education to consider a range of stakeholder views when agreeing on or implementing a set of standards for quality assurance (Garcell et al., 2007).

In this section, student, instructor and administrator perceptions of online education were discussed. To fully evaluate the quality of science online education, the perceptions of the primary stakeholders involved need to be considered. Perceptions among the stakeholder groups are mixed. Students’ and administrators’ generally view the quality of online education positively, while instructors report a more negative viewpoint.

2.5 Quality Perceptions of Online Science Courses – Gaps in the Literature

The literature concerning online science courses focus on comparisons of student learning outcomes to individual face-to-face science courses, specific learning techniques and tools, and the design and development of new online science courses and laboratories. This results in a lack of research focusing on perceptions of the stakeholders involved in science education online. The literature on perceptions of online education overall can serve as a baseline for investigating perceptions of online education in the sciences. The few studies sharing results of perceptions of online education in the sciences, focus on student perceptions and report conflicting results. For example, in a study evaluating student experiences in online laboratory courses, Rowe et al. (2018) found that students who completed at least one online biology, chemistry or physics course perceive online science laboratories to be as effective as similar face-to-face laboratories. However, results from a doctoral thesis by Hill (2013) show that a significant percentage of students enrolled in online versions of undergraduate biology courses reported that they would not recommend biology courses be delivered in the online format again, indicating overall dissatisfaction. While these students did indicate satisfaction with the lecture and laboratory component of their online biology courses, students received fewer A's and more F's as final grades in the online course than their face-to-face course counterparts (Hill, 2013). Mixed perceptions such as these, and among stakeholder groups, indicate that much work is needed in identifying the unique factors and perceptions of online science education (Smidt et al., 2019).

There is a substantial gap in the online learning research considering the university perspective as a whole (Guri-Rosenblit & Gros, 2011), particularly in the sciences online. The success of online programs rests not only on the satisfaction of students and instructors, but on the administrators, who oversee the long-term strategies of the university. Perceptions vary because stakeholders are considering different aspects of online learning when considering quality and overall view of online science education. Diving into the details of the perceptions from all three stakeholders is essential.

This section discussed the need for additional research on perceptions of science online education. The literature concerning perceptions of science online education focuses on the students' view, but results are mixed. Clarity is needed regarding perceptions of science online education to include representation from all three primary stakeholder groups; university students, instructors and administrators.

2.6 Summary

The last two decades has seen a remarkable increase in the availability and overall acceptance of online learning in higher education and it has become a standard component in most university programs (Xu & Xu, 2019). Online learning provides more options for students, breaking down university monopolies on geographic boundaries to education. As such, universities have needed to consider the pressure to keep up with student demand and remain competitive among other universities by offering not only online courses, but fully online degree programs. The increase of fully online degree programs has been instrumental in the increased decisions to implement online science courses because they fill a primary general education requirement for degree completion. Additionally, in the United States, there is an increased awareness of the importance of science education and science literacy, aiding in the increased demand for more availability of science courses (Jeschofnig & Jeschofnig, 2011).

As online courses become more prominent, more research has been conducted on evaluating their effectiveness. The bulk of this research focuses on comparison of student learning outcomes, typically on assessments and course grades, for online courses compared to face-to-face courses. Much of this research has found that student learning outcomes online are not significantly different from those learning outcomes in face-to-face courses. This finding has become recognized among the online education research community as the ‘no significant difference phenomenon’ (Russell, 1999). Research of effectiveness based on student learning outcomes in online science courses and laboratories also report no significant difference compared to face-to-face courses (Brinson, 2015; Lee et al., 2011).

While online education more generally is flourishing, disciplines such as the core sciences continue to be confronted with hesitation and skepticism, particularly regarding online laboratories (Jeschofnig & Jeschofnig, 2011). The basis of such skepticism in light of research showing no significant difference in learning outcomes in online science courses and laboratories is still unclear. In an effort to continue to develop and establish the effectiveness of online learning in higher education, several quality standards have been developed such as Quality Matter and the OLC quality scorecard. Universities across the United States have begun adopting such standards for establishment and evaluation of their online courses. While such standards are useful for online education more generally, they do not address the unique aspects of science learning such as a focus on inquiry learning and laboratories.

Perceptions of stakeholders involved in online education add depth to understanding quality aspects for online education. Perceptions of online education in general, focus on students and instructors but few consider university administrators. A lack of an integrated view of quality is a key issue in understanding the quality of online education (Esfijani, 2018). Additionally, there is little research concerning perceptions of online science education, leaving a gap in understanding of perceptions of what makes quality online science education.

Chapter 3.
Research Methods

This chapter introduces the research methods for this qualitative interview study investigating perceptions of quality in online science courses at the tertiary level. A qualitative interview study allowed for a deeper understanding of university administrators', instructors' and students' experiences regarding online science courses and their perceptions of online science quality. In addition, the use of inductive data analysis provided a way to develop themes from the data in order to interpret and understand differences in quality perceptions. The applicability of a constructivist approach within this study is discussed in this chapter. This chapter also provides details of the methodology, research design, study participants, procedures, analysis method, rigor and ethical considerations.

3.1 Methodology

The purpose of this study was to examine the perceptions of university stakeholders to better understand what is considered quality in online science courses and investigate the rationale behind skepticism of online science education. To establish a clear and comprehensive understanding of what is considered quality in online science courses at the tertiary level, perspectives of three stakeholder groups were included: university students, instructors and administrators. A qualitative research study is appropriate when relying primarily on perceptions and personal experiences in a particular situation (Merriam, 1998; Stake, 2010). In order to investigate the unique perceptions of stakeholders, a qualitative interview study was used.

Qualitative interviewing is a basic qualitative research method that explores people's understanding of their experiences and situations through an interactional dialog between the researcher and interviewee in a relatively informal style, often referred to as 'conversations with a purpose' (Mason, 2018; Merriam, 1998). In this study, the dialog took place through one-on-one, face-to-face interactions with participants and centered upon the topic of quality in online science courses. This research study utilized semi-structured interviews, a major form of qualitative interviews in which questions guide conversation around the main topic but also provide a fluid and flexible structure for unexpected themes to develop (Edwards & Holland, 2013). Mason (2018) argues that most interview studies operate from the perspective that knowledge is situated and contextual. Thus, qualitative interviewing tends to involve the construction or reconstruction of knowledge as opposed to the excavation of it (Kvale, 1996; Mason, 2018). This study is in alignment with this perspective.

This study is built upon a relativist ontological stance in which reality and knowledge are assumed to be created by the individual participants and upon the contextual understanding within the situation (Guba & Lincoln, 1994). By adopting a relativist stance, this study emphasizes the importance of accounting for the diversity of interpretations that can apply to a situation with the goal of creating a collective reconstruction of meaning from multiple perspectives (Guba & Lincoln, 1989). This ontology can be classified as constructivism as it “denies the existence of an objective reality, asserting instead that realities are social constructions of the mind and that there exist as many such constructions as there are individuals (although clearly many constructions will be shared)” (Guba & Lincoln, 1989, p. 43). Epistemologically, constructivism emphasizes that researchers must acknowledge themselves as an inevitable part of the research endeavor. Participants’ views of the quality of online science education are subjective, which involves understanding the participants’ world from their view and understanding from within (Cohen et al., 2011). This study follows the logic that in order to understand perceptions, or interpretations of a participant’s experiences, a researcher must investigate from inside the context understood by the participant not from outside. As such, the researcher’s role is outlined below in Section 3.5, as it cannot be completely separated.

Alignment with such constructivist paradigm gives rise to interpretivist epistemological assumptions which drive the research design, data collection and analysis used for this study (Hitchcock & Hughes, 1995). A qualitative interview study is ideal for the presentation of grounded data that emerges from the contexts identified and where theory and understanding emerge from the data (Guba & Lincoln, 1983). This research strategy is grounded in considering participant perspectives in order to gain an understanding of the overall perspectives towards online science education at the tertiary level (Bryman, 2012).

3.2 Research Design

3.2.1 Research Questions

This research study investigates the quality of online science courses at the tertiary level from the combined perspectives of students, instructors and university administrators. Research about science online education naturally incorporates aspects of online education more broadly in addition to the unique aspects of science learning. Thus, this study of online science courses encompasses analyses of perceptions regarding online education combined with perceptions of the unique aspects of science learning, providing a comprehensive analysis of science in the online environment. Accordingly, the research questions guiding this study address both online education and science online education as follows:

Online education:

1. What does the literature identify as quality indicators for online education?

2. What indicators do the university stakeholders use to evaluate the quality of online education in the context of university science courses?

Science online education:

3. What does the literature identify as science learning objectives, especially for science laboratories?

4. How do the university stakeholder groups evaluate online science courses in relation to the science learning objectives?

The research questions are addressed within Chapters 4 – 6. Chapter 4 presents the results of the quality indicators for online education in the context of science as identified in an initial focused review of the literature conducted prior to interview data collection, answering the first research question. Chapter 5 presents the results of stakeholders’ perceptions of quality indicators which can be broadly applied to all online education with comparisons among the stakeholder groups and the literature, answering the second research question. Chapter 6 presents results focused on the uniqueness of science in the online environment and responds to the last two research questions of this study. First, Chapter 6 presents the results of a second review of the literature which identifies science laboratory learning objectives, answering the third research question. Finally, Chapter 6 presents the results of stakeholders' perceptions of how well online science courses are meeting the learning objectives and presents themes extracted from further analysis of the data answering the last research question of this study.

Table 3.1 gives a detailed account of the research plan as it addresses each of the research questions. Corresponding to each research question, this table presents the data sources, data collection methods, quality standards, data analysis strategies used and the chapter in which the research question is addressed. This table can serve as an overview reference for gaining a clear understanding of the relationship between the research questions and goals of the study.

Table 3.1

Research Plan: Research Questions, Data Sources, Collection and Analysis

Research questions	Data sources	Data collection methods	Quality standards	Data analysis	Location of response
Focus on online education					
1. What does the literature identify as quality indicators for online education?	Existing learning environment, science learning and online learning instruments. Online quality rubrics for higher education.	Focused review of the literature.	Data cross-checking for credibility to include confirmation of validity and reliability of instruments.	Content analysis and in-depth understanding of current literature, instruments and rubrics.	Chapter 4
2. What indicators do the university stakeholders use to evaluate the quality of online education in the context of university science courses?	• Administrators, instructors and students. • University documents, websites. • Existing learning environment, science learning and online learning instruments. Online quality rubrics for higher education.	• Semi-structured interviews. • University campus visits. • Focused review of the literature.	• Triangulation of sources. • Critical reflexivity. • Audit trail (memoing). • Cross-check of literature data for credibility. • Ethical concerns addressed.	Thematic coding of interview transcriptions, field notes transcriptions and observations. Constant comparative analysis and triangulation of: • Content analysis and in-depth understanding of current literature, instruments and rubrics. • Thematic coding of interview transcriptions, field notes transcriptions and observations.	Chapter 5

Focus on science online education:

3. What does the literature identify as science learning objectives, especially for science laboratories?	Existing literature on science learning and science laboratory learning objectives.	Focused review of the literature.	Data cross-checking for credibility to include confirmation of validity and reliability of instruments.	Content analysis and in-depth understanding of science learning objectives identified in the literature.	Chapter 6: *Section 6.1*
4. How do the university stakeholder groups evaluate online science courses in relation to the science learning objectives?	• Administrators, instructors and students. • University and course documents and websites. • Existing literature on science learning and science laboratory learning objectives.	• Focused review of the literature. • Semi-structured interviews and university campus visits.	• Triangulation of sources. • Critical reflexivity. • Audit trail (memoing). • Ethical concerns addressed. • Cross-check of literature data for credibility.	Re-analysis and thematic coding of interview transcriptions, field notes transcriptions, documents and observations. Constant comparative analysis and triangulation of: • Content analysis and in-depth understanding of science learning objectives identified in the literature. • Thematic coding of interview transcriptions, field notes transcriptions and observations.	Chapter 6: *Section 6.2 & 6.3*

3.2.2 Research Approach

This study follows a qualitative research approach using qualitative interviewing of participants from three stakeholder groups: university administrators, instructors and students. As introduced in Chapter 1, literature identified quality indicators were used as a framework to guide the development of interview questions, conduct the interviews, and guide analysis of the interview data. One focused review of the literature provided an initial framework of quality indicators recognized for online education more broadly within the context of science, while the second review focused on science online education specifically by identifying science laboratory learning objectives. Table 3.2 provides an overview of the research approach and processes which are described in more detail in the subsequent sections of this chapter.

Table 3.2

Outline of the Research Approach

Research process	Approach taken in this research study
Methodology	Constructivist / Interpretivist
Research Design	Qualitative Interview Study: • Establishment of literature identified quality indicators and science laboratory learning objectives • Qualitative interviews
Data Collection	Focused literature reviews One-on-one interviews Document collection Observations at universities & in online courses
Data Analysis	Coding of interviews, documents and observations Classification of categories and themes, use of memoing Triangulation and constant comparative method utilizing grounded theory approach
Research Rigor	Triangulation of sources Role of the researcher Critical reflexivity Audit trail
Ethical Considerations	Access – Internal Review Boards Informed consent Privacy and confidentiality

3.3 Establishing the Literature Identified Quality Indicators

Through a focused review of the literature, a list of quality indicators pertaining to science online education was generated. This review created the initial framework for this study, used to guide the data collection and initial analysis of participant interview data. Relevant research conducted about online learning environments, science learning, and the development and use of online learning instruments was reviewed. Chapter 4 presents the results of this initial focused review of the literature, identifying indicators of quality applicable to online education more generally and answering the first research question of this study.

Through a second focused review of the literature, the results of the initial review were expanded upon with more specificity regarding online science laboratories. This second review established a list of science laboratory learning objectives which provided a more robust framework for science online learning specifically. The science laboratory learning objectives were used as a guide to re-analyze the interview data, focusing on science unique quality indicators. Chapter 6 presents the results of this second focused review of the literature, answering the third research question of this study. Participant interview data and results guided by the learning objectives identified in this review of the literature are also presented in Chapter 6.

3.3.1 Initial Review - Literature Selection Methods

A common method to determine or assess aspects of quality in education is through the development and implementation of a survey or instrument. Thus, an initial search of the literature focused on instruments designed to assess the effectiveness of learning environments in online education, science education, laboratory courses, and those focused on computers or Internet-technology in science learning. It is through such instruments that the fundamental aspects determining quality were highlighted. This initial literature search was conducted from July 2013 to June 2014. The literature published between 1995 and 2014 was searched and analyzed. Journals were initially searched using commonly used databases such as ProQuest Education, ProQuest Science, Science Direct, Web of Science, and ERIC. Keywords used for searches were a combination of the primary terms and alternative keywords as outlined in Table 3.3. The article titles, abstracts, and reference lists were then manually and methodically reviewed and organized into the following six delineating categories: 1) Online Science Higher Education, 2) Online Laboratory and Computer Laboratory, 3) Science Learning and Science Laboratory, 4) Science Higher Education, 5) Online Higher Education, and 6) Online Learning. The search was primarily focused towards valid and reliable online learning instruments, which highlight quality factors for online higher education, science education, and science laboratories. Nine theoretical studies, incorporating literature reviews, were included in this process for a consistency check within the broader literature beyond instrument development. In total, 35 studies are included in this review.

Table 3.3

Initial Focused Literature Review Search Terms

Category	Primary terms	Keywords
Learning Type	• Online • Distance	• e-Learning • Internet-based • Web-based
Education Terms	• Education • Learning • Environment	• Teaching • Course(s)
Level	• Higher Education • University • Tertiary	• Undergraduate
Quality Terms	• Quality • Effectiveness	• Perceptions
Discipline	• Science	• Laboratory
Method	• Survey • Instrument	

Analysis of the various quality indicators from the range of studies gave a definitive representation of what researchers in these fields perceived as the most important indicators of quality. For studies reporting on instrument development or directly concerning quality or effectiveness, the indicators were clearly represented. For all other studies, quality indicators were extracted according to the discretion of the researcher. From the expansive list of quality indicators, each indicator was compared to all other indicators, merging similar quality indicators based on the descriptions with major categories and sub-categories. Discussion with science education experts helped to assure that the quality essence was accurately represented by the indicator term. This process aided the overall applicability and reliability of this collective database of quality indicators for science online education. Eight major categories of quality indicators emerged from the review of the literature: *Interaction, Course Design, Technology Adequacy, Science Learning, Satisfaction, Student Learning Outcomes, Instructor Competency* and *Cost Effectiveness.* These eight indicator categories are broad designations that contain several specific quality indicators within each category defined as sub-categories. While the quality indicators were identified within the context of science online education, all of the indicators of quality except science learning, also apply to online education generally. These indicators of quality are strongly grounded through the combined representation across the vast literature of online learning in higher education, making them more transferable. The quality indicators identified for online education more broadly, through this focused review of the literature, answer the first research question of this study.

3.3.2 Second Review – Identifying Laboratory Learning Objectives

The quality indicators specific to science learning identified in the initial review of the literature did not delineate between science lecture and laboratory, incorporating them together as representative of science learning. However, after initial analysis of the qualitative interview data from the three primary stakeholder groups, it was revealed that participants' discussion of science learning was heavily centered on discussion of online laboratories. Initial comments of quality science learning were so engrained with comments about laboratories that more in-depth analysis focused on laboratories was needed.

In order to parse out the uniqueness and specific attributes of science laboratories, it is valuable to elucidate the learning objectives. Often the goals and learning objectives for the laboratory are synonymous with the ones for science education in general (Hofstein & Lunetta, 2003). Corter et al. (2011) argue that in order to evaluate the effectiveness of online science laboratories, it is necessary to first establish what they are designed to teach and what learning objectives are to be met. As there are no universal learning objectives explicitly set for undergraduate science laboratories, it was necessary to establish a set of learning objectives based on the science education literature. Therefore, a second literature review was conducted to identify science laboratory learning objectives which could be used to evaluate online science learning quality indicators. When learning objectives are met, the learning experience is considered effective, allowing the *Science Learning* quality indicators, identified in the initial focused review of the literature, to be traced into the laboratory learning objectives via common definitions as they share the same overall intent (this is elaborated upon in Section 6.1.3).

The motives for laboratory or practical work have remained somewhat unchanged over the last 50 years, except for the reordering of relative priorities or specific focus (Bradley, 1968; Hofstein & Lunetta, 2003). While the motives have remained the same, the task of compiling a list of learning objectives becomes difficult since often objectives are either too general or too specific (Johnstone & Al-Shuaili, 2001; Kirschner & Meester, 1988). A review of the literature from the 1970's to 2017, incorporating research studies and guidelines from national organizations such as the American Association of Physics Teachers (AAPT) and the American Chemical Society (ACS) helped to compile a representative sample of the most common learning objectives for science laboratories in higher education across science disciplines. These learning objectives were grouped into the following categories: *scientific methods and reasoning*; *conceptual understanding*; *interest and motivation in science*; *collaboration and communication*; and *practical skills*. The identification of these science laboratory learning objectives answers the third research question of this study and were used to guide the re-analysis of interview data. A summary of the learning objective groups with a short description is provided in Chapter 6.

3.4 Qualitative Interviews

One-on-one, in-person qualitative interviews allowed for an in-depth investigation into perceptions of quality from those directly involved in online science courses at the tertiary level. Participants from three stakeholder groups included university administrators, online science instructors, and online students. Semi-structured interviews, starting with a set of initial questions, allowed the researcher to guide participants in deeply considering what makes a quality online science course. In addition, with a semi-structured interview format, participants were able to share opinions and experiences which allowed for issues to be illuminated that might have otherwise been overlooked. This approach enabled the narratives of the lived experiences of the participants to be a focus of the interviews, providing a clear description of participants perceptions (Creswell, 2012).

Interviews with participants from the three different stakeholder groups enabled comparisons between perceptions while combining perceptions from the three stakeholder groups, provided a more global perspective of online science quality. Beyond interview data, data gathered via documentation and observation added depth to the understanding of quality and helped to provide a “thick description” of the situation (Guba & Lincoln, 1983). The different universities from which participants were chosen provided different opportunities, particular resources, and thus participants had different vantage points from which to reflect upon their perceptions.

In addition to identifying indicators of quality, this qualitative study aimed to explain why there appears to be a discrepancy in perceptions of science online education and understand the skepticism surrounding the effectiveness of online science courses. Interviews with different stakeholder groups allows for analysis of diverse perceptions. The overall intent of this study was to inform and guide future advancement within the online science education field with the knowledge learned regarding quality and diversity of perceptions.

3.4.1 Participating Universities and Stakeholders

Participants in this study were selected from five Midwestern universities in the United States. Only universities located in the states of Kansas, Southern Illinois, and Missouri were considered. As of Fall 2012, this geographical area, also referred to as the plains, had the highest percentage of the university student population enrolled exclusively in distance education courses in the United States (Ginder & Stearns, 2014). Such a large enrollment percentage in online courses made universities in this region ideal for this study. To this day, the Midwestern plains region of the United States has one of the highest percentage of students enrolled in online courses, only becoming second to the Rocky Mountain region as of Fall 2014 (U.S. Department of Education, 2019a). This geographical area of focus was additionally ideal due to the researcher's experience and familiarity with the culture and organization of universities in this region. The researcher's experience originated from teaching face-to-face and online courses at a Midwestern university over the last ten years.

Selection Methods and Demographics of Participating Universities. Only four-year institutions that offered at least one core science bachelor's degree were considered. Core science refers to disciplines of physics, chemistry, biology, astronomy, and earth sciences. Earth sciences include the disciplines of geology, oceanography, and meteorology (Tarbuck et al., 2012). In addition, the university needed to offer at least two undergraduate, core science courses online, fitting the Online Learning Consortium definition of online (80+% content delivery is online) in order to qualify for this study (Allen et al., 2016). These courses must have been offered between Spring 2013 and Fall 2015.

A university was included as part of the study once at least two administrators and two instructors agreed to participate. Potential student participants were later invited to participate via email after referral from instructors. An overview of the selection criteria are outlined in Table 3.4.

Table 3.4

Minimum Criteria Necessary for a University to be Included in the Study.

Selection criteria for university participation
• 4-year University
• At least one core science bachelor's degree offering
• Offers at least two undergraduate, core science courses fitting the Online Learning Consortium definition of online (80+% content delivery is online)
• Courses offered between Spring 2013 and Fall 2015
• University IRB approved – research access granted
• Two administrator and two instructor participants officially agree to partake

The detailed search for potential universities and participants was completed in several iterations. The first iteration established a list of universities within Kansas, Southern Illinois, and Missouri, which offered bachelor's degrees in the sciences. This initial list was produced using university public websites and US News and World Report university ranking websites. These initial searches were limited to four-year institutions that offered at least one bachelor's degree in a core science. From this list, searches within each university's public website, course catalogs, and course enrollment listings, were used to further narrow the focus of potential participants based on offering of introductory online science courses.

Next, university course catalogs and course enrollment pages were searched from Fall 2013 to Spring 2015 to provide a list of currently applicable universities. Past, current, and future online science courses were also searched in an effort to identify course types and online science instructors. This search further focused the list of potential universities to those that offered undergraduate-level science courses between Spring 2013 and Fall 2015. This search yielded a list of over 30 potential universities.

To finalize the university interest, initial contact was attempted through emails to the university administrators and instructors. These initial contacts served as an informal request to determine if the university would be interested in participating in the study. Twelve universities responded with initial interest. The process of formally requesting participation began with each university's Internal Review Board. At completion and approval from the university's Internal Review Board, formal participation requests were sent via email to university administrators and instructors (Appendix A). Once the minimum of two administrators and two instructors agreed to participate, potential student participants were later invited by referral from instructors.

In order to help the transferability of findings from this study, an effort was made to maximize the variability in the university size. Institutional size ranges were determined from official university websites. The list of participating universities was finalized once a full range of institutional sizes agreed to participate. Table 3.5 provides the demographics of the five participating universities.

Table 3.5

Demographics of Each of the Participating Universities.

	Size of Institution	No. of Administrators	No. of Instructors	No. of Students	Online Science Courses Discussed
BigU	Large	3	4	4	- Meteorology - Geology - Biology - Physics
PCU	Medium	2	2	2	- Geology - Oceanography - Mammalogy - Ecology
WRU	Medium	3	3	2	- Meteorology - Geology - Astronomy
RBU	Medium	4	3	0	- Chemistry - Biology - Physics - Astronomy
LittleU	Small	4	2	12	- Biology - Earth & Astronomical Science - Astronomy

Note: Size of the institution is based on the total student enrollment in 2014: Large (>20,000 students), Medium (10,000 – 15, 000 students), and Small (1,000 – 5,000 students).

Selection Methods and Demographics of Participants. Within each of the five universities, participants were initially selected using a priori purposive sampling. There was no change in the selection criteria of participants as the research proceeded. A type of a priori purposive sampling, called maximal variation sampling, was also commissioned (Creswell, 2012). Participants were sampled based on their unique subgroup within the university: university administrator, instructor, or student. These three groups of participants maximize the diversity of perceptions of the quality of online science courses, allowing for a full representation of those involved in university online science. The large experience and positional variation between each participant group allowed for a rich investigation into views unique to each group as well as shared views across the variation of participant type. The purpose of using maximal variation sampling for this research was to gauge aggregate perceptions of a diverse selection of participants that collectively represent the university population as a whole.

As data collection progressed, participants were added to the study using snowball sampling techniques. Snowball sampling is a non-probability sampling method where participants with whom contact has already been established refer the researcher to other potential participants with experience or knowledge well suited to the research study. This type of sampling is often useful in finding and recruiting less obvious participants (Bryman, 2012). Often at the conclusion of an interview session, the participant would refer other potential participants whom they thought would be willing and had the experience to contribute to this research study. This was the most effective method of recruiting additional instructor and student participants at each university.

University administrators and instructors were formally invited via email communication to participate in this study. Email addresses were obtained from the university website personnel directories or from referral from colleagues or university administration offices. Often, after an interview session with the instructor of an online science course, the instructor was willing to email his or her current or past online science students to aid in recruiting student participants. The majority of student interviews were established while visiting the university via such referrals from their online science instructors. In addition, a recruitment email was sent to students and posted on course management system announcement pages for the current online science courses. The email and course announcement introduced the researcher and briefly described the project and expectations for participation (Appendix B).

Fifty participants across the five universities took part in this research study: 16 administrators, 14 instructors and 20 students. University administrators include university Provosts, Deans, Directors of Online Learning and Department Chairs. About half of the administrators have non-science backgrounds. Instructors of online science courses include full-time and part-time university Faculty, Lecturers, and Graduate Teaching Assistants. Student participants were enrolled in an undergraduate online science course at the time of data collection or had already completed an online science course at their university prior to participation in the study. Student participants' academic level included all undergraduate levels, ranging from freshmen to 5th year seniors, as well as those who had recently graduated. Participants ranged in their experience with online science courses, some experiencing online teaching or learning for the first time, others having several years of experience.

3.4.2 Data Collection

Data collection consisted primarily of interview sessions with participants from each university but also included document retrieval and online course observations. A research study protocol was developed and followed for each participating university, increasing the reliability of the research design (Yin, 2014). This approach helped to prepare for and guide the data collection and analysis. Once the five universities were established, a data collection timetable, travel route, and interview schedules were devised to accommodate all participants.

Interviews were conducted at the university campuses in October 2014, which is mid-term during the U.S. Fall 2014 academic semester. This mid-semester time frame was specifically selected so that instructor and student participants would have had at least one to two months' minimum experience in an online science course before participating in the research study. This helped to ensure that participant perceptions would be based upon a certain amount of recent experience through which effective reflection could occur.

Each university campus was visited for approximately one week, allowing for sufficient time to become familiar with the university population, experience the accessibility to online tools, and to gain an overall feel for the university's unique culture. Observations of the university environment were collected by exploring university libraries, student unions, and computer labs. Accessing the wireless Internet and observing the general happenings of the online and physical educational setting at each university was also informative. Direct access to one online science course through the learning management system provided additional data. These direct observations were added to the data collection, analysis, and theory generation of this research study.

The primary data for this qualitative study was one-on-one, semi-structured, open-ended interviews. The majority of interviews were conducted at university campus facilities. Interviews with administrators and instructors were conducted in offices or conference rooms within department buildings. Student interviews were conducted in university libraries or at the university student unions. After the primary data collection commenced, a few additional interviews were conducted via phone to accommodate the participants. Before each interview session, participants were given an information sheet describing the intent of the research and asked to sign a consent form (Appendix C). Interview sessions were one hour in length and were recorded using a digital audio recorder. Detailed, hand-written notes were also recorded for each interview session.

An open-ended interview approach was used where the exact wording of initial questions was predetermined but the participants could answer the question in whatever way they determined to be most meaningful in their own terms (Patton, 1990). These questions focused on participants' experience with online science courses, overall evaluation of online education, and the quality of online science courses. The full list of initial interview questions for each participant group are provided in Appendix D.

Subsequent questions were asked based on the answers to the initial questions and discussion instigated by participants. Discussion with most administrators and instructors involved a progressive back-and-forth conversation where the initial interview questions were enough to instigate deep discussion and sharing of opinions from participants with little prompting. However, a few student participants were diffident and it became necessary to further prompt discussion by suggesting indicators of quality from the literature and encourage elaboration on very short answers. The researcher acknowledges that by asking students about a particular quality indicator, may have resulted in asking a leading question, where the question itself influences the answer (Cohen et al., 2011). To help mitigate this, the term 'quality indicator' was not used with participants. During all interviews, where participants' meaning was unclear, the researcher asked for clarification or repeated what was understood from the participants' comments in order to check that the comments had been correctly understood. This approach allowed for clarification of perceptions in context and allowed for further information to be gained when responses to the interview questions were unclear or called for elaboration.

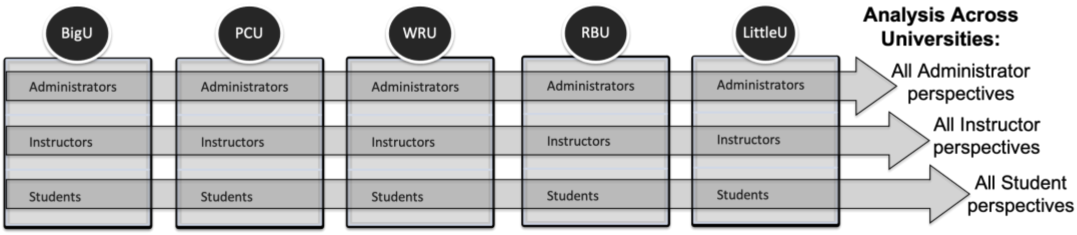
Often during interview sessions, participants would provide supporting documentation relevant to the research study. These documents served as a third type of data collection. Participants supplied documents such as online course syllabi, quality standards booklets, general university demographic information, and example assignments or exams from online science courses. These documents helped to comprehensively understand the science online education environment at each university. At the conclusion of the interview sessions, participants were given, as well as emailed, a debriefing form (Appendix E). This form summarizes the purpose of this research, reference information pertaining to this field of research, and provides additional contact information for participants to voice concerns, complaints or seek additional support as a result of participation in this research study.

3.4.3 Data Analysis

Data were analyzed using inductive analysis (Lincoln & Guba, 1985) and followed a grounded theory approach (Bryman, 2012) by coding interviews, documents and observations for themes. Transcribing and coding of the data was accomplished using NVivo analysis software. Analyses followed a constant comparative method to relate data within stakeholder groups, across stakeholder groups, across emerging categories and construct meaning from the data (Cohen et al., 2011; Glaser & Strauss, 1967). Data within each stakeholder group was analyzed across the five universities from which data was collected. The analytic strategy for this qualitative study involving five different universities is represented graphically in Figure 3.1.

Figure 3.1

Analytic Strategy for this Study.



Triangulation of interview data, across each stakeholder group, the quality indicators identified in the review of the literature, and among documentation and observations from universities was used to develop initial themes from the data. Interview audio recordings were transcribed and coded over several iterations. Initial coding was open-ended and involved labeling sections of data and identifying indicators of quality from the interviews. As coding progressed, a number of categories and indicators arose. Pattern matching was a crucial aspect of the data analysis. A primary use of pattern matching in this research was in the comparison of previously identified indicators of quality for online education with those identified by participants at each university.

The data was *coded a second time* using the indicators of quality identified in the literature a priori, to allow for a constant comparison among the data and further delineate specifics within each quality indicator category. New quality indicators discussed among participants were also identified. New codes were constantly compared to existing data to determine if new categories or themes were emerging. Following a grounded theory approach, analysis of all interviews was conducted again, to see if any new quality indicators or themes existed within the data. The quality indicators identified in the focused review of the literature and those that emerged from the data, provided the framework used to report the analysis of the interview data. Data were displayed graphically to visualize the quality indicators participants discussed most frequently. This analysis answered the second research question of this study which is presented in Chapter 5.

An *additional round of analyses was focused upon science laboratories* to better understand perceptions regarding science specific indicators of quality and answer the last research question of this study. NVivo coding and re-analysis of participant comments of science learning and laboratory was conducted through the lens of laboratory learning objectives identified from the second focused literature review. Inductive thematic analysis guided the identification of implicit and explicit ideas within the data through compare and contrast analysis, identifying connected words and phrases and drawing relationships among the data. Stakeholder perceptions became more defined when analyzed considering each learning objective, illuminating particular views beyond the generalized discussion of science learning quality. This re-analysis helped to categorize participants' language, verbiage, and expressions used to describe laboratories and created a more comprehensive and clear interpretation of participants' overall positive and negative views of online science learning. Finally, explanation building was used to theorize why discrepancies in perceptions of online science education exist among the participant groups (Yin, 2014). This process was done over several iterations and was employed across the five universities and across each participant group. The continual use of memoing throughout the research process helped to guide the explanation building process (Birks et al., 2008). Using a grounded theory framework as an iterative, comparative process allowed for successive focusing of the data to further develop emerging themes, answering the final research question of this study (Charmaz, 2017).

3.5 Research Rigor

Internal validity, often termed as credibility, is the stronghold of qualitative studies since it involves the interpretation, exploration, and explanation of social reality (Bryman, 2012; Guba & Lincoln, 1994). This study worked to establish credibility through the use of triangulation of data sources, the use of member checking during interviews, a clear understanding of the researcher's biases through critical reflection, maintaining an audit trail, and a solid understanding and presentation of the paradigm guiding the research (Bryman, 2012; Merriam, 1998; Patton, 1990).

Multiple sources of data were used in this qualitative study allowing for triangulation among these sources (Merriam, 1998; Patton, 1990). Data were collected from three different stakeholder groups, documentation, observations and reviews of the literature. The credibility of this form of research is strengthened when the empirical and predicted patterns appear to be similar. This was the case with the comparison of previously identified quality indicators in the review of the literature and those identified by interview participants (Yin, 2014). The use of pattern matching, explanation building, and addressing rival explanations in the analysis of data also enhanced credibility.

A form of *member checking* was performed during interviews by restating or summarizing information provided by the participant and then questioning the participant to determine if the restated or summarized information was accurate. To improve response validity from student participants, the researcher had no affiliation with the courses in which student participants were currently enrolled. Student participants were made aware that their responses could not influence their grades and that the recorded interview sessions would only be listened to by the researcher for the purpose of transcription and never discussed with their instructors. Additionally, mitigating any unbalance of power between researcher and participants was necessary to ensure the researcher's online science teaching experience did not negatively affect the research process. This issue was especially considered for student participants at the university who had previously taken one of her online science courses. These students were asked to participate only if they were juniors or seniors and were unlikely to take another of her classes. Students currently enrolled in courses where she was teaching at the time of data collection were not invited to participate in the study.

A clear presentation and understanding of the researcher's *biases and assumptions* about the research process and data, further improve the credibility of this study. In qualitative research, the researcher is the instrument through which data are collected and analyzed, thus affecting the way findings are achieved (Patton, 1990). It is imperative that the researcher be reflective about their role in research, and how they are interpreting the findings (Creswell, 2012). My personal drive for research outlined in Chapter 1 provided the details of my experience, thoughts and beliefs towards online science education. As primary researcher I highlighted my experience and history in online science education in an effort to disclose how my role affects data collection and analysis in this research study.

During the development, implementation, and analysis processes of this research study, I worked part-time as an online science instructor at one of the participating universities in this research study. My direct experience as an online science instructor provided a great deal of insight into the analysis of the data, a detailed understanding of the situations at each university, a fluency in the social context, and an effective lens through which to appropriately conduct interviews with participants. However, this direct experience also opened up the possibility for introduction of bias in the collection and analysis of the data. To help mitigate bias, I remained critically reflective of my role as researcher in data collection, analysis and how findings were interpreted. Detailed journaling of my personal assumptions and beliefs were kept throughout the research process and reflected upon through constant comparison with the reporting of the data. These included personal thoughts on the data and declaration of any personal biases which may have impacted my role as the researcher. Due to my personal experience with teaching and developing online science courses, I had to continually bracket my knowledge and impressions while gathering and analyzing data and developing themes. To mitigate influencing the interpretation of results, personal opinions and expectations were kept in check though critical reflexivity and continual discussion with my doctoral supervisors. Detailed discussions with my doctoral supervisors often took the form of constructive debates which challenged my initial interpretations of the data, helping me to deeply critique my analysis and separate my personal biases and expectations.

The regular use of *reflective activities* throughout the study such as memo writing and constant comparative analysis help to minimize bias, aiding objectivity throughout the study (Bryman, 2012; Glaser & Strauss, 1967). The use of memos aided in critical reflection of the methods and decisions made during the research process (Birks et al., 2008). This included thoughts or concerns related to the study, reflections on the processes of data collection and analysis, and thoughts on codes and themes emerging from the data. The use of memos helped the researcher stay accountable to the results and themes developed from the data. Memos are included as part of establishing an audit trail for this study.

An *audit trail* was maintained throughout the research process consisting of detailed records of all sources of data used, coded transcripts, analysis processes, details of thematic development, and memos documenting communication and reflective thinking activities (Anderson, 1998). A clearly outlined research plan was followed during each step of this research study as has been shown throughout this chapter. The use of a research protocol, as Yin (2014) calls it, allowed for a methodical reporting of the details of data collection and data analysis, allowing for transparency of the research process and results. This manner of reporting permits others to judge the quality of the research as a whole; increasing the validity of the study (Patton, 1990).

3.6 Ethical Considerations

Ethical research conduct is critical to providing a reliable and valid research study (Merriam, 1998). An in-depth consideration of potential ethical issues and their implications within this research study were addressed at all stages of the research process. Following the basic principles of the Belmont Report, and the guidelines outlined by the National Commission for the Protection of Human Subjects on Biomedical and Behavioral Research for the management of ethical concerns in social research, this research addresses the ethical issues concerning access and acceptance, informed consent, confidentiality, and the role of the researcher (National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research, 1979). Approval to collect research data for this study was obtained from the Curtin University Human Research Ethics Committee (Project Number: SMEC-11-14) from 17 March 2014 to 16 March 2018. Curtin University's research ethics approval conforms with the guidelines of the Australian National Health and Medical Research Council (NHMRC) National Statement on Ethical Conduct in Human Research.

Before potential participants were recruited, official access to the institutions was granted to ensure minimal risk to participants. It was important to gain permission from universities in order to comply with any regulations particular to the participating university. Separate Internal Review Board applications were submitted and approved for each of the five universities participating in this study before formal communication with potential participants was initiated. This procedure involved completing an application to conduct research, as well as providing samples of documentation including research information sheets, participation consent forms, and debriefing documents catering towards each participant group. In line with the guidelines described in Cohen et al. (2011), any foreseeable risks, negative outcomes, or worries in regards to the execution of the project, were thoroughly discussed with each university. Once Internal Review Board approval was granted for each institution, contact with university administrators and instructors began with an information email and request to participate. Follow-up emails confirmed participation and were used to schedule interviews.

A crucial element of ethical consideration was in ensuring participants are aware of the risks and implications regarding their involvement in a research study. For this study, informed consent was required from each participant. An information sheet and consent form were provided (via email and hardcopy) before the interview session, to ensure participants were aware of the purpose of the study and what was being asked of them. This communication informed participants that their involvement in the research study was voluntary and they had the right to refuse to participate or withdraw at any time. Information letters were written specifically for each participant group. The information letters and consent forms are available in Appendix C. Before interviews commenced, participants signed a hard copy consent form and went through a verbal consent to ensure that they actually understood the implications of the study (Cohen et al., 2011). The interview sessions were conducted in-person on each university campus. Conducting interviews on campus provided easy access for participants while providing a neutral location. This situation ensured there was no imbalance of power between researcher and participant, thus ensuring low risk of harm to all parties as was reflected upon in Section 3.5.

Informed consent helped to alleviate concerns specific to each participant group. Upon discovering the researcher is also a professor of science, the student participants may have felt they were being evaluated or that their grade may in some way be affected. Students were specifically informed that this study had no effect on their performance or grade in their online science course, and that the researcher was present only in the capacity as postdoctoral researcher. The instructor participants' attitude had the potential to be altered in that they may have thought that their teaching abilities or unique online course designs were being evaluated. It was explicitly stated to instructor participants that the research project aimed to analyze perceptions of quality among participants and determine quality indicators, not to judge quality of individual courses or individual pedagogies. University administrators, similar to instructor participants, may have felt that the online science courses offered at their university were potentially being scrutinized. It was imperative, through full disclosure, to impart upon the university administrators that the project was only interested in studying effectiveness of online science courses in general and that the aim of this research was not to pass judgment on particular courses or universities.

Privacy and confidentiality are reserved beyond the end of the study to ensure minimal risk of participation for all participants. Confidentiality was important for this research to ensure participants felt comfortable sharing their views and opinions especially when sharing examples within their current courses or university. Audio recording transcriptions of interview sessions, including any personal identifying information, remained confidential by being coded with a number and only designated as either university administrator, instructor, or student. The principal researcher is the only person privy to participant names being connected to their original audio data and transcriptions. For presentaion of the data, participant names were repaced by a pseudonym and grouped under the university pseudonym.

During data collection and analysis, data were stored on a password-protected computer and hard drive. At the conclusion of the research project, interview recordings and transcriptions were stored on the password protected external hard drive and are stored in a secure location for seven years after data collection concluded, at which point the data may be destroyed.

Chapter 4.
Literature Identified Quality Indicators for Online Education

This chapter presents the results of the initial focused review of the literature, conducted between 2013 and 2014, which identified indicators of quality applicable to online education in general, answering the first research question of this study. This study sought to investigate perceptions of quality in online science courses. An initial step in this investigation was to identify indicators of quality as a means to understand perceptions of effectiveness, and help guide the collection and analysis of interview data. A set of quality indicators was established through a focused review of the literature, concentrating on instruments designed to measure the quality of learning environments in online and science education. While the review of the literature aimed to identify indicators of quality for online science education, the review compiled a significant amount of literature pertaining to online education more generally. The quality indicators identified are corroborated with more recent literature and thus, the results of this review uncovered what the literature identifies as quality indicators for online education, answering the first research question:

> Research Question 1 – What does the literature identify as quality indicators for online education?

This chapter consists of two main sections: Section 4.1 presents the analysis and organization of the results of the focused review of the literature, and Section 4.2 outlines the resulting definitions of the quality indicators corroborated with more recent literature, answering the first research question of this study.

4.1 Analysis and Results of the Literature Review

The search of the literature was primarily focused towards valid and reliable online learning instruments which highlight quality factors for online higher education, web-based learning environments, science education, and laboratories. It is through such instruments that the fundamental aspects determining quality were highlighted. Instruments designed to measure effectiveness, perceptions of quality, attitudes, and learning environments in online and science environments set the groundwork for understanding quality indicators unique to online science education.

The literature review was conducted prior to the collection of interview data in 2014 and therefore, only the literature published between 1995 and 2014 was searched and analyzed. The details of the methods used to search the literature were presented in Chapter 3 (Section 3.3.1). The resulting article titles, abstracts, and reference lists were manually and methodically reviewed and studies were organized into the following six delineating categories: 1) Online Science Higher Education, 2) Online Laboratory and Computer Laboratory, 3) Science Learning and Science Laboratory, 4) Science Higher Education, 5) Online Higher Education, and 6) Online Learning. Combined, indicators identified within each of these categories represent indicators for online education through the context of science education. In total, 35 studies are included in the review. The basic details of each study were recorded into an overview table provided in Appendix F due to its length. This table provides information such as the study category, purpose of the study, methodologies used, participant types, online course type, discipline, and the specific instrument, rubric or model developed. For studies not reporting on a specific instrument, the study type is identified in this table more broadly as either a survey, literature review (designated as 'lit review') or theoretical study ('theory'). While the studies selected incorporate work from around the world, studies conducted in the United States and Australia make up the bulk of the literature. Most studies in this review report on asynchronous online courses at four-year universities. Identified quality indicators from each study were extracted for further analysis and retrospection.

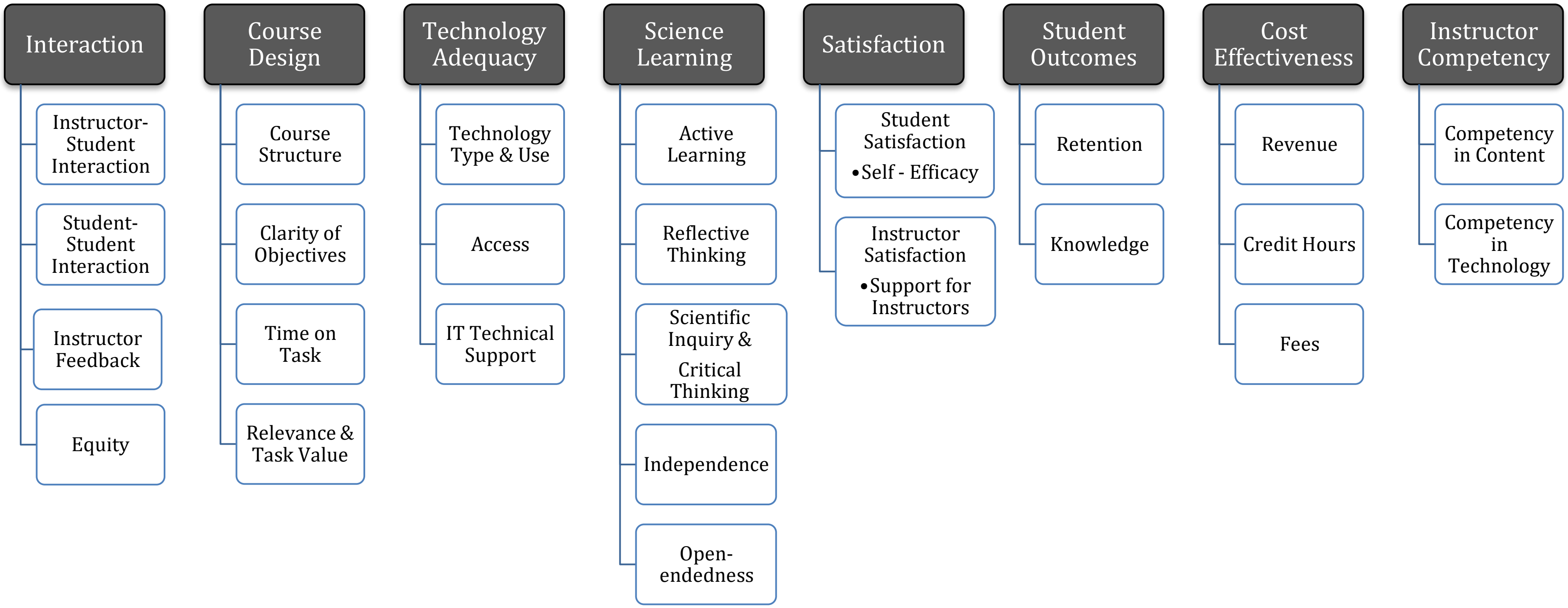
4.1.1 Identification of Quality Indicators

Quality indicators were clearly represented in studies reporting on instrument development or directly concerning quality or effectiveness. For all other studies, the quality indicators were extracted according to the discretion of the researcher. Quality indicators were identified from each study and grouped among like or recurring indicators. Each indicator was globally assessed and examined against others, merging similar quality indicators based on the descriptions within the studies. Eight major categories of quality indicators emerged: *Interaction, Course Design, Technology Adequacy, Science Learning, Satisfaction, Student Learning Outcomes, Instructor Competency* and *Cost Effectiveness*. These eight indicator categories are broad designations that contain several specific quality indicators within each category, defined as sub-categories. While some quality indicators identified in the literature shared the same titles, not all wording fit exactly, as there were various terms used to describe similar quality indicators across the studies. Through several rounds of analysis and organization, names for sub-categories of quality indicators were designated. Each quality indicator identified in a study was organized within a quality indicator category and sub-category. The table in Appendix G shows the original quality indicator terms identified in each study of this review, organized and grouped into the eight main quality indicator categories and sub-categories. As was introduced in Chapter 2 (Section 2.3.5), the literature again shows consistency in quality indicators for online courses and programs, as is evident with indicators matching across the literature (Stewart et al., 2013; Twigg, 2001b).

The results of the literature review identified eight benchmark quality indicators for science online education. All of these indicators, except *Science Learning*, are directly applicable to online education more generally and thus represent what the literature identifies as quality indicators for online education, answering Research Question 1 of this study. Figure 4.1 provides a visual representation of this list of quality indicators. These indicators of quality are strongly grounded through the combined representation across the vast literature of online learning in higher education, making them more transferable. The definitions for each quality indicator were compiled and interpreted from the literature reviewed. These results are corroborated with current literature and are presented in Section 4.2 of this chapter.

Figure 4.1

Literature Identified Quality Indicators for Science Online Education



4.1.2 Significance of Each Quality Indicator

Identifying similar quality indicators across the literature gave a clear representation of what researchers in these fields perceived as the most important indicators of quality. The frequency at which an indicator of quality occurred in the literature provides an indication of the significance of that indicator, representing how well it is agreed upon to be an indicator of quality. Table 4.1 provides a numerical cross-representation of the number of times a quality indicator was identified in the studies reviewed. Each individual indicator extracted from the literature was given a numerical representation of one, and then tallied under its' representative quality indicator title. If multiple aspects of the same quality indicator were represented in the study, a higher numerical value was assigned for the corresponding indicator. For example, a study that reports both instructor presence and communication with instructors as indicators of quality, is designated by a number '2' in the table, as they both address *Student-Instructor Interaction* within the *Interaction* quality indicator. For studies reporting on a review of the literature, a quality indicator may be represented multiple times if it was identified in more than one study within the review. A higher summative value suggests that the quality indicator was more collectively agreed to be essential for effective online science education, as it was addressed more frequently in the literature. This numerical representation quantitatively characterizes the significance of each quality indicator.

The frequency at which each quality indicator was addressed in the literature is displayed as a histogram in Figure 4.2. The values for the number of occurrences that each indicator was addressed in the literature is the summation of the values from Table 4.1. The main quality indicator category is plotted along with the sub-category indicators. Results from this focused review of the literature indicate that *Interaction, Course Design, Technology Adequacy,* and *Science Learning* rank as the top four most significant quality indicator categories, based upon the frequency at which they were addressed in the literature. The particular aspects within the *Science Learning* indicator clarify the uniqueness of science courses. The other quality indicators are highlighted as important for online learning across all disciplines, as well as in the sciences, and thus answers Research Question 1 of this study.

Table 4.1

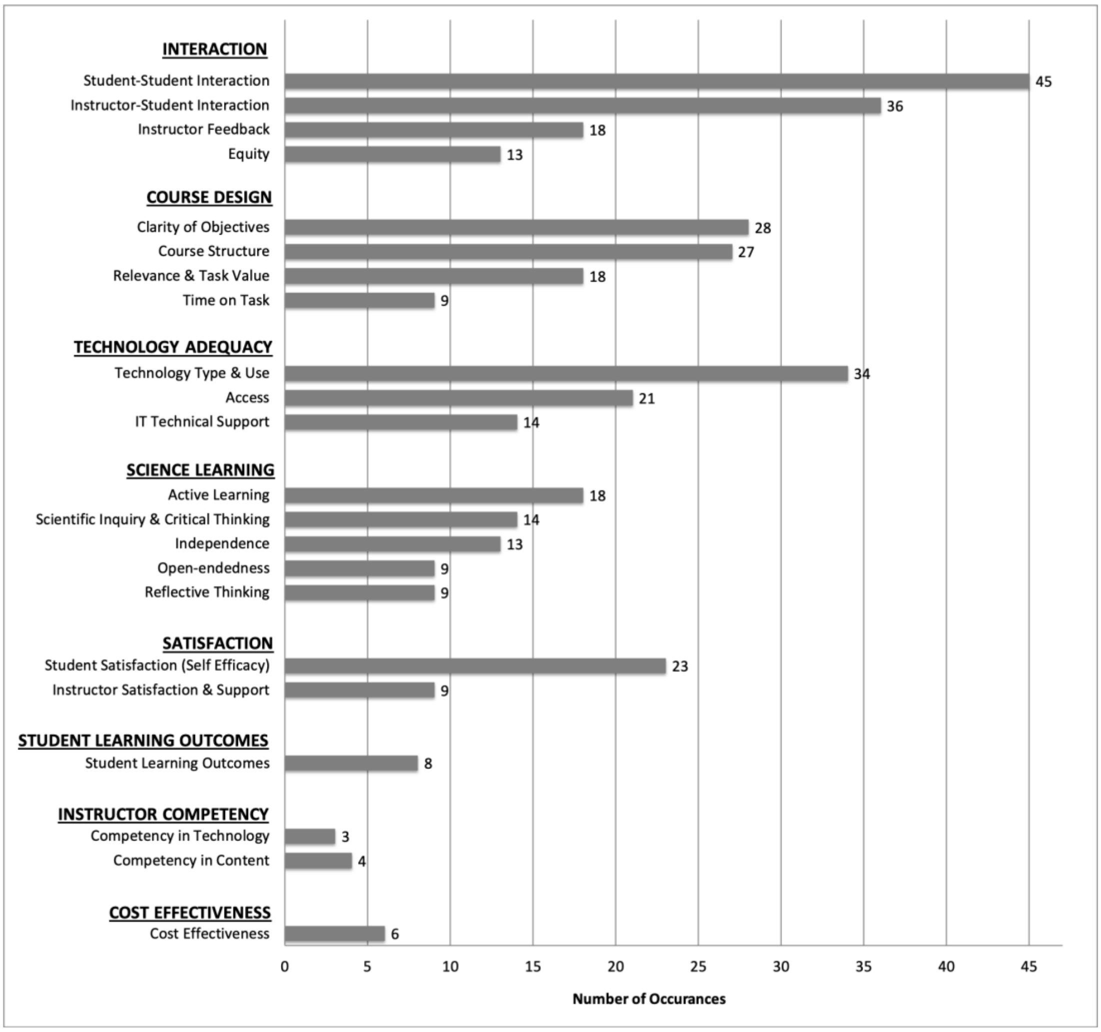
Frequency at which Quality Indicators are Represented in the Literature (1995-2014)

		Study #																																		
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
Interaction	Student-Student Interaction	2	2	1		2	1	1	1	2	1	2	1	1	1	1	1	1	5	1	1	1	1	1	1	1	1	1	1	1	2		1	1	3	1
	Instructor-Student Interaction	1	2	1		3		1	1	2	1	2		1		1	1	1	3	1	1	1	1		1	1	1	1	1	1	1		1	1	1	1
	Instructor Feedback		1				1	1	1	2				1		1			2		1	1	1		1	1	1				1		1			
	Equity	2			1			2											3		1	1			1		1			1						
Course Design	Clarity of Objectives	1			1	2	1	1	1	2	1	1	1	1	1	1	1		3		1	2	1			2					1					2
	Course Structure		1				1		1		1	1	1	2	1		1		4		1	1		1	2	2			1		2	1				2
	Relevance & Task Value				1			1				2	1		1		2			1	1			2						2		1	2		1	
	Time on Task			1		2		1		1						1	1									1										1
Technology Adequacy	Technology Type & Use	1	1		1	1		1	2	2	1	2		1	1	1			3	1	1	2	2	2	4	1			1	1				1		
	Access	1				1	1				1			1	1	1			5			2	1	1	2					2				1		
	IT Technical Support				1					1		1		1		1			1			1	1		2	1		1						1		1
Science Learning	Active Learning		1	1	1			1	1	1	2	2		1					1			1	1		1	1					1		1			
	Scientific Inquiry & Critical Thinking	1	1		1					1	1			1				3		2	1											1			1	
	Independence	1			1	1					1				1		1	1	2										1	1		1	1			
	Reflective Thinking		1	1				1	1							1				1									1	1					1	
	Open-endedness				1					1	1		1			1	1		1		1			1												
Satisfaction	Student Satisfaction *(Self Efficacy)*	1				1	1		1		1	2			2	1	1	2			1		1	2	1		1				1	1		1		1
	Instructor Satisfaction & Support							1			1	1		1											2	1								2		
Outcomes	Outcomes					1						1		1				1	1			1			2											
Instructor Competency	Competency in Content					1		1				1														1										
	Competency in Technology					1						1														1										
Cost Effectiveness	Cost effectiveness					1								2											2									1		

#	Study
1	Aldridge, Dorman & Fraser (2004)
2	Asbell-Clarke & Rowe (2007)
3	Bangert (2006)
4	Blake & Scanlon (2007)
5	Bright et al. (2008)
6	Chang & Fisher (2001/2003)
7	Chickering & Ehrmann/Gamson (1996/1987)
8	Clayton (2011)
9	Davis & Snyder (2012)
10	DeHaan (2005)
11	Downing & Holtz (2008)
12	Fraser, Giddings & McRobbie (1992/1995)
13	Institute for Higher Education Policy (2000)
14	Iyer (2011)
15	Jegede, Fraser & Fisher (1995)/ Williams (2003)
16	Kerr, Fisher, Yaxley & Fraser (2006)
17	Lee et al. (2011)
18	Lowe et al. (2007)
19	Maor & Fraser (2005)
20	Martz, Reddy & Sangermano (2004)
21	Maryland Online (2011-2013 Ed)
22	McGorry (2003)
23	Newby & Fisher (1997/2000)
24	Online Learning Consortium (2014)
25	Perry (2003)
26	Rovai (2002)
27	Slagter van Tryon & Bishop (2012)
28	Swan (2004)
29	Trinidad, Aldridge & Fraser (2005)
30	Veal, Brantley & Zulli (2004)
31	Velayutham, Aldridge & Fraser (2011)
32	Walker & Fraser (2005)
33	Ward, Peters & Shelley (2010)
34	Yeo, Taylor & Kulski (2006)
35	Young & Norgard (2006)

Figure 4.2

Graphical Representation of the Frequency at which Quality Indicators Occur within the Literature



4.2 Quality Indicators as Defined in the Literature

4.2.1 Interaction

Interaction is commonly understood as communication or direct actions between individuals. Interaction is accepted as an integral part of all formal education (Chickering & Gamson, 1987). While interaction was mostly absent in the early implementation of online education, the current online learning literature, in combination with the science learning literature, are consistent regarding the importance of interaction online (Abrami et al., 2011; Bolliger & Martin, 2020). It is the incorporation of interaction in an online course that distinguishes it from a self-study type course. Interaction was the most frequently cited category of quality indicators in the focused review of the literature (Figure 4.2), including: *Student-Student Interaction, Student-Instructor Interaction, Instructor Feedback,* and *Equity*. Moore (1989), who is highly cited in relation to interaction in distance education, identifies an additional type of interaction; student-content interaction as the "process of intellectually interacting with content" (p. 2). This type of interaction is rooted in how students are receiving information, through textbooks, lecture videos, simulation activities, etc. This incorporates how content is delivered and digested by student learners in the online environment. The review of the literature did not directly identify this type of interaction. Instead, such student interaction with content was integrated within the quality indicator categories of *Course Design* (Section 4.2.2), *Technology Adequacy* (Section 4.2.3), and within *Science Learning* (Section 4.2.4). A summary of how *Interaction* is defined as an indicator of quality in the literature is outlined in Table 4.2 at the end of this section.

Student-Student Interaction. Interaction and collaboration among students were the most frequently cited indicator of quality in the focused review of the literature (Figure 4.2). Student-student interaction includes social interactions, course work collaboration, online discussion and group work (Asbell-Clarke & Rowe, 2007; Bolliger & Martin, 2020; Davis & Snyder, 2012). Social interaction takes place both within and outside the structured online class, building relationships between students aside from working on course content together. In this way, students to get to know, help, and be supportive of one another (Newby & Fisher, 2000; Scager et al., 2020). Student interaction through group work or group collaboration includes students actively working together to solve problems or complete projects. Students collaborate on activities to facilitate learning, often through online peer discussion forums (Taylor & Maor, 2000). Interaction and collaboration between students are valued in online education because it is believed to enhance learning and enjoyment (Kurucay & Inan, 2017; Slagter van Tryon & Bishop, 2012). This approach includes support from peers, a sense of social connectedness, and discussions with other students to reflect and share ideas. Students cooperate and work together rather than compete in successful student interactions (Aldridge et al., 2004; Chickering & Ehrmann, 1996). Interaction between students is facilitated through online discussion forums, emails, synchronous communication, social media and learning management system features such as journals and blogs.

Student-Instructor Interaction. The second most frequently identified quality indicator in the literature was *Student-Instructor Interaction* (Figure 4.2) which includes the type and amount of communication between the course instructor and students. Interaction is accomplished when an instructor engages with students in a timely and ongoing matter, both professionally and socially, being accessible in and out of class (Bangert, 2006). Student-Instructor interaction in an online course can be conducted in myriad of ways, including email, discussion boards, synchronous and asynchronous online chat or video conferencing, and phone calls (Bolliger & Martin, 2020). Support is often a key term used to represent desired interaction between students and instructors. Support holds a broad definition, often described as the extent to which an instructor helps, befriends, trusts and is interested in students (Trinidad et al., 2005). This involves providing a level of personalized interaction or social presence within the online course (Bright et al., 2008). Student-instructor interaction also includes instructors forming a relationship with their students in the form of friendship, trust, and showing interest and sensitivity to students' needs (Jegede et al., 1995; Martz et al., 2004).

Instructor Feedback. An indicator of quality online education includes instructors providing timely, detailed and constructive feedback on student learning (Bolton et al., 2019; Bright et al., 2008; Online Learning Consortium, 2019). Frequent instructor feedback is useful for cognitive development and for learning the course content. Feedback allows students to determine their learning progress and provides a sense of interaction within an online course (Chang & Fisher, 2001). This indicator was often highlighted separately in the literature, beyond its integration with *Student-Instructor Interaction*, as it was linked to assessment reports and learning progress as opposed to the personal communication and relationships built between students and instructors.

Equity. An identified integral part of effective interaction is *Equity*. Equity in interaction occurs when instructors treat students equally but respect diverse learning types. Instructors cater to students on the basis of ability, rates of learning, and interest to ensure learning effectiveness for all students (Aldridge et al., 2004). Students are provided opportunities to interact and learn in ways that work for them (Chickering & Ehrmann, 1996; Paechter & Maier, 2010). Equity also includes accounting for and accommodating different student learning types and optimizing individual learning styles (Downing & Holtz, 2008). Effective interaction in an online environment includes feeling part of a classroom community. Feeling part of a learning community includes providing equitable learning experiences in which students educational needs are met (Rovai, 2002).

Table 4.2

Summary of the Definition of Interaction as a Quality Indicator

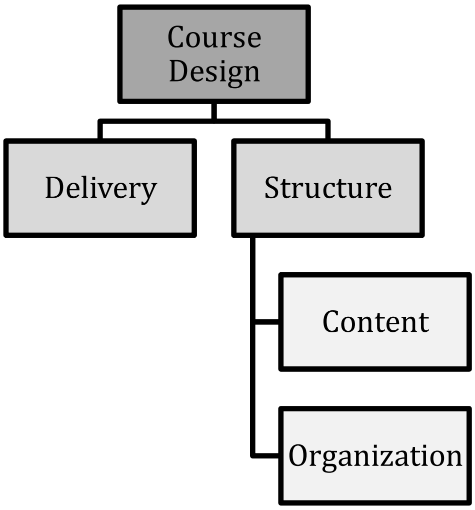
Interaction Quality Indicator	Defining Components
Student-Instructor Interaction	• Timely feedback • Instructor is accessible • Personalized interaction • Instructor engages with students both professionally and socially
Student-Student Interaction	• Discussion board forums, emails, LMS tools • Social interaction • Both in and out of course time • Reflect and share ideas • Group work • Course work collaboration
Instructor Feedback	• Assessment results • Evaluation and progress reports • Reassurance of learning • Timely feedback
Equity	• Equal learning opportunities • Learning geared to diverse learning types

4.2.2 Course Design

The quality indicator category of *Course Design* was the second most frequently cited from the focused review of the literature (Figure 4.2). This category also includes *course structure*, *clarity of objectives*, *time on task*, *relevance* and *task value*. Course design encompasses the overarching framework of an online course, including the delivery method (asynchronous, synchronous or blended/hybrid) and overall course structure to include the content and organization (Figure 4.3). The majority of the studies included in this focused review of the literature concentrated on the asynchronous delivery of online courses. A summary of how *Course Design* is defined as an indicator of quality in the literature is outlined in Table 4.3.

Figure 4.3

Course Design Elements



Course Structure. Course structure refers to the choice, organization and sequencing of course content to support the course learning objectives. The structure of the course is organized such that procedures, expectations, curriculum and course materials are clearly outlined. The structure of an online course is the bedrock upon which the content is taught, learned, and interaction is accomplished. Course structure includes the framework upon which the instructor provides course learning materials, assignments, assessments, opportunities for interaction and direction of cognitive development for students (Soffer & Nachmias, 2018; Swan, 2004). Effective online science courses are structured and organized to be stimulating and visually pleasing to students (Clayton, 2011) in addition to being functional for learning. Learning management systems (LMSs) often provide a basic level of course structure and layouts, but the course developers or instructors determine the more formal structure and subsequent organization of how material is presented. Course structure incorporates content and activities that are organized so as to stay on the subject matter and promote understanding and mastering of science concepts as well as improving science skills (Downing & Holtz, 2008).

Clarity of Objectives. Within a well-designed and structured online course, clear expectations and objectives for learning were identified as an indicator for quality. Effective online courses provide clear objectives and expectations within the curriculum, activities, and overall course (Chickering & Ehrmann, 1996; Iyer, 2011; Jegede et al., 1995). Clear objectives are especially valued for activities and in laboratory courses, which are often guided by more formal rules and in which students need clear instructions on how to use simulations, software or equipment (Bright et al., 2008; Fraser et al., 1995).

Time on Task. *Time on Task*, refers to the amount of time given, required, or expected to complete course assignments or activities. This information also includes the time needed or expected for learning content, working through course learning materials, interacting with other students and for completing the course. Providing students with effective time management through the allocation of realistic allocated amounts of time for course tasks translates to quality in online courses (Bangert, 2006). As an indicator of quality, the time required for students to complete course tasks, activities, and laboratories should be realistic and reasonable (Perry, 2003).

Relevance and Task Value. The *Relevance* or *Task Value* of content was identified as significant, indicating that online science courses should provide content and activities relevant to students' experiences, life, and provide real-world context (Smidt et al., 2017). This includes learning tasks and activities that are interesting, important, and useful to students, allowing them to find value in the course (Velayutham et al., 2011). Value is based on whether students perceive the course as worthwhile and the extent to which students would take the course again or recommend the course to other students (Martz et al., 2004). As part of *Relevance*, effective courses may integrate active learning content into online courses, employing the application of real-life contexts into the course. *Task Value* also includes the extent to which an online course helps students solve real-world problems, contributing to authentic learning (Trinidad et al., 2005).

Table 4.3

Summary of the Definition of Course Design as a Quality Indicator

Course Design Quality Indicator	Defining Components

Course Structure	• Organized framework and design of course
	  o LMS structure and layout
	• Learning and assessment content
	  o Activities to promote understanding of science concepts
	• Facilitation of interaction
	• Stimulating and visually pleasing
	• Presentation of material

Clarity of Objectives	• Clear expectations • Clear objectives for learning • Organized procedures and rules • Clear instruction
Time on Task	• Provide effective time management guidelines • Clear time requirements or expectations to complete assignments • Realistic time requirements
Relevance and Task Value	• Provide real-world context • Provide content and activities relevant to students' experiences • Provide students with valuable tasks

4.2.3 Technology Adequacy

Technology Adequacy was the third most frequently identified category of quality from the focused review of the literature. The literature results centered upon the idea that online courses depend on technology as well as the extent to which the hardware and software are adequate for the learning tasks required (Newby & Fisher, 2000; Smidt & Li, 2019). The literature specifically identified the *type of technology and how it is used*, *access through technology* and *technical support* as important aspects of quality in online education. A summary of how *Technology Adequacy* is defined as an indicator of quality in the literature is outlined in Table 4.4 at the end of this section.

Technology Type and Use. The type of technology or technological tools used in an online course were addressed most frequently within the *Technology Adequacy* category. The type of technology used determines how the course is delivered to students. Some courses use websites to deliver course content, but it is common for courses established within a university to use an online learning management system (LMS). The LMS software application is used to deliver and administer educational course content online. Common LMSs used in universities for online learning include Blackboard, Canvas, Moodle, and Desire2Learn. Technology type also includes any additional software applications, videos, simulations, and websites used as part of the learning environment., Programs used for online laboratory or active learning activities are included within technology type. As an indicator of quality, the type of technology is linked to how efficiently it is used in the educational setting. The literature highlighted the importance of having accessible, reliable, and convenient technological tools that accommodate various operating systems and devices (Chang & Fisher, 2001; Clayton, 2011). Quality online courses consider the extent to which the technology used is tasked focused, functional and easy to use (Jegede et al., 1995; Maor & Fraser, 2005), while also keeping up with modern, leading edge technology (Lowe et al., 2007). This approach includes the extent to which students feel comfortable and enjoy using technological tools within the course (Clayton, 2011).

Access. *Access* includes providing the means for students to access online courses, learning resources, and navigate within a course (Online Learning Consortium, 2019; Quality Matters, 2018). This indicator affirms that the learning environment, technological tools, and learning materials for online science courses and laboratories are easily accessible, readily available, reliable, convenient to use, and easy to set up for both students and instructors (Chang & Fisher, 2001; Iyer, 2011). Flexibility is also emphasized within *Access*, providing time and place independence for learning (McGorry, 2003).

IT Technical Support. Using Internet technology for learning assumes an inherent risk in achieving seamless functionality. In order for the technology to be supportive and effective for online learning, *Technical Support* must be easily accessible (Perry, 2003). As an indicator of quality, *Technical Support* provides technology reliability through administration support, security and resources readily available for students and instructors (The Institute for Higher Education Policy, 2000; Young & Norgard, 2006).

Table 4.4

Summary of the Definition of Technology Adequacy as a Quality Indicator

Technology Adequacy Quality Indicator	Defining Components
Technology Type & Use	• Task focused, functional and inviting to use • User friendly, compatible across devices and systems • LMS, software, website, videos, simulations • Appropriate for learning objectives
Access	• Accessible and reliable learning environment and tools • Ease of use
IT Technical Support	• IT security and resources readily available • Technical support easily accessible • Support for both students and instructors

4.2.4 Science Learning

The indicators of quality aimed specifically at science education are typically rooted in constructivist learning theory and conceptual change theory. A constructivist perspective has long been dominant in science education and has continued to be used in online science learning environments (Harasim, 2012; Ross & Scanlon, 1995; Rovai, 2004). For science learning, such theoretical views weigh heavily on the use of active learning, promotion of critical thinking, and the implementation of practical laboratory application. The indicators of quality for online *Science Learning* highlight these aspects, grounded within a generalized constructivist framework. The three most significantly identified indicators for *Science Learning* are: *Active Learning*, *Scientific Inquiry or Critical Thinking*, and *Student Independence* (Figure 4.2). Laboratories were not independently addressed for online science learning in this initial focused review of the literature, but instead are included within the aspects of *Science Learning.* A summary of how *Science Learning* is defined as an indicator of quality in the literature is outlined in Table 4.5 at the end of this section.

Active Learning. *Active Learning* involves students engaging in authentic hands-on or computer simulated learning activities, including communication activities. Students interact with physical or computer models and materials to complete scientific investigations. Active learning as part of a constructivist framework encourages students to integrate their own existing knowledge with the course learning experiences, allowing for new cognitive development (Bangert, 2006; Hacker & Niederhauser, 2000). Active learning also includes students being active participants in class as opposed to passive observers (Perry, 2003).

Reflective Thinking. Students are given opportunities to reflect critically on their learning and thinking through reflective activities and discussions. *Reflective Thinking* is fundamental for constructing knowledge in science as described through a constructivist approach to teaching and learning. Part of reflective thinking is the extent to which students are encouraged to justify their ideas for themselves and to others, as well as reflect critically on other's ideas (Jegede et al., 1995). Reflections among students are often carried out through course discussions online (Trinidad et al., 2005).

Scientific Inquiry and Critical Thinking. A pinnacle of science learning environments is the incorporation of *Scientific Inquiry*. *Critical Thinking* is incorporated in many disciplines, but is an essential component within science learning; so much so, that within the sciences, the application of traditional critical thinking is specified as scientific inquiry with higher-order problem solving that is student-directed (Kim & Hannafin, 2004). While some see scientific inquiry as uniquely different from critical thinking, for this review, both were included under the same quality indicator. As indicators of quality these include activities or discussions that encourage learners to engage in scientific inquiry for problem solving and investigations. Students participate in these activities which engage and challenge them in developing their own understanding of scientific ideas (Asbell-Clarke & Rowe, 2007). Challenging students to think critically or use inquiry learning is in fact an important characteristic for constructivist learning theory (Maor & Fraser, 2005). Much of scientific inquiry practice takes place in science laboratories, but can be incorporated in science courses through a range of methods and activities in class.

Independence. Student independence as well as open-endedness identifies opportunities for students to be responsible and have control over their own learning pace and curriculum. Within the constructivist framework lays the importance of students conceptualizing and constructing their own understanding. An essential component in providing students with successful avenues to accomplish this is a bit of independence and flexibility in learning. *Independence* includes students being given opportunities to be responsible and independent within a course. This allows them to initiate ideas and have more control over their learning, classroom behavior, and pace of curriculum and assessments (Paechter & Maier, 2010). Online courses can be adaptable and at some level tailored to student needs, allowing for more independent learning (Blake & Scanlon, 2007). Independence allows for student autonomy and increased responsibility for their own learning (Trinidad et al., 2005).

Open-endedness. The flexibility in teaching and learning underlying constructive learning theory creates the indicator of quality, *Open-endedness*. This indicator of quality emphasizes course activities and laboratory activities that promote student-directed learning and experimentation. This involves open-endedness and flexibility in the course structure or curriculum, and a variety of activities for learners (Davis & Snyder, 2012). Students are allowed to direct their learning and choice of processes when completing scientific activities or laboratories (Fraser et al., 1995). Instructors are able to direct the learning process though open-ended choice of laboratory activities and implementation of activities in the classroom or laboratory in order to promote a constructivist learning approach.

Table 4.5

Summary of the Definition of Science Learning as a Quality Indicator

Science Learning Quality Indicator	Defining components
Active Learning	• Engaging activities • Hands-on learning • Communication activities • Computer simulated activities
Reflective Thinking	• Reflective activities and discussion • Reflections to justify ideas (self and peers) • Reflect critically on concepts learned
Scientific Thinking & Critical Thinking	• Higher-order problem solving • Activities in science inquiry • Investigation activities ○ Student directed activities • Science laboratory practice
Independence	• Students responsible for their learning • Conceptualize and construct understanding of concepts • Control learning pace • Flexible and independent learning
Open-endedness	• Variety of activities • Experimentation • Student-directed learning

4.2.5 Satisfaction

Satisfaction is the amount of enjoyment one perceives and the feeling that one's needs or expectations are met. Within online science education, satisfaction was identified in the literature as a quality aspect that includes both student and instructor satisfaction. A summary of how *Satisfaction* is defined as an indicator of quality in the literature is outlined in Table 4.6 at the end of this section.

Student Satisfaction and Self-Efficacy. *Student Satisfaction* includes the enjoyment or anxiety students feel learning online as well as self-efficacy. *Self-efficacy* is the extent to which students feel confident in their ability to do the necessary tasks to succeed in their online courses (Lee et al., 2011). This also includes students taking control of their own motivation to succeed at the level they see necessary for success (Velayutham et al., 2011). *Student Satisfaction* represents the extent to which students enjoy the course, feel confident in their ability to successfully complete science-learning tasks, and have an overall feeling of wellbeing in the online environment. This is also correlated to student involvement and social interactions which include the extent to which students have attentive interest and participate in the course (Bright et al., 2008; Online Learning Consortium, 2019). Student satisfaction is dependent on student type and especially individual learning types (Swan, 2004). Particularly in online courses, student age and geographic location tend to be widely varied. As with *Equity,* consideration of the types of students and their unique learning styles and optimizing learning as a result of these variations is believed to increase the effectiveness of online courses (Downing & Holtz, 2008)

Instructor Satisfaction and Support for Instructors. Effective online science courses employ satisfied instructors and provide them with support (Online Learning Consortium, 2019). *Instructor Satisfaction* includes the extent to which instructors are pleased with teaching online, feel confident in their ability and knowledge of online learning environments, and are satisfied with their workload and job status. A primary aspect of instructor satisfaction is *Instructor Support* from the university. This includes technological support, training, and assistance transitioning to teaching in the online environment (The Institute for Higher Education Policy, 2000). Support from the university for training and transition assistance incorporates various forms of professional development, mentoring and assistance for learning how to teach in the online environment and how to appropriately transition from teaching face-to-face to online (Chickering & Ehrmann, 1996; The Institute for Higher Education Policy, 2000; Ward et al., 2010). Instructor support also includes support in online course development, preparation, and delivery, as well as support resources for course maintenance and updates.

Table 4.6

Summary of the Definition of Satisfaction as a Quality Indicator

Satisfaction Quality Indicator	Defining Components
Student Satisfaction	• Self-efficacy/confidence • Dependent on Student Type • Enjoyment in learning
Instructor Satisfaction	• Pleased with teaching online • Confident in abilities • Instructor support

4.2.6 Student Learning Outcomes

As with many educational evaluations of effectiveness, the literature identified *Student-Learning Outcomes* as an indicator of quality for online education. Student learning outcomes include not only direct assessment of student knowledge but also the retention of knowledge. As a measurement of quality, student learning outcomes should meet or exceed institutional, industry, or community standards (Bright et al., 2008; Online Learning Consortium, 2019). In addition, intended learning outcomes are reviewed regularly in a quality course (The Institute for Higher Education Policy, 2000). Many of the quality indicators identified from the review of the literature are contributing factors to achieving desired student learning outcomes in the online environment (Bright et al., 2008). A summary of how *Student Learning Outcomes* is defined as a quality indicator in the literature is provided in Table 4.7.

Table 4.7

Summary of the Definition of Student Outcomes as a Quality Indicator

Student Outcomes Quality Indicator	Defining Components
Knowledge	• Student assessed knowledge meets or exceeds institutional, industry or community standards • Learning outcomes reviewed regularly
Retention	• Student retention of knowledge meets or exceeds institutional, industry or community standards

4.2.7 Instructor Competency

Instructor Competency was the least frequently identified indicator in the focused literature search. However, the literature indicates that the competency of the instructor as an expert and professional, does not go unnoticed by students (Chickering & Gamson, 1987). *Instructor Competency in Content* includes how well the instructor appears to understand and be well versed in the subject matter. In an online course, the ability to understand and explain not only the course content, but also help trouble shoot and explain the technological aspects which run the course was found as an indicator of quality. The course instructor *Competent in Technology* is highly knowledgeable in the use of the course technology including computer, learning management systems, and laboratory technology (Perry, 2003). A summary of how *Instructor Competency* is defined as an indicator of quality in the literature is outlined in Table 4.8 below.

Table 4.8

Summary of the Definition of Instructor Competency as a Quality Indicator

Instructor Competency Quality Indicator	Defining Components
Competency in Content	• Instructor is well versed in the subject matter • Instructor has the ability to explain the course content
Competency in Technology	• Instructor has knowledge in technological aspects ○ Computer use, LMS and lab technology

4.2.8 Cost Effectiveness

For the university as an institution, *Cost Effectiveness* becomes a factor in considering quality online education. Cost effectiveness includes increasing revenue, while decreasing fees. Revenue is typically calculated by the number of enrolled students taking a certain number of credit hours, with the goal to achieve capacity enrollment (Online Learning Consortium, 2019). Data on enrollment, student attrition rates and costs contribute to the evaluation of online program effectiveness (The Institute for Higher Education Policy, 2000). Free from the constraints of a physical classroom, online courses can accommodate higher student enrollment which can decrease the use of "over-crowded buildings" and labor for the university (Moore, 2005). For students enrolling in a university, cost effectiveness is expressed in the cost of attending courses online. Cheaper tuition rates in online courses lend to a more cost-effective option for students (Magda et al., 2020). To maintain quality, institutions require polices for continual improvement in developing and evaluating cost-effective measures and practices (Online Learning Consortium, 2019). A summary of how *Cost Effectiveness* is defined as an indicator of quality in the literature is outlined in Table 4.9.

Table 4.9

Summary of the Definition of Cost Effectiveness as a Quality Indicator

Quality Indicator	Defining Components
Cost Effectiveness	• Allow for higher student enrollment • Increase revenue • More cost-effective for students o Cheaper tuition rates

4.3 Chapter Summary

This chapter presented the analysis and results of the initial focused review of the literature that was used to establish quality indicators for online science education. The following eight quality indicator categories were identified: *Interaction, Course Design, Technology Adequacy, Science Learning, Satisfaction, Student Outcomes, Instructor Competency* and *Cost Effectiveness*. Detailed descriptions compiled from the literature for each quality indicator were presented. A full list of the identified quality indicators and the primary components combined and summarized from the literature are presented together in Table 4.10. These quality indicators identified in the literature apply to online education more generally, beyond the focus on science online education specifically. Thus, presenting the quality indicators that the literature identifies for online education, answers the first research question of this study. The primary quality indicator components identified under *Science Learning* are presented separately in Table 4.11.

The quality indicators identified in this focused literature review guided the development of interview questions, helped in focusing discussion with participants during interviews, and provided a framework for analysis of perceptions in this qualitative study. Chapter 5 presents the qualitative interview data analysis and results, focusing on stakeholder perceptions of quality indicators for online education more generally and how they compare to the quality indicators identified in the literature from this review.

As was introduced in Chapter 3 (Section 3.3), the quality indicators identified in this review of the literature were valuable for analysis of perceptions pertaining to quality indicators applicable to online education more generally, but the indicators focused on science learning specifically (presented in Table 4.11), needed more specificity. Thus, a second review of the literature was conducted to identify laboratory learning objectives. The results of a re-analysis of the qualitative interview data based on these objectives are presented in Chapter 6.

Table 4.10

Overview Descriptions of the Quality Indicators for Online Education as Identified in the Literature.

Quality Indicator		Primary Defining Components
Interaction	Instructor-Student Interaction	• Communication • Relationship / Personalized • Feedback • Access to Instructor • Instructor Presence
	Student-Student Interaction	• Communication with other Students • Discussions • Relationships • Support • Social • Group Work & Collaboration
	Instructor Feedback	• Assessment Results • Progress Reports • Reassurance of Learning • Timely Feedback
	Equity	• Equal learning opportunities • Learning geared to different learning types
Course Design	Course Structure	• Organized framework and design of course • Learning and assessment of content • Stimulating and visually pleasing • Functional for learning
	Clarity of Objectives	• Clear expectations • Clear learning objectives
	Time on Task	• Reasonable time given to complete tasks • Reasonable time expectations
	Relevance & Task Value	• Content and activities are relevant to students • Authentic Learning / Real-world context • Student perceives course as worthwhile
Technology Adequacy	Technology Use & Type	• Learning management systems & software • User friendly • Reliable • Compatible across various platforms • Task focused and functional • Appropriate for learning objectives
	Access	• Ease of use • Accessible – Learning environment, content and tools

Quality Indicator		Primary Defining Components
	IT Technical Support	• Technical support readily available and easily accessible • IT Security • Resources for students and instructors
Satisfaction	Student Satisfaction	• Enjoyment or anxiety • Self-efficacy • Student involvement
	Instructor Satisfaction	• Confidence in ability to teach online • Support from university • Transition support • Training provided
Student Learning Outcomes	Knowledge	• Student assessed knowledge meets or exceeds institutional, industry or community standards • Learning outcomes reviewed regularly
	Retention	• Student retention of knowledge meets or exceeds institutional, industry or community standards
Instructor Competency	Competency in Content	• Instructor is subject matter expert • Instructor can explain the course content
	Competency in Technology	• Instructor is knowledgeable in course technology, tools and online content
Cost Effectiveness	Revenue	• Increase course enrollment
	Fees	• Low cost for online courses

Table 4.11

Overview Description of the Quality Indicators Unique to Science Online Education

Quality Indicator		Primary Defining Components
Science Learning	Active Learning	• Active participation • Hands-on or computer simulation activities
	Reflective Thinking	• Reflect critically on learning
	Scientific Inquiry & Critical Thinking	• Higher-order problem solving • Inquiry learning activities
	Independence	• Flexibility in learning • Students responsible for their learning – conceptualize and construct knowledge • Students given independence
	Open-endedness	• Flexibility in course structure and activities • Student-directed learning and experimentation

Chapter 5.
Stakeholders' Evaluation of Online Science Courses in Relation to the Quality Indicators

For this qualitative interview study, participants from the three stakeholder groups; students, instructors and administrators, were interviewed regarding their perceptions of quality in online science courses. This chapter presents the results of the detailed conversations with participants, where they identified quality indicators for online education in the context of science courses. In addition, this chapter presents the results of a direct comparison of stakeholder perceptions with the quality indicators identified in the focused review of the literature as presented in Chapter 4. The results presented in this chapter answer the second research question of this study:

> Research Question 2 - What indicators do the university stakeholders use to evaluate the quality of online education in the context of university science courses?

This chapter begins with a broad overview of the results to set the stage for the remaining in-depth presentation of results of stakeholder perceptions. This is followed by a detailed presentation of stakeholder perceptions for each quality indicator including a comparative analysis among the three stakeholder groups and a comparison between the literature and stakeholder perceptions. The quality indicators that can be applied to online education more generally provide the overall structure of the results presented here in Chapter 5. This excludes the quality indicator *Science Learning* which is presented as part of Chapter 6 with the focus on results for science unique quality aspects.

5.1 Overview of Quality Indicator Results

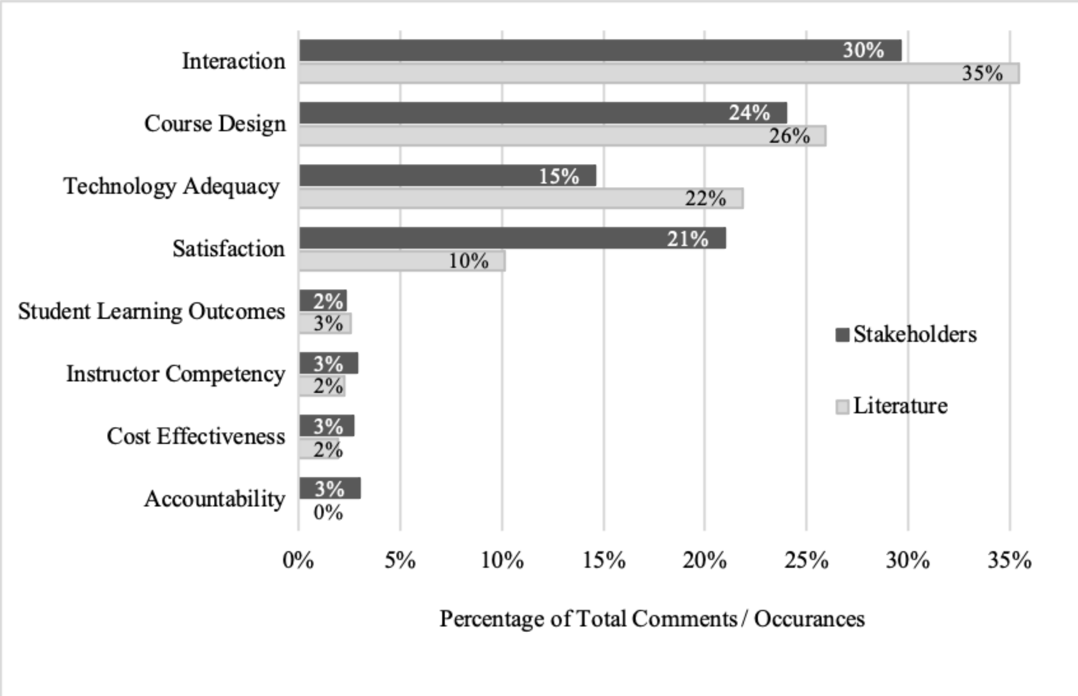
Fifty participants across five universities in the Midwestern United States took part in this qualitative interview study: 16 administrators, 14 instructors and 20 students. In the interview sessions, each participant was asked, "In your opinion what makes quality online science education?" Responses to this question, combined with the analysis of the interview sessions as a whole, revealed participant's identification of quality indicators for online science courses. The combined perspectives from university administrators, instructors and students across the five universities correlate well with the quality indicators identified from the focused review of the literature.

Comparison of the frequency that quality indicators for online education were discussed among all stakeholders and within the literature show that there is a high degree of congruency for most indicators. Both the literature and participants discussed *Interaction* and *Course Design* more frequently than other quality indicators. The literature and stakeholders diverge in the frequency of discussion of *Satisfaction* which is more readily discussed by stakeholders than was represented in the review of the literature. *Technology Adequacy*, on the other hand, was represented more often in the literature than among stakeholders.

Figure 5.1 provides a graphical overview of the frequency at which quality indicators pertaining to online education were addressed by both university stakeholders and the literature. In the plots, frequency is represented as the percentage of the total comments from stakeholders or occurrences found in the review of the literature for each indicator. The data for the university stakeholders represents the combined comments of all three stakeholder groups. The number of instances that participants addressed the main quality indicator categories was tallied using NVivo coding. In this plot, the data from the focused review of the literature is the same as was presented in the histogram plot in Chapter 4 (Figure 4.2) for the eight main quality indicator categories. The data is displayed as percentages of the total discussion of all indicators of quality identified for online education. This plot excludes the indicator category of *Science Learning*, which is addressed in Chapter 6 for science unique quality aspects.

Figure 5.1

Overview of Quality Indicators Discussed Among Stakeholders and the Literature



Note: The percentages are of the total discussion of all quality indicators addressing online education (not including *Science Learning* quality indicators).

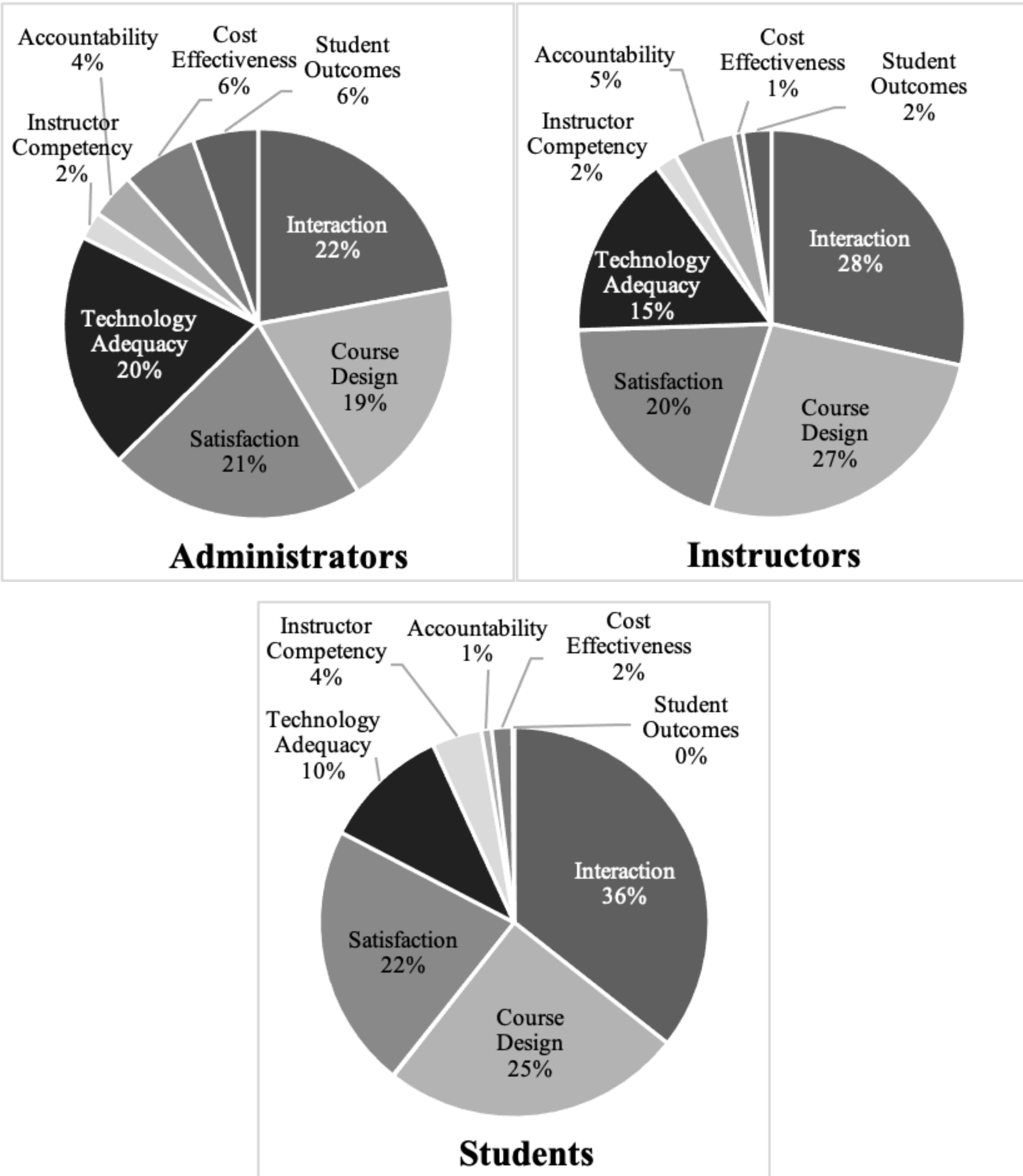
In this chapter, the quality indicators identified are applicable to online education more generally, while still discussed among participants within the context of university science courses. The most frequently identified quality indicator categories among all participants were: *Interaction*, *Course Design*, *Satisfaction* and *Technology Adequacy*. Participants identified a new indicator of quality that was not identified in the focused review of the literature: *Accountability*. While this indicator was not discussed as readily as other indicators, participant reflections of this new quality indicator added insight into continued skepticism surrounding online science courses. Similar to the results from the review of the literature, three quality indicator categories were scarcely addressed by participants: *Instructor Competency, Student Outcomes* and *Cost Effectiveness*.

Among the stakeholder groups, both administrators' and instructors' discussion of quality online education focused on *Course Design* and *Interaction* with almost equal frequency. Students, on the other hand, discussed *Interaction* more frequently compared to other quality indicators. Figure 5.2 provides a visual representation of this comparison between the stakeholder groups using pie charts. The charts show the percentage at which a quality indicator was mentioned, out of the total number of comments from the stakeholder group. These plots give a quick overview of the frequency at which a quality indicator was discussed among each participant group. Similar to the presentation of quality indicator data from the focused review of the literature in Chapter 4, the more often a quality indicator was discussed, the higher percentage it takes of the total conversation, giving some insight into the significance of that indicator.

In the next sections of this chapter, stakeholder perceptions regarding each quality indicator are presented and discussed in detail. Additionally, for each quality indicator, stakeholder group perceptions are compared and addressed in relation to results from the focused review of literature.

Figure 5.2

Frequency of Discussion of Online Education Quality Indicators Among Each Stakeholder Group



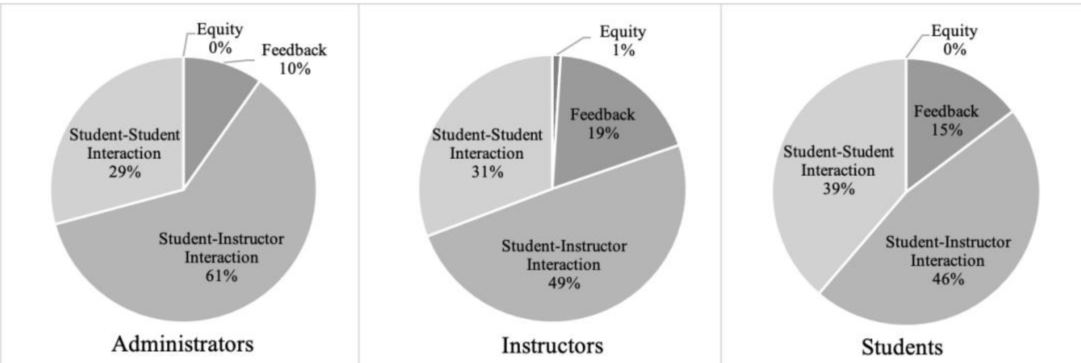
Note: The *Science Learning* quality indicators are not included in these comparison charts, as they are discussed as part of the analysis for science specific quality indicators in Chapter 6.

5.2 Interaction

Participants' perceptions tightly correlate with the results of the focused literature review, as *Interaction* was one of most frequently discussed indicators among all stakeholder groups combined. Interaction, as discussed among participants, includes interaction between the student and instructor and among students. While the review of the literature references student-student interaction more often (Section 4.1.2), participants' discussion of interaction addressed the importance of student-instructor interaction more frequently. While the three stakeholder groups highlighted different aspects within the interaction quality indicator groupings, they discussed each with similar frequency. All three stakeholder groups highlighted the importance of student-instructor interaction more frequently than student-student interaction. Instructor feedback was primarily discussed within the context of student-instructor interaction. *Equity* as an indicator of quality was scarcely discussed, with only 1% of instructors' total comments addressing issues of equity. The frequency of discussion of each of these sub-categories are shown as percentages of the total number of comments regarding *Interaction* for each stakeholder group (Figure 5.3).

Figure 5.3

Breakdown of Stakeholders' Discussion of Interaction



Note: The discussion of each sub-category by participants is expressed as a percentage of the total discussion of the *Interaction* quality indicator for each stakeholder group.

5.2.1 Student-Instructor Interaction

Student-instructor interaction was one of the most discussed indicators of quality among interviewed participants, addressed by 94% of administrators and 100% of instructors and students. Participants collectively used the term 'interaction' but, through deeper analysis, it was discovered that each participant recognized unique aspects and interpretations of interaction between students and instructors. The delivery of feedback from the instructor was a primary aspect of interaction identified across all stakeholder groups. Instructor feedback was discussed within the context of student-instructor interaction. Thus, feedback is presented here within student-instructor interaction as opposed to a separate indicator. Other recurring aspects within student-instructor interaction included: real-time adaptive interaction for teaching and learning, office hour communication, a feeling of personalized communication or relationship, and the creation of a community atmosphere. Participants identified these aspects of interaction as necessary for quality learning, but often felt these aspects were lacking online or that the feeling of interaction was not being met. This created an overall negative perception of the quality of online student-instructor interaction among participants.

Prompt, detailed and more personalized feedback from instructors to students was perceived to be one of the most crucial elements of interaction necessary for an effective online science course across all stakeholder groups. In an online course, when instructors reply quickly to student emails and give prompt, detailed and personalized feedback on assignments, students feel the online course is of higher quality.

Administrators - It was acknowledged among university administrators that interaction between students and instructors is a crucial aspect of learning science, with 61% of their total comments of interaction being focused on this quality aspect (Figure 5.3). This is something administrators expect their instructors to maintain, to the best of their ability, in the online environment. Administrators' overall perceptions of the quality of student-instructor interaction was not very cohesive as a group, but they highlighted a few crucial aspects: creating a community atmosphere, office hours for communication, personalization, and instructor feedback.

> We want there to be interaction between the instructor and the student. That's quality. We don't want it to be that all is just automatically graded. We don't want it to be 'cookie cutter'. (*Alice, administrator at LittleU*)

At the smaller and more rural universities, administrators were concerned with the need to continue to provide the "university community" feeling for online students.

As part of a community, administrators want to ensure instructors get to know their students and can mentor students outside the classroom, in addition to providing prompt feedback and communicating with them in their teaching. In order to ensure such a community, some administrators noted the importance of office hour requirements, and limited online class sizes.

Administrators expect instructors to provide office hours for online courses, just as is required for face-to-face courses. They expressed the opinion that much of the personalized communication and mentoring between students and instructors takes place during office hours, stressing the importance of providing such opportunities online. In order to provide this valuable interaction online, administrators acknowledged that more time and effort is required from instructors in learning new communication tools and adjusting times to meeting with students across many time zones.

> Online instructors have the same requirement for office hours as face-to-face instructors do. [They] will have more [online] live hours, so [that] the students and the instructor are available to talk by phone or by Skype at certain periods of the day.
> (*Ann, administrator at PCU*)

Learning becomes more personalized as interaction between students and instructors increases. Personalization within classes helps create the intimate university community feel that most universities strive to maintain. Because of the inherent feeling that online classes lack quality interaction, many administrators expressed that limiting online student enrollment per class is essential for effective online learning. A limit on the number of students in an online class helps to ensure there is adequate time for instructors to interact with all students allowing the course to be more personalized. Personalized interaction in the classroom also helps to maintain the more intimate community feel that the smaller and more rural universities strive for.

> Well, the personal interaction with professors is the number one thing. The [university] president uses the term, "LittleU Community" and that's definitely the truth here.
> (*Archie, administrator at LittleU*)

Administrators at the larger universities explained that proof of interaction is required in all courses in order to remain compliant with their accreditation. They felt that as long as they are providing the resources, instructors should be able to interact with students online.

Instructors - Instructors were more explicit and direct than administrators regarding the importance of student-instructor interaction and expressed that it is lacking in online learning. Forty-nine percent of instructors' comments regarding interaction were focused on student-instructor interaction (Figure 5.3). For instructors, 'interaction' was frequently referred to as having an active discourse with students, enabling them to adapt their teaching to meet student's immediate needs. This type of adaptive teaching and learning depends on impromptu communication between students and instructors during class, such as question and answer sessions, and discussing inquiries brought up by students in the moment. Instructors highlighted this aspect of interaction as the lead contributing factor to the overarching feeling that student-instructor interaction is missing in their online science courses. In combination with this, instructors also perceived interaction as part of forming a more personal connection with students and making the course more personal overall, allowing for one-on-one attention to be given to students.

> The great thing about an…in-person class is that you can see when a group is struggling with something and you can sit down and you can use Socratic questioning and try to draw out where their thought train is breaking … That's just not something you have an opportunity to do with an online class … it's frustrating, I don't feel like I'm giving them as much [online]. (*Ivana, instructor at BigU*)

Instructors generally communicate with their online students through email and through the course management system. While most instructors admitted that they find themselves checking and responding to email all hours of the day and night, they often try to set boundaries for such communication, making students aware that they should not expect a response after midnight or on weekends. Such requests are common, which highlights the fact that in order to maintain effective communication in online learning, instructors felt they have to work harder, putting in more hours and effort to maintain communication in a timely manner.

In line with administrator views, instructors admitted that class size is an influential variable in the ability to have effective, personalized interaction with students. Online class size should be kept small in order for instructors to be able to develop relationships with their students on a more individual and personal basis.

> [T]he fewer the students, the more [attention] they get from me. (*Irma, instructor at RedBrickU*)

In an effort to maintain quality interaction, some instructors are incorporating a wide range of communication opportunities. To foster personalized interaction within their courses and abide with the university regulations regarding office hours, some online science instructors provide online synchronous office hours using programs such as Skype, Adobe Connect, and Zoom. These tools allow instructors to communicate with students in real-time and even share documents and interactive desktops. This is in addition to providing the more traditional communication avenues of email and phone calls.

> I don’t know what I can do better with communication but, my tools are limited so far. I wish I could figure out something that really works better than my announcements on Blackboard, better than email. I try to [offer]; ‘if you need to see me make an appointment’. I try to keep those to a minimum because of the fairness issue that I don’t know how fair it would be as not everybody has that access. *(Ibrahim, instructor at BigU).*

Although some instructors do offer such communication avenues, often students do not utilize these resources enough to keep the interaction alive and useful. These instructors highlight that in lieu of the communication opportunities they provide their students, very few students actually interact with them in their online courses, beyond email communication. This leaves instructors feeling a lack of communication and interaction with their students. It is clear that interaction can only happen if all stakeholders make the connections and effort to communicate.

> [Students] prefer [email]. They email me during my office hours and we kind of instant message each other through email, a lot of times. I think they feel most comfortable [with this]. Whatever works! As long as they are getting in touch with me, that's the important part. (*Ivonne, instructor at PCU*)

***Students* –** Students immediately recognized interaction with their instructors as a vital factor for effective online science learning, often perceiving quality interaction as the feeling that the instructor is there to help and support them. Following instructor perceptions, some students noted the aspect of adaptive learning as a key component of effective interaction. Students view this aspect of interaction as the ability of the instructors to visually note when students have a question and give immediate responses, adapting and catering more personally to their learning. The ability to participate in one-on-one interaction provides a more fluid atmosphere of communication between the student and instructors.

> [It's] more the personal relationship [that's missing] … if I'm in an online class and the instructor can't see me, how my expressions are, they don't know if I understand or not. (*Steph, student at WRU*)

While students admitted to not taking full advantage of the interaction opportunities offered by their instructors, they still expressed a feeling that their online science courses lacked interaction, making them feel unconnected in the online environment. Students expressed more of a desire to bond with their instructors than have access to additional tools for communication.

> I guess it's just the relationship you form with the professor. Online you really don't have much relationship; you're just a name on a screen that they see. (*Samantha, student at LittleU*)

Students noted that when an instructor adds lecture videos, personalized videos, or audio segments, they feel an extreme improvement in the interaction and communication element in their online courses. The desire to form a relationship with their instructors is abetted when instructors bring more of their personality into the online course. Students perceived forming more personal relationships with their instructors as an aspect of interaction, allowing them to feel more connected and supported.

> You know, it was kind of funny because she had so many online presentations, I almost felt like I knew her!
> (*Sharon, student at PCU*)

All participants in this study expressed that student-instructor interaction is a primary indicator of quality for online science courses. Interaction is perceived as vital, allowing students and instructors to really get to know each other, creating an effective online course. Participants identified specific aspects of interaction perceived as crucial for quality online learning. The aspect of interaction highlighted by all stakeholder groups was the necessity of timely feedback from instructors. Instructors and students noted the importance of adaptive teaching and learning as part of the feeling of interaction, and a feeling of closeness with instructors through their personality or through the formation of a relationship. Administrators and instructors highlighted the need for accessible office hours in order to provide interaction. And finally, administrators emphasized how interaction helps to create the feeling of a university community within an online course. Interaction with instructors was addressed within multiple quality indicators, including online course design, satisfaction, and in science laboratories. It was also a prominent factor in the discussion of discipline differences and the needs of science majors versus non-majors in online science courses. Although the universities attempt to provide many of these aspects of interaction, there remained an overarching feeling among all participants that online learning is lacking student-instructor interaction.

5.2.2 Student-Student Interaction

Student-student interaction was found to be the most frequently cited indicator of quality within the focused review of the literature. This quality indicator did not rank as high among participants, but was within the top ten most frequently discussed indicators among all quality indicators. All students (100%), 73% of administrators and 93% of instructors discussed aspects of student-student interaction. The three stakeholder groups converged on the perception that student-student interaction is lacking in online education, and in lieu of utilizing synchronous communication methods, there is no clear way to effectively achieve such interactions in online courses. Consistent with the literature (Section 4.2.1), student-student interaction was discussed among participants in three primary ways: casual interactions, group work, and discussion forums.

***Administrators* –** Administrators were very pessimistic of the ability to provide quality student interaction online. They explained that such interaction is important, especially for science laboratories but that real-time interaction with quick dialog is difficult due to the time and space separation of students in online courses. One administrator from RedBrick University stated that the university does not require student interaction online and that even synchronous online interactions do not work well.

> But, in terms of discussion boards and things like that, I just don't see how you bring the enthusiasm to the class when all of the experience on the part of the students is through a computer screen. That would be a big concern of mine.
> *(Andrew, administrator at RedBrickU)*

Most administrators commented that some quality discussion can happen online, but generally, there is a lack of online community between students.

***Instructors* –** Instructors expressed a desire to provide more avenues to foster interaction among students in their online courses, but several explained they did not know how. As a result, a few instructors did not instigate any type of discussion among their students. They explained they did not have the time, resources or training necessary to foster effective student-student interaction which they knew they needed. They explained that social and collaborative elements in online courses are difficult; hoping that technology in the future will be able to better foster communication between students.

> Maybe in ten years there will be enough easy, smooth, well-functioning, high-functioning technology that that won't be an issue anymore but right now … I would not be able to get the social and collaborative piece as much as I would want.
> (*Ivana, instructor at BigU*)

Students **–** Students explained they did not, nor expected to, make friends or have more casual conversions beyond the course with other students in their online courses. When students described forming study groups, or interacting with other students on a regular basis, they were friends before the course started. Otherwise, students said they were very independent in their online learning, saying they were comfortable working alone. Students' comments on whether they enjoyed getting to know other students in their online courses were mixed. Some students indicated that even a little connection among classmates online made the course more enjoyable, while others indicated that there is little desire to get to know each other.

> When we get into discussion boards, my ideas match with a lot of other students, which was kind of weird, to me. Because I have very conservative views, I didn't think people in my generation had those views anymore and from this I learned that they do. I really like that, relating to some other students. *(Samantha, student at LittleU)*

> *Interviewer:* Do you feel you get to know the students that you are working with, at all?
> No. I don't know if anyone cares to get to know other students online either. I do enjoy working with students, that are helpful. However, in my experience, it's usually not the case, and it ends up taking longer

> as a group, than alone. So, I guess I prefer to work alone, when it comes to homework or class work. *(Samuel, student at LittleU)*

Group Work. Group work was discussed as part of student-student interaction by 40% of administrators, 60% of instructors and 60% of students. Administrators expressed that group work is an important aspect in science learning where complex ideas require more interaction. Group work was perceived as necessary in laboratory courses and for science career preparation. Instructors, who described group work in their courses as successful online, often used discussion forums for student-student interaction, which provided the instructor a way to monitor the interactions between students. Two instructors said that the ability to see the interaction take place in the discussion forum made it easier to make sure all students were participating in the group work.

> And so, they did it [group work] all on the discussion board, so I can see who's contributing and what are they contributing. Everybody working together, anybody leading the discussion, trailing on the discussion, etc., it allows me to see a lot more of the process. (*Ivonne, instructor at PCU*)

Instructors and administrators also discussed the use of synchronous learning tools to facilitate group work but said they did not consider that to be what the university defines as online learning, indicating that online is only asynchronous.

> In the online environment I just could not get my head around how to get the students working in teams because I had somebody who was in Saudi Arabia and I had somebody who was in California and I know that there are tools to do that but I don't know how to use those tools well enough. *(Ivana, instructor at BigU)*

In regards to more formalized or assigned group work, students indicated that online collaboration with students in different time zones and with family or work obligations was problematic. While students enjoyed interacting with classmates, most indicated they would rather work individually instead of in assigned groups.

Discussion Forums. Participants from all stakeholder groups (40% of administrators, 60% of instructors, and 80% of students) were mixed in their accounts of the use and quality of discussion boards in online science courses. Administrators conjectured that discussion forums would be beneficial in fostering collaboration between students.

> And the other thing I think is really a powerful thing in online courses is the discussion…on the discussion board, everybody can be a part of that discussion. It allows people that may not be comfortable in front of a class…to actually get engaged in a meaningful discussion about a topic. [I]n that discussion board, they're just a name, they're not in front of all their peers. [I]t allows everybody a more equal playing field, despite their personality. (*Alan, administrator at RedBrickU*)

Some students enjoyed the discussion forums as a means to get to know some of their fellow classmates and not feel alone in the course. Others felt the discussion forums implemented in their online science course were a waste of their time, akin to busy work, and they did not get to know any of their classmates in the process.

> I feel it's really superficial. I think it's more we're doing what we need to do to get a good grade in the class. No one really cares what the other one is saying. We're just doing what we have to do. (*Sophia, student at LittleU*)

Instructors were also mixed in their perceptions of discussion forums as a means for interaction, some regularly implemented them and found students were engaged, while others felt they were not important for the learning process and were unconvinced of their ability to foster realistic communication between students. The most positively perceived use of discussion forums for building classroom community was the use of introductory "icebreaker" discussions at the start of a course where students share who they are so the class can get to know one another.

5.2.3 Interaction – Comparison with the Literature

Stakeholder's perceptions correlate well with the results of the focused review of the literature, defining student-instructor and student-student interaction as foundational indicators of quality in online education within the context of science courses.

The focused review of the literature identified instructor feedback as a separate indicator of quality from student-instructor interaction (Section 4.2.1). In the review of the literature, feedback highlighted the timely response of instructors on student learning progress and assessment results as separate from the more personalized communication and relationships built as a result of feedback within an online course. Stakeholders on the other hand, perceived feedback within student-instructor interaction as feedback was discussed as a communication avenue and personal connection builder between students and instructors. Participants' discussion of feedback as in indicator of quality steered towards establishment of a fluid line of personal communication and less towards the evaluative components of timely feedback. Participants were in agreement that student-instructor interaction is perceived to be difficult to achieve at the level of quality desired in the online environment.

Equity was identified in the review of the literature but was scarcely addressed by participants. While participants discussed utilizing various forms of interaction, thus ensuring equitable involvement for students, the conversations were not robust enough as to address equity as a separate indicator of quality.

The literature and the three stakeholder groups all appear to recognize the importance of professional, productive student-instructor interaction (Section 4.2.1). However, administrators tended to focus on managerial aspects of interaction, such as the importance of keeping set virtual office hours and providing feedback on student work. Administrators equated the use of such traditional, or direct methods, to creating a community atmosphere online. On the other hand, instructors emphasized the importance of timely response to students' emails and more direct interaction through synchronous meetings to keep students engaged. The students appreciated more indirect methods of interaction, feeling a connection to the instructor not only though personalized and timely feedback but through instructors' video recordings and the personality instructors conveyed within the course.

Student-student interaction was addressed most frequently among the literature, highlighting its significance in creating quality online courses (Section 4.1.2; Figure 4.2). Stakeholder groups on the other hand discussed student-student interaction less frequently. All stakeholder groups agreed that interaction among students is a desirable quality, but is lacking in online courses. The use of discussion boards and assigned group work were the two primary methods of instigating such interactions, however perceptions were mixed regarding the success of such approaches. The community social structure and more personal interactions that were outlined in the literature as contributing to quality online courses, was identified among participants to be lacking. Stakeholders explained that successful interactions among students tended to be more formal or procedural. Social and more personal interactions which often establish the community among learners, was found missing in the online courses described by participants at their universities. The stakeholder groups collectively perceived student-student interaction to be inadequate, yet were at a loss of how to foster this interaction without either new technological tools or the use of synchronous communication.

Table 5.1 provides an overview of the quality sub-categories within *Interaction*, from both the review of the literature and the three stakeholder groups. The main components presented here for the literature are the same as was presented in Chapter 4 for *Interaction* quality aspects (Table 4.2). Next to the literature review results, an overview summary of the main components addressed by participants, as presented in the sections above, are provided for each stakeholder group.

Table 5.1

The Main Aspects of Interaction as Identified in the Literature and Among Stakeholder Groups

Quality Indicator	Review of the Literature	Participant Perceptions		
		Administrators	Instructors	Students
Interaction				
Student-Instructor Interaction	• Timely feedback	• Instructor feedback	• Timely and personalized feedback	• Timely and detailed feedback
	• Instructor is accessible	• Office Hours	• Accessible through email	• Help and support from instructor
	• Personalized interaction	• Small class sizes – more opportunity for interaction	• Small class size is necessary for personal interaction	• Feeling of personality from Instructor • Video and Audio from Instructor (asynchronous)
	• Instructor engages with students both professionally and socially	• Community atmosphere		
			• Active discourse with students for adaptive teaching/learning (synchronous)	• Real-time adaptive interaction
Student-Student Interaction	• Discussion board forums, emails, LMS tools	• Discussion forums		• Discussion forums allow students to meet one another
	• Social interaction • Both in and out of course time • Reflect and share ideas		• Social and collaborative elements	• Social interactions • Interaction most common when students already know each other
	• Group work • Course work collaboration	• Group work needed for laboratories	• Group work using discussion forums to monitor progress	
		• Community among students	• Advanced technology/avenues to facilitate interaction	

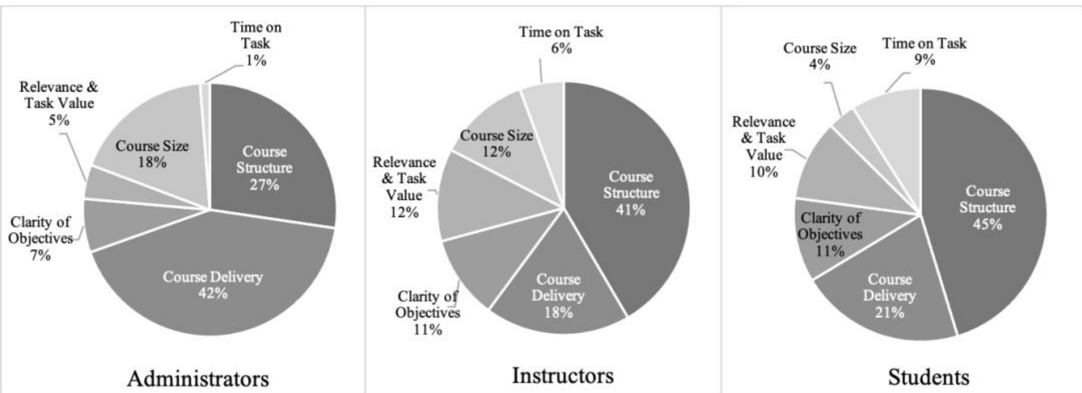
Quality Indicator	Review of the Literature	Participant Perceptions		
		Administrators	Instructors	Students
Interaction				
Instructor Feedback	• Timely feedback • Assessment results • Evaluation and progress reports • Reassurance of learning	• Prompt feedback	• Timely and personalized feedback	• Timely and detailed feedback
Equity	• Equal learning opportunities • Learning geared to diverse learning types		• Use a variety of types of interaction/communication	

5.3 Course Design

All participants (100%) discussed some aspects within course design in their explanation of what makes quality online science courses. *Course Design* was identified by participants as one of the most prevalent indicators of quality. Different from the review of the literature, *Course Design* was discussed only slightly less than *Interaction* among all stakeholder groups (Figure 5.1). The design of a course includes the delivery method and overall structure of the course, including content and organization. In line with the literature results, participants discussed *course structure*, *clarity of objectives*, *time on task*, *relevance* and *task value*. Participants also identified *course size* as necessary to consider for effective online courses, a component not addressed in the focused review of the literature. Course delivery was not addressed in the focused review of the literature, as asynchronous online courses were the focus of the review. However, participants' discussion of online course design included notable discussions of course delivery as participants shared their views on each type: asynchronous, synchronous and hybrid/blended. Instructors and students discussed course structure more than any other component of *Course Design*, whereas administrators focused much of their discussion on the course delivery type (Figure 5.4)

Figure 5.4

Breakdown of Stakeholders' Discussion of Course Design



Note: The discussion of each aspect by participants is expressed as a percentage of the total discussion of the *Course Design* quality indicator for each stakeholder group.

5.3.1 Course Structure

Course structure as a component of effective online courses was discussed by 81% of administrators, 100% of instructors and 95% of student participants. Additionally, course structure was the most frequently discussed aspect of *Course Design* among the instructors and students (Figure 5.4). The structure of an online course dictates how students access the course material and interact with the instructor and other students. Across all stakeholder groups, the basic course structure and content described was similar: textbook reading assignments, lecture notes in PowerPoint, discussion board questions with required posts and replies, and quizzes or exams. There were some variations such as the addition of homework assignments and activities or laboratories, but most followed this fairly basic course structure often seen in face-to-face science courses. Most participants described these elements as organized within a learning management system, typically with the material divided into learning modules either by week or by chapter. Participants from all three of the stakeholder groups emphasized the necessity of the course structure to be organized and easy to navigate, including a clear schedule, timeline of expectations, and clarity of objectives.

***Administrators* –** Structural uniformity among online courses across the university was also highlighted as important, particularly among participants at LittleU, WRU and PCU. Administrators and instructors from these three universities described the development of online course templates that go through a rigorous review either developed by the university (LittleU) or using a commercialized review process such as Quality Matters (WRU and PCU). At the time of the interviews, WRU and PCU had recently adopted a university-wide system to ensure newly developed online courses follow agreed upon course design specifications, utilizing the Quality Matters course design rubric (Quality Matters, 2018). Administrators at these universities explained the course design process utilizing this rubric:

> [The Quality Matters rubric] identifies key components that are required for every course. You know, a certain number of exams and just the general structure. And we do have a checklist for all online

> courses that we require that are met before we even turn the course on. *(Adam, administrator at WRU)*

> [W]e have standardized our online courses…so there are certain modules that are required on all of our online courses. [A] peer evaluator group looks to make sure that it is all there as well, but then they also look to see does every module - does it flow - does it make sense to the student to go through a particular course. [Instructors] have flexibility but it is not approved to go online until it conforms to what it needs to be. *(Ann, administrator at PCU)*

Instructors – Across all the universities, instructors utilized a similar basic structure in their online courses: chunked units (or modules) organized by week or chapter, each incorporating lectures, assignments and quizzes or exams. The units or modules provided logical navigation and overall organization to course.

> Well, this has been the hardest part for me to sort out because when we talk about the instructor presence, yes there's the communication presence, but there's also the construction of the course; the organization of the course. That is a component of the teacher presence. Okay? When my courses aren't organized well, I get all kinds of emails and stuff. But, once I get it where it's slick, I don't get emails. So, it's an indicator of either poorly organized course or inadequate content. So that's why, for that component of instructor presence, it's not quite what we thought it was.
> *(Irene, instructor at BigU)*

As instructors described their online science courses, two primary components were highlighted as essential: video/audio lectures and engaging content. The courses that were discussed as good examples of quality included not only audio enhanced lecture notes, but engaging content and additional resources or activities to promote understanding of science concepts. Additional resources included interactive web-based simulations, website articles, videos, participating in blogs or journals and working through interactive textbook publisher resources.

Students **–** Students echoed instructor and administrator views that clear organization, expectations and purposeful instructor guidance were essential aspects of quality in their online courses. While lecture notes were perceived as a basic necessity to the course structure, students were in agreement with instructors, explaining that audio or video enhanced lectures notes are the most effective. Students whose courses did not have these enhancements expressed desire for such features.

> I think it would be amazing, for online classes in general, if teachers would video tape their lectures, for us to watch. It would make such a big difference, for me. I've been using other universities that have posted online video lectures for their online students. (*Sophia, student at LittleU*)

Participants from all stakeholder groups stressed the importance of incorporating avenues for student-instructor interaction in the basic course structure. Students expressed a desire for explanatory communication with instructors, providing a feeling that the instructor is guiding the learning. Avenues for fluid discussion through the course to include frequent communication and feedback were expressed as part of the course structure that can make online courses effective.

5.3.2 Clarity of Objectives

Of the total number of participants, 63% of administrators, 71% of instructors and 70% of students highlighted the importance of clear objectives and expectations in online courses. Among these participants, all stakeholder groups were aligned in their perspectives that quality online courses provide clear expectations, learning objectives and schedules. Perceptions matched with what was identified in the review of the literature. Administrators explained that it is the responsibility of all stakeholders, from the administration to the student to be clear in what is expected in online education.

Clearly outlined expectations were highlighted important not only for what is expected of students, but what students can expect from instructors. In what time frame will instructors reply to email, provide feedback on assignments or open up the next modules? Participants explained that outlining such expectations provides a clear understanding of how the course operates. Student noted appreciation for instructors that provided a detailed calendar of assignments and due dates as well as for courses that followed the syllabus and outline of course procedures, assignments and expectations. Students expressed the need for more guidelines and schedules so that nothing was a surprise:

> A good [online] course [has] a well-organized form, where everything goes by the syllabus. The syllabus is detailed. I like when the modules are up ahead of time, so I can see what I have to do next week. Everything is organized in accord with the time.
> *(Shira, student at LittleU)*

5.3.3 Time on Task

Few participants discussed time on task as an indicator of quality, but among the three participant groups, students highlighted it the most (13% of administrators, 29% of instructors and 40% of students). Students' responses were similar to the focused review of literature results, emphasizing the importance of clear guidelines of how long activities or laboratories were designed to take (Section 4.2.2). Those who were not given such guidance found their online classes to be more work than expected and struggled to effectively work on the various components of the course.

> No, we weren't given any idea of how long it should take. I assumed it would take about an hour with only 20 questions. It takes upwards to 3 hours to do! Most of it is in the book, but sometimes the questions can get pretty obscure. *(Sean, student at BigU)*

Instructors explained that students are given a lot of flexibility in how they manage their time completing coursework, but moderating weekly modules helped to keep students focused and on pace. This was described as particularly important for compressed 8-week online courses, where students need guidance to balance their time.

5.3.4 Relevance & Task Value

Twenty-five percent of administrators, 64% of instructors and 65% of students highlighted the importance of incorporating online components that are relevant to students' experiences and provide real-world context. Administrators and instructors noted that real-world applications are incredibly engaging to students allowing students to more deeply relate to the content and enjoy the learning experience. In addition, they explained that science courses, especially at the general education level, are all about application to the real world. Instructors also explained that if they can relate the content covered in class to more personal experiences of students, students can relate more easily and are more engaged in their learning. Students' comments confirmed these intentions, explaining that they enjoyed when they learned about the practical and real-world applications to the material they were learning. When asked what are a few things you think make a good online course, Spencer, a student from LittleU replied:

> A teacher that can relate it to real world experiences. I had a class where he focused everything on making it real world. Like, how it actually happened and what you would actually do. I think that was a lot more helpful … *(Spencer, student at LittleU)*

For science, discussion of relevance and task value was strongly linked to laboratory experiences where students complete real-world activities. This point is further discussed within the results of *Interest and Motivation in Science* in the presentation of the science learning and laboratory results (Chapter 6). Besides the laboratory, instructors used open-ended discussion questions, project-based activities and video lectures in their online course as an avenue to engage students in relating their own experiences and real-world applications to the content.

5.3.5 Course Size

A component within course structure that was not identified in the review of the literature, but was acknowledge by participants as important to providing quality online education was the consideration of *Course Size*. Course size refers to the maximum student enrollment for an online course. Course size was addressed by 69% of administrators, 71% of Instructors and 20% of students. Administrators and instructors had a larger percentage of their total conversion regarding *Course Design* centered upon course size compared to students (Figure 5.4). However, the simple, agreed upon conclusion among all stakeholder groups, is clearly stated by Aiden at BigU:

> I would say there's interest in doing the online courses, as long as the course are held at a certain level, they're not too large. It lets us take students to those higher levels of learning and one can do that fully online, it would just require a small number of students really to make it work effectively. *(Aiden, administrator at BigU)*

Instructors and administrators were clear that large enrollments in online courses can be done, but quality online courses need to have smaller student-to-faculty ratios. Administrators at PCU explained that originally, they had a cap of 25 students per online course but eventually allowed courses to enroll upward of 200 students. They explained that much of the difference depends in the subject matter and the instructor's ability to handle large classes.

> If you have a Science course and has 180 students in it, and then it doesn't meet synchronously, which is typically the case, most of them are asynchronous. Then trying to interact with 180 students in virtual venues is tough. *(Alan, administrator at RedBrickU)*

Course enrollment limits were set with the intention that in order for instructors to effectively interact with students, keep up with discussion boards and grade student work in a timely matter, courses must be kept relatively small. Administrators and instructors explained a method used to accommodate more students, instead of increasing the course enrollment, is to add more sections of a particular course. The push for large enrollment from the university administration as a whole, was resisted by most participants in this study. Below, two instructors relay similar experience and rationales with aiming to keep online course enrollments limited:

> We are still trying to limit the number of students in our astronomy class. I think maximum I have had is about 40. Beyond that, I think

> it would be impossible to provide any kind of quality feedback individually to the student. That's my main concern. We haven't had a scenario where we went over 40, but I would guess that would mean just opening up another section. *(Ian, instructor at WRU)*

> Usually, I keep my Astronomy capped at 20. Administration originally wanted me to do 65 online. I said, are you nuts?! I'm not gonna do that. I said you can cap it at 50 and I'll do the best that I can, but I'm not going to do 65. It's just the logistics, because you are going to increase the number of people asking questions. I didn't want my day to become just one giant office hour.
> *(Igor, instructor at RedBrickU)*

While LittleU and PCU reported course enrollment limits at 20-25 students, this appeared to be the lower limit of the universities participating in this study. RedBrickU, WRU and BigU indicated online enrollments could be as large as 100-150 students. Interpolating from participants' discussions, enrollments limited to about 40-50 students appears to be an agreed upon acceptable enrollment for maintaining quality in the online environment.

5.3.6 Course Delivery

The overall design and subsequent structure of an online course is fundamentally dictated by the delivery type: asynchronous, synchronous or hybrid/blended. The universities in this study determined the delivery type of their online science courses based upon either the direction outlined by the institution or as a necessity to suit the instructor's unique situation. The majority of the online science courses discussed among participants were asynchronous; however, one synchronous course and a couple of hybrid courses were discussed. All participants discussed course delivery as they discussed their experiences with online education, so much so that it was a prominent percentage of each stakeholder groups' discussion of *Course Design* (Figure 5.4). Forty-two percent of administrators' discussion of *Course Design* centered upon the advantages and disadvantages of the types of course delivery.

Asynchronous - Asynchronous is the most prominent online course delivery and typically is the assumed definition of online education unless otherwise specified. Some administrators were under the impression that asynchronous is a poor online course model, envisioning static lecture notes, reading and automated feedback on quizzes. Instructors explained that this is often the result of when a course is lacking the essential features that participants have discussed as effective in the course structure: instructor presence, interaction, engaging activities and audio or visual enhanced lecture notes.

Synchronous - LittleU did not consider synchronous online as part of their online course offerings but an astronomy course was offered a few times to accommodate a unique situation for the instructor. The students who discussed their synchronous online experience expressed that they enjoyed being able to ask the instructor questions, see and hear the instructor explain the material as they looked at the lecture slides and that the course felt interactive. Other participants speculated that a synchronous experience would be effective, imagining the increased interaction with the instructors and many thought the structure would work very well for office hours. However, the limitation of less flexibility in when learning can occur, compared to asynchronous learning, was perceived to decrease the effectiveness of synchronous learning, particularly among students.

Hybrid/Blended - Half (50%) of all administrator participants and two instructors perceived that for science a hybrid model would work best. They explained that this would allow for student self-study and learning online, while problem-solving and laboratory work would be conducted face-to-face with the instructor. As explained by two administrators, the physics department at BigU was in the process of converting all of their introductory physics courses to a hybrid design so that students could get more interactive time with the instructor and help with problem solving.

> Now, one of the things that is important to the university is retention. If you want retention, you cannot have online classes. I think that blended courses have a chance at working really well. We started a

> year ago to teach a blended physics course, which is not online, but it's partially online. *(Abe, administrator at BigU)*

> I've also been involved in the Course Redesign Taskforce of the university, moving to hybrid classes, and I'm currently sort of running a grant from the university to help the physics department move to hybrid classes. So, a working definition of 'hybrid class' was that as much as possible of what we might think the 'easy' part of physics would be done online by the students, for example, reading and perhaps they would be familiar with at least the content of the chapters and the vocabularies in the chapters, have some access to beginning problems, perhaps some videos of Professor doing problems and then that [face-to-face] class time would be predominantly devoted to group problem solving. *(Andy, administrator at BigU)*

One unique case of a hybrid online science course was a mammalogy upper-level biology course for majors taught by Ivonne, an instructor at PCU. She explained that the course should not be online, but due to her having to suddenly move to another state, the department compromised by having her teach the course online but have the students conduct laboratories under the supervision of a graduate student on campus. While she did not necessarily condone this course design, the administrator and instructors who discussed the benefits of a hybrid design, described such a situation as an ideal solution to providing online science courses. However, one administrator from LittleU explained that a hybrid design would prevent universities from serving students who are geographically dispersed and not able to come to campus, which is why asynchronous delivery was chosen.

5.3.7 Course Design – Comparison with the Literature

University stakeholders' perceptions of *Course Design* aspects that are influential in creating effective online courses were consistent with those identified in the focused review of the literature (Section 4.2.2).

Stakeholders highlighted the importance of course structure for successful online learning. While the course structure provided was viewed as adequate, participants confirmed that these basic components needed improvement to achieve a quality online course structure. Participants voiced a clear idea of what makes quality online science courses that distinctly parallels the research literature. Online courses designed to include engaging content, interactive learning activities, incorporation of audiovisual multimedia and real-life applications were suggested. Participants indicated a desire for more instructor presence, interaction and active learning.

In direct alignment with the results of the literature, stakeholder groups emphasized clear expectations for both students and instructors, clear course schedules, an understanding of time requirements for learning and inclusion of real-world or relevant context to learning as important for quality online courses. In addition, administrators and instructor participants discussed the need to limit student enrollment in online courses, explaining that in the online environment smaller class sizes are more effective so as to promote student-instructor interaction and accommodate manageable workloads for instructors.

The focused review of the literature did not analyze the type of course delivery, as the focus of the review was on asynchronous online courses (Section 4.2.2). The majority of courses offered at the universities included in this study were delivered asynchronously. However, as participants discussed their experiences with the three types of delivery methods, they highlighted some notable perceptions regarding hybrid or blended course delivery. Administrators and some instructors suggested that a hybrid or blended delivery type would pedagogically best suit science in the online environment. These participants viewed a hybrid design as best for learning science compared to asynchronous delivery because the perceived nature of the design allowed for more interactive time with the instructor, hands-on laboratory experiences and an environment for proctored exams.

Table 5.2 provides an overview of the quality sub-categories within *Course Design*, from both the review of the literature and the three stakeholder groups. The main components highlighted in the literature are the same as was presented in Chapter 4 for *Course Design* quality aspects (Table 4.3). Next to the literature review results, an overview summary of the main components addressed by participants is provided for each stakeholder group.

Table 5.2

The Main Aspects of Course Design as Identified in the Literature and Among Stakeholder Groups

Quality Indicator	Review of the Literature	Participant Perceptions		
		Administrators	Instructors	Students
Course Design				
Course Structure	• Organized framework and design of course ○ LMS structure and layout	• LMS to organize the course	• Organized • Easy to navigate • LMS weekly learning modules	• Organized • Easy to navigate • LMS weekly learning modules
	• Learning and assessment of content: ○ Activities to promote understanding of science concepts	• Additional resources/activities to promote understanding of science concepts • Engaging content	• Additional resources/activities to promote understanding of science concepts	• Additional resources and activities to engage with content
	• Facilitation of interaction	• Avenues for interaction and collaboration	• Avenues for interaction	• Avenues for fluid discussions with instructors
	• Stimulating and visually pleasing • Presentation of material	• Audio/Video enhanced lecture notes (PPT)	• Audio/Video enhanced lecture notes (PPT)	• Audio/Video enhanced lecture notes (PPT)
		• Approved/Reviewed course templates • Small class size	• Approved/Reviewed course templates • Small class size	

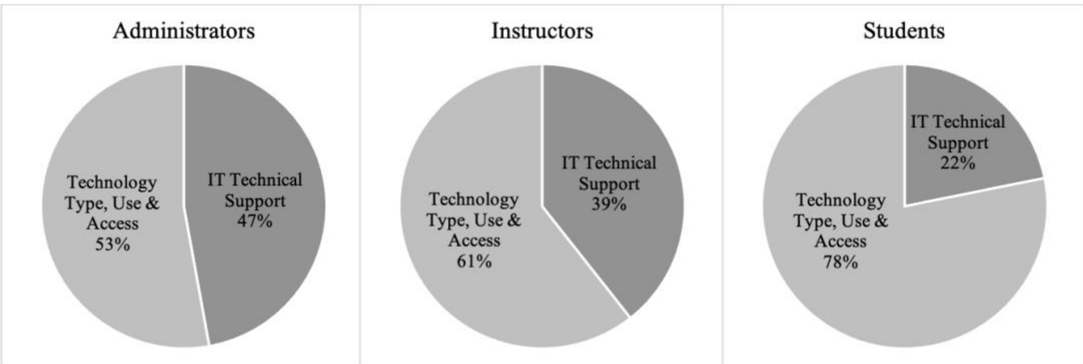
Quality Indicator	Review of the Literature	Participant Perceptions		
		Administrators	Instructors	Students
Course Design				
Clarity of Objectives	• Clear expectations • Clear objectives for learning • Organized procedures and rules • Clear instruction	• Clear expectations – for students and of instructors • Clear learning objectives	• Clear expectations – for students and of instructors • Clear learning objectives	• Clear expectations of what is required in course
				• Detailed syllabus • Outline of schedule and clear due dates.
Time on Task	• Provide effective time management guidelines	• Moderate pace of learning – use of modules	• Moderate pace of learning – use of modules • Guide for how many hours are expected in course.	
	• Clear time requirements or expectations to complete assignments			• How long assignments are expected to take • Clear due dates
	• Realistic time requirements			
Relevance and Task Value	• Provide real-world context • Provide content and activities relevant to students' experiences • Provide students with valuable tasks	• Real-world applications: activities and laboratories	• Real-world & personal applications: activities, laboratories, discussions, projects	• Content shown in context to real life • Relatable application to content
Course Size		• Smaller is better	• Smaller is better • ~40-50 student enrollment limits desired	

5.4 Technology Adequacy

All stakeholder groups equally discussed technology's role in quality online education, with 95% of participants from each group discussing how technology makes online courses function. How technology is used and the types of tools chosen to create an online learning environment can directly impact the perceived quality of the course. While the literature separately identified the importance of the *type of technology and how it is used* and *access through technology*, participants discussion of technology adequacy intertwined these aspects. Participants explained that the main need for better technological tools was to provide a more interactive learning experience and ease of communication between instructor and students. Interactive learning experiences included working with real-world problems, participation in inquisitive problem solving and for providing simulated laboratory experiences. In line the with results from the focused review of the literature, administrators (81%), instructors (93%) and students (50%), also discussed the role of *IT technical support* in developing and running effective online courses. Of the total discussion regarding *Technology Adequacy*, administrators referred to technological support 47% of the time, instructors 39% and students 22%. The rest of the discussion focused on the technology type, use and access (Figure 5.5).

Figure 5.5

Breakdown of Stakeholders' Discussion of Technology Adequacy.



Note: The discussion of each aspect is expressed as a percentage of the total discussion of the *Technology Adequacy* quality indicator for each stakeholder group.

***Administrators* -** Administrators expressed that one of the major limitations of providing a range of high-level technological tools for online course accessibility is cost.

> We haven't been able to afford everything that we've wanted for Blackboard…we try to stay abreast of the latest versions of Blackboard, but we've not yet really been able to afford all of the add-ons that we'd like. (*Amber, administrator at LittleU*)

Two administrators and two instructors expressed a desire to provide the more advanced interactive software for science courses, explaining that these programs provide activities involving real-world problems and total immersion experiences for students. A couple administrators described virtual reality as the future of effective science education, but explained as far as they knew such technology was not yet readily available for college science courses.

***Instructors* -** Instructors explained that the tools they use for increasing communication and providing more interactive learning are often already integrated into the software programs (or LMSs), but they either don't have access to the advanced functions or they don't know how to incorporate them into their online courses.

> I know that there are tools to do that [group communication] but I don't know how to use those tools well enough. (*Ivana, instructor at BigU*)

***Students* -** A couple students gave examples of how they wished their online course were more integrated, making interactions, activities, videos, lectures and assessments accessible through one program and easier to use. Many students expressed a view that the technology provided by the university was not being used to its full potential, for example, being accessible on mobile devices and providing more communication tools.

> I really think that the technology capabilities are certainly there. But I don't think that the institutions spend enough time teaching Faculty how to make the best use of it. (*Steven, student at. LittleU*)

The students who discussed issues with the technology used in their online courses expressed a bit of disappointment of what was provided, thinking that surely there was more advanced technology available for science online.

> When I thought of taking a Science Lab online, I thought there would be interactive web sites that you would be able to use. I would be working with 3-D models. Maybe I would be working with pressure gradients online and getting to plug those in and see how they work and how it ends up working out in the system. But there is nothing like that. It's just your quizzes and your lab that you print off and scan in every week. It's kind of a letdown. (*Sean, student at BigU*)

While participants did not discuss many major failings of the technology used in their online course experiences, several participants did discuss technical support offered at the university as a necessary and expected component for providing effective online courses. The more responsive and available the technology support was perceived to be in helping solve internet, software or LMS issues, the more confident the participants expressed they felt in teaching or taking online courses at the university. Instructors also highlighted the need of technical support in the initial development of their online courses. This point is further addressed by participants under the quality indicator *Support for Instructors* within *Instructor Satisfaction* (Section 5.5.2).

5.4.1 Technology Adequacy – Comparison with the Literature

Stakeholders' discussion of the importance of the type of technology, access and technical support aligned with the results of the review of the literature. Both the literature and stakeholders highlighted the importance of considering the extent to which the hardware or software used in online courses are suitable for the learning tasks required. A sentiment shared among stakeholder groups and implied in the literature is that while online learning depends on technology, learning should not be completely technology driven. Instead, the chosen technological tools must be grounded in the pedagogical principles driving the learning. The literature discussed how technology can deliver course content, while participants focused more on the need for technological tools to foster interactive learning experiences (Section 4.2.3). Participants focus on the importance of technology centered on easing communication between instructors and students. Both the literature and participants recognized the need for specific technology to provide active learning experiences in the sciences, to include laboratory experiences. Such experiences included working with real-world problems, participation in inquisitive problem solving and for providing simulated laboratory experiences. Participants questioned whether more advanced technological tools are available which could better support teaching science online, or whether the available tools were being used to their full potential.

Using technology to its full potential depends on how accessible it is. The literature defined access as a separate indicator of quality (Section 4.2.3), whereas participants' discussed access as an integral aspect of the technology and how it is used for online learning. Both the literature and participants highlighted the importance of technology that is easily accessible, convenient to use and is easy to set up for both students and instructors. Participants explained that providing easy access to technology includes providing effective technical support. Technical support includes support for instructors to capitalize on the technical tools available.

The issues presented by participants in this study echo those addressed in the research literature. Overall, participants were satisfied with the learning management systems that provided the foundational structure of their online science courses but many expressed the feeling that their courses could be improved through more advanced technological tools and consistent technological support. Participants conveyed two issues: 1) the technological tools exist but instructors and universities are not capitalizing on them, and 2) the technological tools don't exist yet for science disciplines online and at the level of learning needed. These issues are further explored in Chapter 7.

Table 5.3 provides an overview the main contributing aspects of the quality indicator *Technology Adequacy,* from both the review of the literature and the three stakeholder groups. As with the previous overview tables in this chapter, the main components presented here for the literature are the same as was presented in Chapter 4 for *Technology Adequacy* (Table 4.4). An overview summary of the main aspects addressed by participants are provided for each stakeholder group. Participants' discussion of *Access* was intertwined with their overall discussion of *Technology Type and Use*, however for ease of comparison with the literature, in Table 5.3, access is separated out.

Table 5.3

The Main Aspects of Technology Adequacy as Identified in the Literature and Among Stakeholder Groups

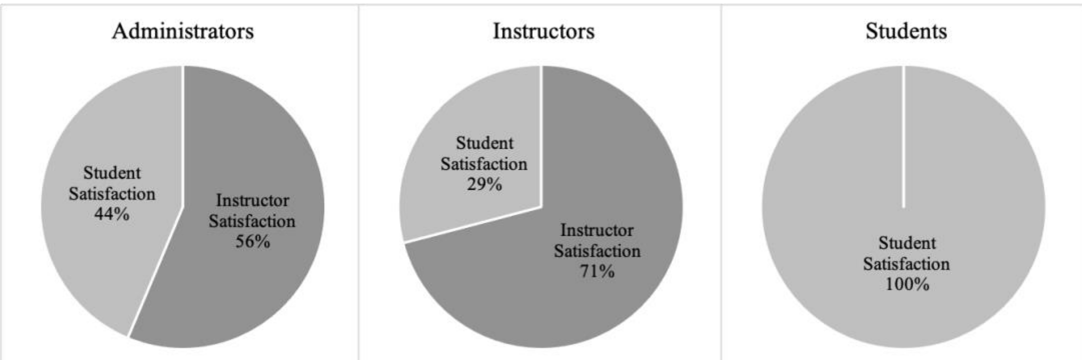
Quality Indicator	Review of the Literature	Participant Perceptions Administrators	 Instructors	 Students
Technology Adequacy				
Technology Type & Use	• Task focused, functional and inviting to use	• Interactive learning experiences • Foster interaction between instructors and students	• Interactive learning experiences • Foster interaction between instructors and students	• Interactive learning experiences • Integration of activities, interaction and course materials into one program
	• User friendly, compatible across devices and systems • LMS, software, website, videos, simulations • Appropriate for learning objectives			• User friendly, compatible across devices and systems
Access	• Accessible and reliable learning environment and tools • Ease of use		• Access to advanced functions of software and tools	
		• Decrease costs		• Use of mobile access to software and tools for convenience
IT Technical Support	• IT security and resources readily available • Technical support easily accessible • Support for both students and instructors	• Information Technology Services – assist instructors and students • LMS support	• Responsive IT support on LMS and Internet connectivity • Instructor support to help capitalize on existing technological tools or software • Support in course development	• Responsive IT support on LMS use and access support • Email and LMS support

5.5 Satisfaction

According to the review of the literature, a measure of a quality online course includes whether students and instructors are satisfied, measuring their perceived enjoyment of the course and whether they feel their expectations were met (Section 4.2.5). Satisfaction was identified indirectly by participants, but interview data exposed the importance of satisfaction in stakeholder's perceptions of quality. Participants accounts of satisfaction in creating quality online courses followed the components outline in the focused review of the literature, identifying both student and instructor satisfaction. Within *Student Satisfaction*, student type was highly addressed. Rationales for why students take online courses was also addressed among participants, shedding light into student satisfaction. In discussing *Instructor Satisfaction*, participants discussion centered upon instructor time and support, paralleling the results of the focused review of the literature. Administrators' discussion of satisfaction was fairly evenly divided among student and instructor satisfaction (Figure 5.6). Instructors provided more discussion of instructor satisfaction (71%) compared to student satisfaction (29%), and students only added insight regarding student satisfaction.

Figure 5.6

Breakdown of Stakeholders' Discussion of Satisfaction



Note: The discussion of each aspect is expressed as a percentage of the total discussion regarding *Satisfaction* for each stakeholder group.

5.5.1 Student Satisfaction

Student satisfaction, as addressed by student participants, highlights personal accounts of satisfaction in their online science courses, whereas the coding of data under student satisfaction from instructor and administrator interviews captures perceived satisfaction of students. All students, except one (95%) discussed aspects of satisfaction more generally as opposed to discussion of other quality indicators specifically; 88% of administrator and 79% of instructor participants provided general comments of student satisfaction. Administrators' and instructors' discussions are a combination of their perceptions of student satisfaction and retelling students' accounts. Perceptions from all three stakeholder groups are presented together within the two elements of student satisfaction: *student type* and *why students choose online courses*.

Student Type. Participants confirmed the literature regarding the connection of student type and satisfaction in online science courses (Section 4.2.5). All participants, except one administrator, addressed the type of student who is perceived as successful and satisfied in learning science online. Participants concentrated on a few descriptors of student type: strong self-efficacy, mature, non-traditional and good with time management.

Self-efficacy is a student's individual motivation and confidence in completing learning tasks. Self-efficacy was perceived as essential for student success in online courses based on the perception that the instructor will not be present to actively guide and motivate students in their learning. Students explained that the type of students who succeed online are those who are comfortable being independent and self-paced in their learning, with little assistance or guidance from the instructor. As a result, participants explained that students find online courses harder than face-to-face courses.

Instructors and administrators said their online science courses fill every semester, indicating student interest. However, they explained that retention appeared to be lower in online courses throughout the duration of a course. Instructors reported students drop their online courses more frequently than face-to-face courses due to the time, effort and motivation required.

> [I]n the first week or so, I see a lot of students dropping the class because they see that the workload is going to be so much. They may or may not be able to handle it. (*Ian, instructor at WRU*)

Instructors expressed that students register for online courses thinking online will be easier and then discover the courses are harder than expected. Student participants concurred, again explaining that online courses require more self-motivation and self-regulated leaning.

> The fear I have of any online class is [it] requires extra work … I didn't believe I had it in me to pull it off. You have to keep up with yourself, so to speak. (*Seth, student at LittleU*)

Self-efficacy was the most discussed descriptor of student type among participants, followed by the distinction that successful online students tend to be more mature or categorized as non-traditional students.

Administrators and instructors explained that student age is not a predictor of success or satisfaction in an online course, but see more success from mature students. Along with maturity, a few participants from each stakeholder group mentioned that Freshmen should not take their science courses online because they are not adjusted to the university lifestyle and are too immature. Two students mentioned they waited to take online courses until they felt they were ready to handle the time management and self-disciplined nature of learning online, that as Freshmen they were too immature. Maturity is closely correlated with the classification of non-traditional students. Non-traditional students were described as working while being students and older students with families and full-time jobs. They were perceived as the type of student who needs online courses to suit their lifestyle. Of the students who participated in this study 50% were non-traditional students, working full-time or had families while completing their undergraduate degrees.

Why Students Choose Online Courses. Administrators and instructors conjectured that an increase in student demand and interest in taking online science courses indicates students are satisfied. Therefore, looking at why students choose to take their science courses online can help to understand how student satisfaction plays a role in quality.

Administrator, instructor and student comments regarding the rationale for taking online science courses were very congruent and overlapped in many aspects. Of the participants who discussed student satisfaction, 85% of administrators, 45% of instructors and 74% of students shared views of why students chose to take online courses. Student satisfaction was measured by the interest students expressed towards taking online science courses combined with student retention in those courses.

> That's our measure for quality: satisfaction and retention. [W]e've been growing our program double each of the last three years…we're doing something right when our numbers [of students] keep going up. (*Alice, administrator at LittleU*)

All three participant groups explained that the flexibility of online (asynchronous) courses make them desirable because students can fit the courses around their schedules (school, work and life schedules). Administrators commented that it is not that students particularly like online courses more than face-to-face courses but they like the scheduling flexibility and convenience they provide. According to administrators and instructors, the flexibility of learning any place and any time was expressed as a main reason that students do not like hybrid or blended online courses and prefer fully online courses. In hybrid online courses, students have to attend class sessions on campus, negating the schedule flexibility of learning "anytime, anywhere" benefits of fully online courses. Administrators and instructors explained that providing online courses in the sciences allows access to education for student populations who would normally not be able to attend campus to continue their education (such as full-time employed, military or out of state students), allowing the university to serve a more diverse population. The popularity of online science courses over the summer was also noted as something students favor, allowing them to go home to family but still attend classes without having to stay at the university. Student participants agreed.

> It’s just a great option for me, I can work during the day, then do my [course]work when I was at home, on the weekends, in the night … it was more convenient for me as a working student. (*Sharon, student at PCU*)

Participants also reported that students appreciate having more choices for their introductory courses, due to the flexibility of when they can work on the course assignments, giving students more control over how they organize their learning time. Part of the satisfaction of the flexibility of online courses, is that students enjoy the ability to access course materials multiple times.

5.5.2 Instructor Satisfaction

Instructor satisfaction was consistent with the focused review of the literature and centered around two main components: *instructor time* and *support for instructors*. Instructor satisfaction in online science courses was discussed among 95% of administrators and 100% of instructors. Students did not provide comments on this indicator.

Instructor Time. Eleven administrators (73%) and 13 instructors (93%) described instructor time as a contributor to satisfaction. Data from administrators and instructors regarding *instructor time* are presented together, as perceptions between the two groups often overlapped. Instructor time involved two unique components: time needed to develop online science courses and time devoted while teaching an ongoing online course, described as instructor workload. All administrators and instructors agreed that the initial development of an online science course takes a significant amount of time and effort. Instructors discussed the desire for more time to develop advanced simulated laboratories, audio or video recorded lectures and online activities. However, even if the time was awarded, many felt they did not have the skills to develop the type of online materials that were needed. Time and resources allocated to instructors specifically for the development of online courses was the most common request among instructors for improving satisfaction.

> It depends on how you set it up, but certainly the upfront construction of a good online course is very labor intensive. And even after that's constructed … things like discussion boards, its time consuming. I think maybe the longer you run it, it might even out. But I don't think there's less time involved in the day to day running of an online course than there is in face-to-face and the initial investment is certainly quite heavy. (*Arleen, administrator at RedBrickU*)

After the initial development and setup of an online course, the amount of instructor effort varies, just as in face-to-face courses. While each teaching experience is unique to the course and the instructor, 42% of participants, mainly administrators, who discussed the issue of instructor time, expressed the view that teaching online courses takes more instructor time and effort. These participants were explicit that effective online courses require more instructor time fielding student questions and giving feedback throughout the course. They expressed that if a quality online course is provided, then the instructor is putting in a lot of time teaching.

> A good online course essentially involves a lot of feedback and a lot of interaction with the instructor to make it work … our feeling is that staffing of a good online course takes about 50% more Faculty time (*Aiden, administrator at BigU*)

The amount of the time spent during the course depends on how the course is structured and if interactive elements are included. While two instructors believed the amount of instructor time during teaching is equivalent for online and face-to-face courses, about one quarter of participants, mainly instructors, described online teaching as less work throughout the duration of the course, after the initial development.

> [I]t was a lot of work the first semester when I was trying to add climate change, but now it's all set up … I can practically forget I'm teaching, except for sending out the same mass emails and syllabus and all the instructions. I feel like I don't get very much demand for questions from the students. (*Imogene, instructor at BigU*)

These participants explained that online teaching becomes more streamlined and takes less effort over time because the initial effort is put in upfront. There is a strong correlation between quality and quantity of interaction and the time required from the instructor in online courses: for those less concerned with providing interaction in their online course, the less time-consuming teaching online courses was perceived to be. Those that focus on providing more interaction with students commented on the large amount of time required from the instructor.

Support for Instructors. Eleven administrators (73%) and eight instructors (57%) highlighted the necessity of instructor support as part of satisfaction.

Administrators - Administrators described their efforts to support their online instructors, whereas instructors discussed situations in which more support was desired. Administrators mentioned various methods of instructor training or direction in order to provide successful online science courses. Their discussion of such support aimed at providing consistent, quality courses at their universities whether they are online or face-to-face. The support elements included providing pre-designed templates of full online courses so that instructors can walk right into a prepared course, providing clear expectations of what instructors are expected to achieve, and professional development workshops aimed to train instructors in how to build and teach online courses. Two administrators also explained their efforts to provide online instructors with teaching assistants, typically graduate or postdoctoral students, who can relieve the instructor load by grading assignments and emailing students.

Instructors - Instructors' discussion of support centered on the perceived need for more support, including resources, training and especially time to develop and teach online courses. This was discussed in the previous section on instructor time. Most instructors described some level of training or expectations given to them from their universities, but the general consensus among instructors was that more support in the form of training, tutorials, personal assistance, and especially time, is desired.

5.5.3 Satisfaction – Comparison with the Literature

Participants' perceptions of student and instructor satisfaction as a factor in assessing the quality of online science courses correlated well with the review of the literature. Student type, instructor time, and support for instructors were aspects identified in the literature that were echoed in this study (Section 4.2.5). Table 5.4 provides an overview the main contributing aspects identified within *Satisfaction* for both the review of the literature and the three stakeholder groups. As with the previous overview tables in this chapter, the main components presented here for the literature are the same as was presented in Chapter 4 for *Satisfaction* (Table 4.6).

Just as was included in the review of the literature, stakeholders recognized that student satisfaction is dependent on student type. Participants in this study identify the type of students that are satisfied and succeed in online learning as those with high self-efficacy (independence and self-motivation) and maturity. Participant results also indicated that students take online science courses primarily to take advantage of the flexibility that online courses provide.

Instructor satisfaction was identified by stakeholders to be heavily determined by how well instructors believed their online courses were developed and how much time they have to devote to teaching online. Additional time and support were the most common request among instructors to improve satisfaction in online teaching. While the importance of instructor support expressed among stakeholders aligned with findings from the review of the literature, participants emphasized that a lack of instructor support is one of the major roadblocks for the success of online courses. Results from this study indicate that instructors primarily desire additional time for the development and active management of the course, creating online presence and facilitating interaction. However, many instructors generally considered that they were inadequately prepared, and lacking the knowledge to design quality online courses. As a result, instructors in this study noted a desire for additional support particularly for online course development and learning to use and integrate technology. Support also included more time for the development of online courses. Administrators outlined two avenues of support they felt were helping instructors: 1) providing pre-designed online course templates and 2) offering professional development workshops on designing and teaching online courses. Results from the review of the literature align with stakeholders' identification of support, suggesting that support include course development, delivery and maintenance support. However, additional time allocated for course development, as was highlighted by instructors, was not highlighted among the literature.

Table 5.4

The Main Aspects of Satisfaction as Identified in the Literature and Among Stakeholder Groups

Quality Indicator	Review of the Literature	Participant Perceptions: Administrators	Participant Perceptions: Instructors	Participant Perceptions: Students
Satisfaction				

Student Satisfaction	• Self-efficacy/confidence
	• Dependent on student type
	• Enjoyment in learning
		• Self-efficacy
		• Dependent on student type
		  ○ Maturity
		• Workload expectations
		• Interest in/demand for taking online science course
		  ○ Flexibility
		  ○ Choices
			• Self-efficacy
			• Dependent on student type
			  ○ Maturity
			• Workload expectations
			• Interest in/demand for taking online science course
			  ○ Flexibility
			  ○ Choices
				• Self-efficacy
				• Dependent on student type
				  ○ Maturity
				• Workload expectations
				• Interest in /demand for taking online science course
				  ○ Flexibility
				  ○ Choices

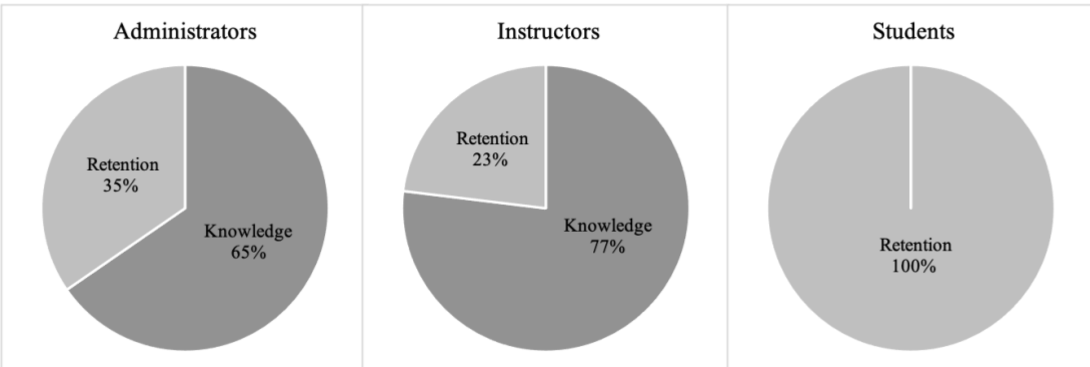
Instructor Satisfaction	• Pleased with teaching online
	• Confident in abilities
	• Instructor support
		• Instructor time for:
		  ○ Course development
		  ○ Teaching
		• Instructor support:
		  ○ Course templates
		  ○ Professional development workshops
		  ○ Teaching assistants
			• More instructor time for:
			  ○ Course development
			  ○ Teaching
			• Instructor support:
			  ○ Resources
			  ○ Training
			  ○ More time	

5.6 Student Learning Outcomes

Among all stakeholder groups, Student Learning Outcomes was the least addressed indicator of quality, accounting for only 2% of the total discussion (Figure 5.1). Administrators were the primary stakeholder group who addressed students learning outcomes, with 88% of administrators, 50% of instructors and only one student providing comments. Two main perceptions were voiced among these participants: 1) student learning outcomes from online course should be the same as from face-to-face courses, and 2) student retention suggests effectiveness. Following the main designations from the review of the literature, the percentage of total discussion regarding student learning outcomes was divide among student retention and knowledge. Figure 5.7 provided a quick visual of how much each stakeholder group discussed each type of student learning outcome.

Figure 5.7

Breakdown of Stakeholders' Discussion of Student Learning Outcomes



Note: The discussion of each aspect is expressed as a percentage of the total discussion regarding *Student Learning Outcomes* for each stakeholder group.

Administrators - Administrators argued that for online courses to be considered quality, the learning outcomes must be the same as for face-to-face courses. They explained that courses completed online are not designated any differently on student transcripts or on their degrees. Amber, an administration at LittleU explained that online courses and face-to-face courses are not designated differently in the course catalogs. While the course may be delivered via a different modality and even consist of different assignments, the course descriptions and the course learning goals are the same. This response was shared by several administrators.

> The content's the same. The degree is the same. [W]e don't even identify on our transcripts which courses were online because it's the same course. A course is a course. Same degree same outcomes.
> *(Adam, administrator at WRU)*

Retention was discussed most among administrators and instructors as a means of measuring the quality of an online course. Participants explained that high retention in an online course implies that students successfully complete the learning outcomes were able to succeed to the next level of the course.

5.6.1 Student Learning Outcomes – Comparison with the Literature

Stakeholders' perceptions were once again in agreement with the literature in establishing student learning outcomes as an indicator of quality for online education. As outlined in the review of the literature (Section 4.2.6; Section 2.3.2), stakeholders from this study agreed that student learning outcomes for online courses should meet or exceed the standards of the university to be considered of quality. Stakeholders explained that online courses were not designated any differently than face-to-face courses in course catalogs or on student transcripts and thus must provide the same learning outcomes. The literature emphasized the retention of knowledge, while stakeholders explained that the retention of knowledge was critical for students in science courses to be able to advance to higher-level courses. A summary of these results is provided in Table 5.5.

Table 5.5

The Main Aspects of Student Outcomes as Identified in the Literature and Among Stakeholder Groups

Quality Indicator	Review of the Literature	Participant Perceptions		
		Administrators	Instructors	Students
Student Outcomes				
Knowledge	• Student assessed knowledge meets or exceeds institutional, industry or community standards • Learning outcomes reviewed regularly	• Learning outcomes for online courses should be the same as for face-to-face courses	• Learning outcomes for online courses should be the same as for face-to-face courses	
Retention	• Student retention of knowledge meets or exceeds institutional, industry or community standards	• Retention of knowledge for students to succeed in higher-level courses	• Students retain knowledge learned	• Retain content knowledge

5.7 Instructor Competency

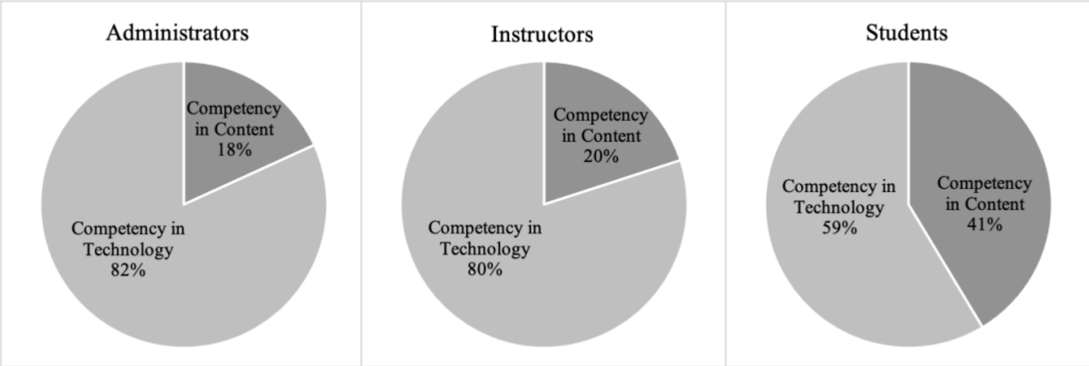
This indicator was not readily addressed among stakeholders, covering only 3% of the total discussion among all stakeholder groups (Figure 5.1). However, the discussion that ensued highlighted a few notable aspects influencing perceptions of quality. The type of instructors who develop and teach online courses can be influential to the perceived quality of those courses. The instructors who were able to provide quality courses were described as clearly passionate, knowledgeable, and experts in their field.

> The best teachers are enthusiastic and passionate about their subject. And they also are supportive of student learning at the same time as holding high academic standards.
> *(Arleen, administrator at RedBrickU).*

In line with the literature, instructors who are competent with the content and technology were highlighted (Section 4.2.7). Also, as noted in the literature, student participants explained that instructor's competency (perceived or actual) in both the content and technology does not go unnoticed. Seventy percent of students in this study (along with 44% of administrators and 50% of instructors) pointed to these aspects as influential in creating a quality online learning experience. Most (~ 80%) of administrator and instructors' discussion of instructor competency focused on an instructor's ability to use and work with technology, while students' discussion was more evenly divided among competency in content (41%) and technology (59%) (Figure 5.8).

Figure 5.8

Breakdown of Stakeholders' Discussion of Instructor Competency



Note: The discussion of each aspect is expressed as a percentage of the total discussion regarding *Instructor Competency* for each stakeholder group.

5.7.1 Competency in Content

Administrators – The two administrators who commented on instructor competency in content stated that the best quality courses depend on the instructors driving the content. They explained that instructors are the subject matter experts, they know their content better than anyone and they know what works in the classroom. Participants emphasized the importance of instructors keeping their knowledge of their field current and relevant, noting that this was especially important in the sciences.

Students – Students further suggested that quality instructors are able to relay personal, real-world experiences in addition to being experts in the field:

> I think it's important they can have relatable experiences … some form of experience in their field … some experience with what they're teaching. You know, outside of the classroom.
> *(Slater, student at LittleU)*

Participants' discussion of the importance of instructors to keep abreast of the knowledge in their fields aligns with the identified indicator of quality, *Relevance and Task Value* as part of *Course Design* (Section 5.3.4). Keeping current in the field allows for instructors to provide relevant and real-world applications to their courses.

5.7.2 Competency in Technology

Instructors who were perceived to do well and enjoy teaching online were described as having a high tolerance for technical issues and the ability to trouble-shoot such issues, allowing the courses to run smoothly.

Administrators / Instructors – Both administrators and instructors described instructors who were passionate about developing and teaching quality online courses, as those who could provide effective online courses. This included instructors who would actively look for new resources to improve their courses and who had a willingness to try new innovative technologies or techniques:

> In general, my feeling is that if you are more or less tech savvy, comfortable with the technology and the changes that are coming in, then you would [do] fine teaching online. *(Ian, instructor at WRU)*

Participants explained that when instructors are comfortable and confident in their use of the technology, they are able to be more responsive and attentive to students in helping them learn.

Students - Students noted that when instructors were more familiar with the technological tools (such as the LMS) the course ran smoother, and was more structured and organized overall.

5.7.3 Instructor Competency – Comparison with the Literature

Instructor Competency was one of the least frequently addressed indicators of quality in both the literature and among stakeholder groups. However, participants aligned with the literature in identifying instructor competency in both content and technology as helpful aspects in providing quality online courses. The details provided by participants and from the review of the literature are summarized in Table 5.6

Just as was stated in the review of the literature (Section 4.2.7), students in this study explained that the competency of the instructor as a content expert and savvy with technology does not go unnoticed by students. In addition to the aspects outlined in the review of the literature, participants in this study added that instructors who are passionate about and keep current in their understanding of their field of expertise were perceived to provide a more quality learning experience. This includes providing more relevant and real-world examples for students, which contributes to and aligns with the importance of these aspects as introduced as part of the *Course Design* quality indicator (Section 5.3.4). As with the review of the literature, stakeholders recognized instructors' ability to handle technological issues, as well as feel confident in the use of new technologies as important for providing quality online courses.

Table 5.6

The Main Aspects of Instructor Competency as Identified in the Literature and Among Stakeholder Groups

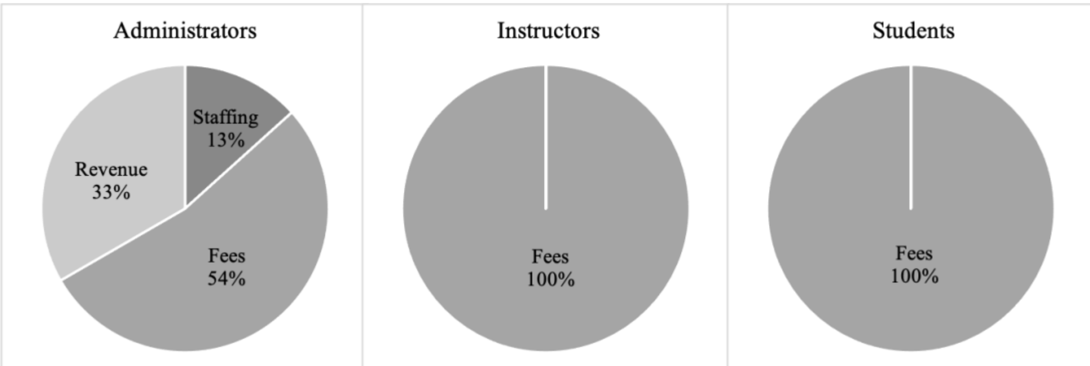
Quality Indicator	Review of the Literature	Participant Perceptions: Administrators	Participant Perceptions: Instructors	Participant Perceptions: Students
Instructor Competency				
Competency in Content	• Instructor is well versed in the subject matter	• Instructor keeps current in the field • Instructor is a subject matter expert	• Instructor keeps current in the field	• Instructor is experienced with the content ○ Real-world
	• Instructor has the ability to explain the course content		• Instructor feels confident in content area	• Instructor can explain and answer questions
		• Instructor is passionate		• Instructor is passionate
Competency in Technology	• Instructor has knowledge in technological aspects ○ Computer use, LMS and lab technology	• Instructor seeks innovative ways to deliver content		• Instructor understands the technology used in the course
		• Instructor is comfortable with technology	• Instructor is comfortable with technological tools ○ LMS ○ Course content	• Instructor is comfortable with technology ○ Responsive and involved with students

5.8 Cost Effectiveness

Cost effectiveness was not directly discussed as an indicator of quality among interview participants. However, administrators (75%) and students (50%) highlighted a few details related to the cost of online education that aligned with factors identified in the focused review of the literature. Instructors (29%) had little to contribute regarding cost effectiveness of online courses in their interviews. The breakdown of stakeholders' discussion of cost effectiveness for online courses, provided in Figure 5.9, shows that both instructors and students contributions focused only on student fees associated with online courses. As administrators are inherently more involved with the financial situation of the universities, administrators contributed discussion of not only fees but also revenue generated as a result of more online courses and the importance of increased staffing in relation to the overall cost of providing online courses.

Figure 5.9

Breakdown of Stakeholders' Discussion of Cost Effectiveness



Note: The discussion of each aspect is expressed as a percentage of the total discussion regarding *Cost Effectiveness* for each stakeholder group.

Administrators – Administrators explained that offering more online courses aided in the overall mission of the university to increase student enrollment. Online courses allow the universities to reach a broader audience of students, thus increasing student enrollment, bringing in more tuition and increasing revenue. In addition, online courses free up physical classroom space, allowing more courses to be scheduled overall and thus increasing revenue. On the other hand, administrators also noted that developing and running an online course takes considerable resources, from the technology to the added personnel and instructor time. In this light, online courses were reasoned to be less cost effective in the long run.

Regrading tuition cost for online courses, administrators explained that online courses often cost more per credit hour than face-to-face courses, thus decreasing cost effectiveness for students. Administrators at PCU, LittleU and WRU explained that each online course has a technology fee associated with it. The exact purpose or use of this fee appeared not well understood.

***Students* –** The student perspective focused on the cost to take online courses. Students expressed that they felt like taking online course should be cheaper because they are working from home with less support and resources than they would receive on campus. Students were disappointed that the cost of their online courses were the same or often higher than their face-to-face courses. Students noted that an extra technology fee per credit hour was often added, but so were extra costs associated with online laboratories such as purchasing rock kits and simulation software.

5.8.1 Cost Effectiveness – Comparison with the Literature

As an indicator of quality, cost effectiveness seems up for debate. As participants in this study indicated, the cost per course is often higher for online courses. Technology fees are often added to tuition, making online courses less cost effective for students. This result is in direct disagreement with the results from the focused review of the literature which suggests that online course tuition rates are lower, making online learning more cost effective (Section 4.2.8). Additionally, as discussed among stakeholders in this study, the infrastructure and costs required to develop, run, and maintain online courses was considered to be significant. At the university administration level, the ability to free up physical classroom space on campus and enroll more students suggested online education may be cost effective. However, enrolling more students per course is in contrast to the suggestions of participants in this study who expressed concern over large enrollments in online courses (Section 5.3.5).

Different from other aspects pertaining to quality, stakeholders' perceptions were divergent from the results from the review of the literature, identifying online courses as less cost effective overall. While the review of the literature included cost effectiveness as an aspect of quality online (Section 4.2.8), the results from the three stakeholder groups did not directly identify cost as a factor to consider in determining online course effectiveness. Table 5.7 provides a summary of the aspects included in cost effectiveness for online education. Identifying aspects which contribute to online courses being more cost effective was part of participants' discussion. Thus, few components are included under each stakeholder group in the table. However, the main components identified in the review of the literature are included.

Table 5.7

The Main Aspects of Cost Effectiveness as Identified in the Literature and Discussed Among Stakeholder Groups

Quality Indicator	Review of the Literature	Participant Perceptions		
		Administrators	Instructors	Students
Cost Effectiveness	• Allow for higher student enrollment • Increase revenue	• Increased student enrollment ○ Increased revenue		
	• More cost-effective for students ○ Cheaper tuition rates	• Fees still apply to online courses ○ Technology fees		• Decreased cost per credit hour • No fees
		• Additional resources needed: ○ Personnel		

5.9 Accountability

Accountability is holding students and universities responsible for maintaining academic integrity in online learning which includes minimizing academic misconduct such as cheating and plagiarism. Accountability was not identified as an indicator of quality in the focused review of the literature. However, it was identified in the interview data from this study as a factor in ensuring quality in online science courses. Fifty percent of the administrator participants and 71% instructor participants discussed issues of accountability in their interviews.

Participants varied widely on the level of concern and actions taken in addressing the issue of academic misconduct online. One end of the spectrum utilized more direct oversight, where accountability was addressed by using proctoring centers or online services to administer examinations. The other end of the spectrum utilized less direct oversight, where instructors held students to an honor code of conduct while manipulating exam formats and questions to prevent cheating. Much of this variation depends on the pedagogical beliefs of individual instructors concerning how student learning should be evaluated and expectations for how assignments and exams are completed. For example, many instructors expect students to work independently on their online coursework, particularly on assessments such as examinations. However, some instructors encourage students to discuss their online material with other students. These instructors see the collaboration and discussion between students as a way to foster learning and take a more relaxed approach to the typical independent nature of assessments.

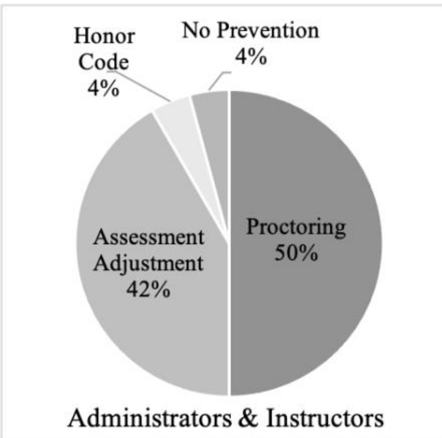
While two participants did note that they felt student discussion during examinations is acceptable, this view was on the outskirts of the spectrum of methods addressing accountability online. These instructors expressed a *laissez faire* attitude to assessment accountability, noting that if students are looking up answers and discussing with others, they are still learning, and that was fine with them. This pedagogical view is less concerned with methods to control cheating and instead follows the idea that learning as a social process can take place even during examinations.

…but other Faculty take another tactic and say, well so they are discussing the material, Great! So, they are looking at it the other way around (*Archie, administrator at LittleU)*

Administrators' and Instructors' comments on accountability along the spectrum of methods addressing accountability online were intertwined and generally in agreement, so are presented together to express their combined view and perceptions. In addition, much of administrators' comments were relaying what instructors in their Department or School have done to address accountability in online courses. Thus, administrators' perceptions are heavily mixed with those of instructors. Participants' discussion of accountability primarily focused on methods used to address academic misconduct online, from proctoring services to adjusting assessment structure and type. Thus, this new indicator of quality is linked to the *Course Design* quality indicator category as it is directly related to course structure and design. Figure 5.10 provides a quick overview of the discussion among administrators and instructors regarding ways to prevent academic misconduct on assessments in online courses. Most of the discussion was centered upon the use of proctoring services and active methods to prevent academic misconduct, labeled as 'assessment adjustment' in Figure 5.10.

Figure 5.10

Discussion of Methods Used to Prevent Academic Misconduct on Online Course Assessments



Note: The discussion of each aspect is expressed as a percentage of the total discussion regarding *Accountability.*

5.9.1 Proctoring Services

Some instructors decided a way to hold students accountable for their work was through the use of proctoring services. Administrators added insight into the various proctoring services tried by the universities. Participants who viewed proctoring as the most effective method to address accountability focused on providing fairness among students, courses, and among universities. Many instructors and administrators stressed that on-campus exams are proctored, so to provide fair learning experiences across the board, examinations online should also be proctored. Instructors using proctoring services shared a pedagogical belief that examinations should be completed independently so that students are only showing their individual knowledge without the aid of external resources. In addition, students earning the same credits from differing modalities or from different institutions should be evaluated under similar conditions. Proctoring services are used to prevent students from cheating which includes using external resources such as the Internet, collaborating with others, or falsifying their identity.

There are two types of proctoring services participants discussed: in-person proctoring centers and online software proctoring services. In-person proctoring typically involves students taking exams at a location where they can be monitored, either at a university campus, library, or a face-to-face proctoring center. Instructors can send an examination to proctoring centers all over the world, giving students access at a variety of locations. Students take their exams at a set time and place and have a third party accountable for their actions during the exam, such as whether or not they use the Internet, look at resources, or talk to others. The use of proctoring to prevent cheating and holding students accountable has been an effective strategy for some participants, ensuring online students are being held to the same standards as those in face-to-face courses.

> Interviewer: Are you proctoring exams just to prevent cheating?
>
> Yes, and it still is my primary reason. And it’s because I know it occurs. They're not only doing it open book, they’re collaborating.

> And my view is that the [face-to-face] class, has a proctored exam [where] they can't have their phones out, there's somebody making sure they don't have a cheat sheet. So why should the online class not be the same. They're gonna get the same exact record on their transcripts. It is extremely unfair to not proctor the exam. (*Iris, instructor at WRU*)

Other instructors have implemented the use of online proctoring software. They described the use of such software as a method to prevent students from accessing anything on their computer screen except the online exam or assignment. Some institutions even require students to have their computer webcams running while they complete online examinations, preventing Internet searching, collaborating with others and aiding in student identification. Online proctoring software such as Proctorio, Respondis and ProctorU provide avenues for addressing accountability online.

> We were worried that students were using textbooks on tests that they shouldn't be using when we're saying it's a closed book test. Now that we have the software Respondus monitor, where there's a camera and they're being recorded while they're taking their tests, they can't have those resources near them…it is giving the instructors the tools and the reassurances that we can ensure the quality and we can ensure that students aren't, you know, having someone else take their tests. (*Alice, administrator at LittleU*).

Due to the nature of the online learning environment both instructors and administrators were unsure how to trust that the students enrolled in their courses were actually the individuals doing the course work and taking the exams. Proctoring services helped to alleviate this concern by requiring students to show an identification card before they take an examination or complete an assignment through the service. In online classes, instructors are often unable to see their students' faces or actually meet them. Many instructors and administrators felt more at ease knowing that the proctoring services provided the security that students are the ones actually completing the examinations.

Administrators considered that they had helped abate concerns of academic misconduct in online courses by providing and implementing resources such as these proctoring services. While some participants expressed satisfaction with the security of proctoring services for their online courses, some instructors were still unsure of their effectiveness.

> The Sciences are more resistant and for many [instructors] it had to do with the kind of assessments they felt they needed to do. If they can't have good proctoring of their tests, then the validity is in question. They have tried some different systems, like ProctorU and regional centers…[t]hey still have plenty of glitches in all those kinds of systems. (*Alan, administrator at RedBrickU*)

With the perception that accountability software systems and proctoring centers are not foolproof yet, many participants felt that in the sciences, accountability continues to be an issue without a reasonable solution.

5.9.2 Active Methods to Preventing Academic Misconduct

On the opposite end of the spectrum from utilizing proctoring services, some instructors implement methods such as randomization of exam questions, multiple versions of questions or full examinations and using a variety of question types to lessen or prevent cheating. Instructors also expressed that by placing a shorted time limit for students to complete an exam and randomizing the order of exam questions, they prevent students from having time to look up answers in the textbook, search the Internet, or collaborate with classmates. Collectively, this approach could be labeled as 'assessment adjustments' as they involved adjusting the type or way assessments are administered for use in the online environment. These methods for addressing accountability were popular among participants whose pedagogical approach to assessment focuses on adapting assessment formats and execution as best suited to the learning situation. This method of actively trying to control academic misconduct requires a lot of upfront work on the part of the instructor. These participants felt there was no need to use proctoring services, instead the limitations and variability used in assessment was beyond sufficient to abate academic misconduct. Such approaches are also practiced in face-to-face courses and many participants believed that it was an approach appropriate to prevent students from cheating in their online courses. Others encourage open book exams but hold students to an honor code, often explicitly stating that students will not confer with others while taking exams. Some of these participants feel the online modality implies that all course components should be accessible online as opposed to requiring face-to-face sessions for proctoring. One administrator, who also has experience teaching online shared this attitude:

> To me if its online, even assessment needs to be online… [I]f I'm taking an online course in say, Australia, why should it be proctored here? But some people still worry about cheating. (*Amare, administrator at PCU*)

Many of these participants acknowledged that there is always an inherent risk in academic honesty and that online is no different. Some use additional assessment activities in their online science courses, making the summative exams less pressured. The higher the stakes, the more pressure students feel to perform well, often leading even well-intentioned students towards academic misconduct. By utilizing a variety of assessment types and lowering the stakes of individual examinations, some instructors expressed they feel their students are less stressed and therefore less likely to cheat in order to perform well.

> [O]ne of the problems with online learning is academic honesty. When the stakes are so high on the tests, you're going to increase the likelihood of someone wanting to cheat to get their grade. If you have enough other activities built into the course, it reduces the pressure a little bit because they know there's a buffer there. (*Irene, instructor at BigU*)

In addition, some instructors and administrators believed that the more students feel part of the university community, the less likely they will cheat. While they admit that this is looking at the situation with "rose colored glasses", they hope that implementing more interaction and personal connection in their online science classes that students will feel less inclined to cheat.

> Nope, I don't [do proctored online exams]. Partly it's because I do so much interaction with [students], I'm not sure it's necessary. They've got a buy-in to the class and therefore they're gonna do the class. Then the other reason is you don't know who is sitting in your class anyway, I don't check IDs, even for when they turn in the exams [face-to-face]. (*Ingrid, instructor at WRU*)

Along this end of the spectrum of methods used to address accountability, instructors decided that active methods, such as catering the exam format and execution to the modality of learning, are appropriate. These approaches to address issues of academic misconduct rely more heavily on students being held accountable via a code of honor in addition to instructors providing clear expectations of what constitutes cheating.

5.9.3 Student Response

Regardless of the tactics used to address accountability in online science courses, the concern of students cheating is not unjustified. Two students admitted to using Internet searches or textbooks during exams and discussing their work with classmates. However, these students did not seem overly concerned with their actions as being dishonest, feeling the course was set up or designed for such actions, or their instructors knew they were doing this anyhow.

> Interviewer: So, you had the indication that maybe you shouldn't be collaborating?
>
> Yeah, but we still did. Two other people in the class I know were also working together. I don't know… (*Sky, student at BigU*)

None of the students interviewed raised issues with the methods of accountability put in place by their universities. Only one student interviewed discussed the use of proctoring in their online course, mentioning that his midterm exam was going to be on-campus, but he was waiting on the instructor to say where exactly. This student was taking other on-campus classes in addition to the online science course and said that having to come to campus to take the exam was no big deal for him since he comes to campus each week. As a member of the school club sports teams, he did say he was sure that if he was traveling for a week for a game, there was no online alternative to take the exam. Other students discussed examinations and quizzes that were administered directly in their online course. Many students said they were well aware when an instructor did not want them to look up answers or collaborate with other students during online assignments and examinations. Students felt that when instructors outlined their expectations, they were more inclined to follow them.

> I think when you've got a teacher that is adamant about being strict about the rules they have set, that lets the student know [the expectations] …well you know how students are, you give them and inch, they'll take a mile. How you set it up…I think it makes a difference. (*Sally, student at LittleU*)

Students expressed that well designed and administered course materials made them appreciate their instructors' efforts. This appreciation often translated into students being aware of their own accountability.

Accountability as in indicator of quality is unique in that it was not previously identified in the review of the literature but identified directly by participants. There was a wide spectrum of ways in which instructors and administrators addressed academic misconduct in their online science courses. From the use of proctoring services to depending on the manipulation of assessment structure and time constraints, participants agreed that students' cheating in online courses is a factor to be addressed. Measurements of accountability in online courses are based on course structural components, so could be considered as an aspect within the *Course Design* quality indicator category. Table 5.8 provides an overview summary of stakeholders' perceptions regarding *Accountability* in online courses. Unlike previous summary tables in this chapter, this table does not include results from the review of the literature for comparison, as *Accountability* was not identified as an indicator of quality in the literature review.

Table 5.8

Summary of Accountability as Identified Among Stakeholder Groups

Quality Indicator	Participant Perceptions: Administrators	Instructors	Students
Accountability	• Prevent academic misconduct, including cheating and plagiarism	• Prevent academic misconduct, including cheating and plagiarism	• Clear policies from instructors, guide student actions
	• Upholding academic integrity		• Nature of the online environment condones some academic misconduct – not viewed as cheating
	• Extent to which accountability is addressed – Spectrum: ○ Direct oversight - Proctoring services (online and physical) ○ Less direct oversight – Assessment adjustments, honor code, no active prevention	• Extent to which accountability is addressed – Spectrum: ○ Direct oversight - Proctoring services (online and physical) ○ Less direct oversight – Assessment adjustments, honor code, no active prevention	

5.10 Chapter Summary

This chapter presented the results from qualitative interviews with three stakeholder groups, namely, university administrators, instructors, and students, regarding their perceptions of quality in online education through the context of science courses. The results presented in this chapter did not address quality indicators unique to science; these are presented in Chapter 6. Instead, this chapter focused on the identified quality indicators which can be applicable to online education more generally, beyond just the scope of science.

This chapter began with a broad overview of the interview results showing that perceptions of quality from all stakeholders aligned with the quality indicator results from the initial focused review of the literature (as established in Chapter 4). *Interaction*, *Course Design*, *Satisfaction*, and *Technology Adequacy* were discussed most among stakeholders and within the literature, indicating their significance as quality indicators for online education. Next, the details of stakeholder perceptions for each quality indicator were presented. For each quality indicator, analysis among the three stakeholder groups and a comparison between the literature and stakeholder perceptions was provided. These results answered the second research question of this study:

> Research Question 2 - What indicators do the university stakeholders use to evaluate the quality of online education in the context of university science courses?

In an effort to understand what makes quality online science courses, this study identified indicators of quality for online education in the context of science courses. Quality indicators identified from a review of the literature guided the analysis of interview data from the three stakeholder groups. These stakeholders provided their perceptions of what makes quality online science courses. Those results confirmed and added to the quality indicators identified in the review of the literature. Stakeholder perceptions of quality also offered significant insight for understanding the challenges of providing quality online science courses.

Interaction was identified more than other quality indicators among both stakeholders and the literature, followed closely by *Course Design*. Much of stakeholders' perceptions indicated that current online courses are able to achieve the quality aspects identified within *Course Design*. On the other hand, stakeholders emphasized that quality *Interaction*, both instructor-student and student-student interaction, is something still lacking or in need of improvement, in online learning. Other quality aspects that stakeholders identified as major challenges to providing quality online education are the effective use of and access to technology, instructor support in developing and teaching online courses, and providing accountability. *Accountability*, holding students and universities responsible for maintaining academic integrity in online learning, was identified by stakeholders in this study as an indicator of quality, but was not addressed in the review of the literature. Acceptable ways to achieve accountability in online courses were debated among stakeholders, identifying accountability as an additional challenge in providing quality online education. The results from stakeholder perceptions suggest that online courses should be held to the same quality standards as face-to-face courses, to include upholding the same level of accountability, student learning outcomes, interactivity, and support for teaching and learning. Chapter 7 provides further in-depth discussion of these major challenges and issues as they contribute to skepticism of online science courses.

Considering the variations of perception among the three different stakeholder groups provided a robust and inclusive understanding of how quality online education is perceived among those directly involved. Administrators provided perspectives with broader views of the university as an institution, adding insight from the knowledge of the goals and decisions at the university, school or department level. Instructors provided insight from the perspective of the course provider, including pedagogical decisions and those pertaining to the individual course or discipline needs. Lastly, students provided perspectives as the online education consumers, giving feedback from their experiences on the utility and reception of the courses. This chapter provided the results of each stakeholder group individually, but their combined perspectives are insightful for providing an overview of what stakeholders in online education collectively perceive as essential for quality (Section 2.4). Collectively, the perceptions of these three stakeholder groups can represent the university as a whole. Thus, Table 5.9 provides a simplified summary of the results from the literature with additions from the combined results of all stakeholders in this study. This table provides a robust overview of what components are necessary to achieve quality online education, in the context of science courses. While these quality indicators were identified within the context of online science courses, they are applicable to online education more generally and may be transferable to many disciplines.

Table 5.9

Simplified Summary of Quality Indicators for Online Education

Quality Indicator		Primary Components from the Literature	Stakeholder Additions
Interaction	Student-Instructor Interaction	– Communication – Relationship /Personalized – Feedback – Access to Instructor – Instructor Presence	– Community – Multiple methods of communication – Adaptive
	Student-Student Interaction	– Communication ▪ Discussions ▪ Relationships ▪ Support ▪ Social – Group Work & Collaboration	– Community – Communication technology provided
	Instructor Feedback	– Assessment Results – Progress Reports – Reassurance of Learning – Timely Feedback	
	Equity	– Equal learning opportunities – Learning geared to different learners	– Multiple methods of communication
Course Design	Course Structure	– Organized framework and design of course – Learning and assessment content – Stimulating and visually pleasing – Functional for learning	– Learning Modules – Easy to navigate – Audio/Video enhanced lectures – Small class sizes
	Clarity of Objectives	– Clear expectations – Clear learning objectives	– Detailed syllabus – Clear schedule and due dates
	Time on Task	– Reasonable time given to complete tasks – Reasonable time expectations	– Moderate pace of learning – Guidelines on how much time expected
	Relevance & Task Value	– Content and activities are relevant to students – Authentic Learning / Real-world context – Student perceives course as worthwhile	

Quality Indicator		Primary Components from the Literature	Stakeholder Additions
	Course Size	*Not addressed in the review of the literature*	– Smaller is better
	Accountability	*Not addressed in the review of the literature*	– Academic integrity is upheld – Clear expectations and policies – Prevent academic misconduct ▪ Proctoring ▪ Honor code ▪ Adjusted assessment format
Technology Adequacy	Technology Use & Type	– Learning management systems & software – User Friendly – Reliable – Compatible across various platforms – Task focused and functional – Appropriate for learning objectives	– Provides interactive learning experiences – Fosters interaction between instructors and students – Provides integration of multiple course materials
	Access	– Accessible and reliable learning environment and tools – Ease of use	– Inexpensive – Mobile access
	IT Technical Support	– Technical support readily available and easily accessible – IT Security – Resources for students and instructors	– LMS support – Online course development support
Satisfaction	Student Satisfaction	– Self-efficacy – Enjoyment – Dependent on the type of student	– Clear course workload expectations – Flexibility – Course choices – Student type: Maturity
	Instructor Satisfaction	– Confidence in ability to teach online – Instructor support	– Instructor time for: ▪ Course development ▪ Teaching – Instructor support: ▪ Resources ▪ Training ▪ Course templates

Quality Indicator		Primary Components from the Literature	Stakeholder Additions
Student Learning Outcomes	Knowledge	– Student assessed knowledge meets or exceeds institutional, industry or community standards – Learning outcomes reviewed regularly	– Learning outcomes for online courses should be equivalent to those for face-to-face courses
	Retention	– Student retention of knowledge meets or exceeds institutional, industry or community standards	
Instructor Competency	Competency in Content	– Instructor is subject matter expert – Instructor can explain the course content	– Instructor keeps current in the field – Instructor has real-world field experience – Instructor is passionate
	Competency in Technology	– Instructor is knowledgeable in course technology, tools, and online content	– Instructor is comfortable with technology – Instructor can explain and problem solve technical issues – Instructor uses technology to seek innovative ways to deliver content
Cost Effectiveness		– Increase Revenue: ▪ Increase course enrollment – Fees: ▪ Lower cost for online courses	– Decrease cost per credit hour – Eliminate technology fees

Chapter 6.
Achieving Science Learning Objectives Online – Stakeholders' Perceptions

This research study investigates the quality of online science courses at the tertiary level from combined perspectives of university administrators, instructors and students. This chapter presents the results of participants' perceptions regarding the unique aspects of science in the online environment, mainly science laboratories. It explores overarching themes identified from the qualitative interviews regarding the challenges and rationales behind skepticism of online science courses. The results presented in this chapter answer the last two research questions of this study.

An initial analysis of the interview data from the three primary stakeholders was conducted using the *Science Learning* quality indicators from the initial focused review of the literature, as defined in Chapter 4 (Section 4.2.4). However, participants' discussion focused heavily on laboratories, making definitive comparisons of the quality indicators difficult. A second focused review of the literature identified science laboratory learning objectives which were used as a framework for re-analysis of interview data. This chapter presents the results of this second focused review of the literature, identifying learning objectives for science laboratories and answering the third research question of this study:

> Research Question 3 - What does the literature identify as science learning objectives, especially for science laboratories?

Next, this chapter focuses on a comparison of participants' perceptions of how online science courses are meeting the science laboratory learning objectives to understand how these perceptions impact the overall perceived quality of online science courses. Section 6.2 presents the detailed results of the stakeholders' perceptions through the lens the laboratory learning objectives. The last section of this chapter, section 6.3, presents the overarching themes identified within participants' perceptions, highlighting the context and basis of skepticism and diversified perceptions towards online science courses. These results present in Section 6.2 and 6.3 answer the last research question of this study:

> Research Question 4 – How do the university stakeholder groups evaluate online science courses in relation to the science learning objectives?

6.1 Identifying Laboratory Learning Objectives

The initial focused review of the literature (presented in Chapter 4) identified indicators of quality for online science education, providing an initial guide for analysis of participant perceptions. Most of the identified quality indicators identified in the review can be applied to online education across many disciplines, however the *Science Learning* indicators were identified as unique to the sciences. Quality indicators that were more specific to the learning of science captured a constructivist approach, a common pedagogical framework in science learning.

6.1.1 Science Learning Quality Indicators

As was presented in Chapter 4, the initial focused review of the literature identified the following quality indicators unique to science learning: *Active Learning*, *Scientific Inquiry*, *Reflective Thinking*, *Independence* and *Open-endedness* (Section 4.2.4). This initial review incorporated studies analyzing both science lecture courses and science laboratories. However, the indicators resulting from the review did not delineate between those for lecture or laboratory, incorporating them together as representative of online science learning.

Initial analysis of the qualitative interview data from the three primary stakeholder groups revealed that participants' discussion of science learning was heavily centered on online laboratories. Participants discussed laboratories at length, explaining that the laboratory component is an essential feature rooted in the overall quality of online science education. Indeed, the educational role of the science laboratory has long been regarded important in supporting students' learning (Hofstein & Lunetta, 2003; Jeschofnig & Jeschofnig, 2011). Much of participants' discussion of the *Science Learning* quality indicators were overly generalized and intertwined with discussions of laboratories, making a detailed analysis of the data difficult. Therefore, as was introduced in Chapter 3 (Section 3.3.2), a review of the literature was conducted to identify science laboratory learning objectives, as the goals and objectives for the laboratory are often synonymous with those for science education in general (Hofstein & Lunetta, 2003). The learning objectives were used to guide a more in-depth analysis of stakeholders' perceptions.

6.1.2 Learning Objectives for Science Laboratory

The results of the second review of the literature identified learning objectives for science laboratories which were grouped into the following categories: *Scientific Methods and Reasoning*; *Conceptual Understanding*; *Interest and Motivation in Science*; *Collaboration and Communication*; and *Practical Skills*. When learning objectives are met, a learning experience is considered effective. Thus, these learning objective categories were used for analysis of stakeholder perceptions. The results of the review of the literature concerning each laboratory learning objective is provided below, answering the third research question of this study. Additionally, a summary of the definitions of each learning objective is provided in Table 6.1.

Scientific Methods and Reasoning. Scientific reasoning, investigative, and observational skills prepare students to experience and process scientific phenomena through the methods of science (Ross & Scanlon, 1995). Science laboratories provide students an avenue to investigate phenomena, solve problems, and pursue scientific questions through observation and prediction, engaging them in scientific methods and reasoning (Friedler et al., 1990; Hurd, 1929). Scientific reasoning depends on the higher-order cognitive skills of problem-solving and critical thinking. Well-designed laboratory activities demand scientific reasoning and critical thinking skills as students work through scientific processes (Dalgarno et al., 2009; Friedler et al., 1990). Students develop problem-solving capabilities as they address issues with scientific equipment and materials during laboratory activities. The scientific reasoning and authentic problem-solving skills are what contemporary science educators recognize as the core of scientific practices to be taught in undergraduate science laboratories (Domin, 1999; National Academies of Sciences Engineering and Medicine, 2015; Suits, 2004). The goal is to teach students these skills while students learn the methods of science, learn how to conduct experiments and how to carry out scientific research (Etkina et al., 2020; Shulman & Tamir, 1973). However, many undergraduate science laboratories still rely on cookbook or recipe style laboratory tasks due to the limited resources and time commitment at universities (Domin, 1999; Hofstein & Lunetta, 2003). There have been constant calls for re-conceptualizing or redesigning the undergraduate laboratories to provide students with problem solving tasks that simulate authentic science research practices and helps build scientific reasoning skills (DeHaan, 2005; Johnstone & Al-Shuaili, 2001). Nevertheless, science educators argue that one of the top learning objectives of science laboratories is to help develop student's scientific thinking and reasoning skills in order to work through authentic methods of science (National Science Teachers Association, 2007).

Conceptual Understanding. Another important objective of the science laboratory is helping students understand fundamental science concepts and principles (and the application of them) through observation or experimentation. The application of conceptual knowledge in laboratory activities can introduce, demonstrate, and reinforce concepts taught in other parts of the science course (Hurd, 1929; Ross & Scanlon, 1995). Ideally, laboratories provide an environment in which students can connect the theories and concepts from the classroom, including lectures and textbook readings, with observations of phenomena and through experimentation and application (Hofstein & Lunetta, 2003). Unfortunately, often laboratories do not afford students the time necessary for the deep processing of information needed to fully tie conceptual knowledge from the classroom into practice (Domin, 1999). Students often focus on obtaining correct results within a laboratory experiment, but in doing so they are inevitably using their prior knowledge and building upon their conceptual understandings to work through an experiment to get their desired results. Conceptual learning in the laboratory goes beyond rote memorization of facts and theories by concentrating on enhancing students' understandings of basic scientific concepts through inquiry and developing a general understanding of the nature of science.

Interest and Motivation in Science. The science laboratory is often seen as an important avenue to enhance students' attitudes towards science, stimulating interest and motivation to learn and enjoy science with greater confidence (Hofstein & Lunetta, 2003). Cultivating students' interest in science and interest in learning science through laboratories, enables students to appreciate and understand how concepts are integrated into a broader understanding of science (Johnstone & Al-Shuaili, 2001; National Research Council, 2006). Ideally, laboratory experiments provide the excitement of science, making science come alive and adding to and expanding the classroom content (Clough, 2002). This laboratory work includes making science real by using real-world problems, demonstrating the relationship between science and other disciplines (Reid & Shah, 2007; Shulman & Tamir, 1973), and relating science to daily life (American Association of Physics Teachers Committee on Laboratories, 2014; Tatli & Ayas, 2013). The laboratory allows students to briefly experience the work of scientists, building up personal and practical experiences allowing them to develop appreciation for the complexity of the real scientific world (Ross & Scanlon, 1995). In laboratories students are typically exposed to the sounds, smells and demonstration of exciting scientific events such as explosive chemical reactions or observing the night sky (Scanlon et al., 2004). Such laboratory experiences can be impeded due to the time and resources to keep the laboratories current, relevant, and exciting. Motivation for science is crucial to help students continue to build upon their understanding of the natural world, not only in their science course and laboratory, but throughout life.

Collaboration and Communication Skills. Laboratory experiences provide an ideal opportunity for students to develop collaborative and communicative skills. Often laboratory experiments are completed in small groups of students. Working in groups fosters collaboration among students, helping them learn by discussing ideas and considering differing points of views and solutions to problems (Goodrum & Druhan, 2012). Collaboration encourages students to articulate and explain their reasoning, aiding them in clearly summarizing and presenting experimental findings and preparing or presenting scientific reports (Kirschner & Meester, 1988; National Research Council, 2006). Arming students with such communication skills aids them in excelling in any discipline or career they pursue. Ideally, laboratories foster teamwork as well as independent work, by giving student opportunities to share leadership roles as well as contribute individual work (Goodrum & Druhan, 2012). However, often one student in the group takes the lead, actually performing the experiment, leaving the others little opportunity to perform meaningful laboratory work (Jeschofnig & Jeschofnig, 2011). While such group dynamics are unfortunate, laboratories often require substantial individual effort in order to effectively communicate results or write laboratory reports, hopefully counteracting such setbacks.

Practical Skills. The laboratory is where most, if not all, of the practical skills and hands-on experience in science learning takes place (American Chemical Society, 2017; Bradley, 1968; Johnstone & Al-Shuaili, 2001). Laboratories provide a safe environment where students can participate in effective physical manipulation of materials, equipment and instruments (Dalgarno et al., 2009; Hurd, 1929; Reid & Shah, 2007; Ross & Scanlon, 1995) as well as learn laboratory or fieldwork techniques and procedures (Jeschofnig & Jeschofnig, 2011). The acquisition of scientific practical skills allows students to link theory of the classroom to physical practice in the laboratory (Woodfield et al., 2005). Scientific investigations often involve working with sophisticated equipment to advance knowledge. Undergraduate laboratories often do not offer students access to state-of-the-art scientific equipment and facilities (Cooper & Ferreira, 2009) but science laboratories are designed to help students understand and practice the procedures and techniques with science equipment to conduct scientific investigations (Kirschner & Meester, 1988).

Table 6.1

Literature Identified Learning Objectives for Science Laboratory

Laboratory learning objective	Description
Scientific Methods & Reasoning	Develop scientific problem solving, critical thinking, and scientific reasoning skills. Investigate phenomena, solve problems, and pursue scientific questions through observation and prediction, engaging in scientific methods.
Conceptual Understanding	Introduce, illustrate and reinforce scientific concepts and theories. Enhance understanding of scientific concepts by connecting the theories and concepts from the classroom with the observations of phenomena and application through activities/experiments.
Interest & Motivation in Science	Cultivate interest and motivation and enhance students' attitudes and perceptions of science to include applying scientific knowledge to everyday life and real-world problems.
Collaboration & Communication Skills	Practice working in teams as well as individually and presenting, reporting and discussing scientific results.
Practical Skills	Develop scientific practical skills through use of equipment, technology, and instrumentation. Apply technical and professional protocols and practice scientific techniques, procedures, and measurements.

6.1.3 Integration of Science Quality Indicator Categories

The *Science Learning* quality indicators from the initial review of the literature (Section 4.2.4) can be traced into the learning objectives for laboratories (Section 6.1.2) via common definitions, as they share the same overall intent. Table 6.2 shows how the *Science Learning* quality indicators map into and align with the definitions of each laboratory learning objective category. The *Science Learning* quality indicators are therefore included within the learning objectives identified for laboratories. This inclusion allowed for the laboratory learning objective categories to act as a guide for re-analysis and presentation of stakeholder interview data regarding science learning and laboratories.

From the *Science Learning* quality indicator category, *Open-endedness*, *Independence* and *Reflective Thinking* can be traced to several learning objectives as they embody the constructivist learning theory framing much of science learning.

The indicator *Scientific Inquiry & Critical Thinking* is naturally aligned with the *Scientific Methods & Reasoning* objective category. The indicator *Active Learning* is an integral component of laboratories and thus is included within each laboratory learning objective category. In fact, the use of active learning and laboratories are the overarching methods by which unique aspects of science learning are conducted. *Active learning*, as an indicator of quality, was discussed as a component accomplished within laboratories, but also as separate from laboratory, taking place in the lecture course (Section 4.2.4). Laboratories inherently include active learning but not all active learning takes place in a laboratory. Therefore, the learning objectives outlined in Table 6.1 apply for both laboratories and active learning in the classroom because these are the primary methods by which the unique components of science are conducted.

This section answered Research Question 3 of this study, presenting what the literature identifies as science laboratory learning objectives (Table 6.1). These learning objectives provided a more focused framework to analyze stakeholders' perceptions regarding the quality of the unique aspects of science online. Participants' perceptions of these learning objectives for laboratories are discussed in the sections below, highlighting the quality aspects perceived as necessary for effective online science and answering the last research question of this study.

Table 6.2

Alignment of the Literature Identified Science Learning Quality Indicators with the Laboratory Learning Objectives

Laboratory learning objective	Learning objective description		Corresponding quality indicator defining components	Corresponding quality indicator(s)
Scientific Methods & Reasoning	Develop scientific problem solving, critical thinking, and scientific reasoning skills.	⇔	• Higher-order problem solving • Activities in science inquiry • Investigation activities ○ Student directed activities	Scientific Inquiry & Critical Thinking
	Investigate phenomena, solve problems, and pursue scientific questions through observation and prediction, engaging in scientific methods.	⇔	• Flexibility in course structure and activities • Student-directed learning and experimentation • Active participation • Hands-on activities	Open-endedness Active Learning
Conceptual Understanding	Introduce, illustrate and reinforce scientific concepts and theories.	⇔	• Students responsible for their learning - conceptualize and construct knowledge	Independence
	Enhance understanding of scientific concepts by connecting the theories and concepts from the classroom with the observations of phenomena	⇔	• Reflective activities and discussion • Reflect critically on concepts learned	Reflective Thinking
	Enhance understanding of scientific concepts by connecting the theories and concepts from the classroom with application through activities/experiments.	⇔	• Active participation • Hands-on activities	Active Learning

Laboratory learning objective	Learning objective description		Corresponding quality indicator defining components	Corresponding quality indicator(s)
Interest & Motivation in Science	Cultivate interest and motivation and enhance students' attitudes and perceptions of science to include applying scientific knowledge to everyday life and real-world problems.	⇔	• Students responsible for their learning - conceptualize and construct knowledge • Flexible and independent learning • Student-directed learning • Active participation • Engaging activities	Independence Open-endedness Active Learning
Collaboration & Communication Skills	Practice working in teams as well as individually	⇔	• Reflective activities and discussion	Reflective Thinking
	Presenting, reporting and discussing scientific results.	⇔	• Active participation • Engaging activities • Communication activities	Active Learning
Practical Skills	Develop scientific practical skills through use of equipment, technology, and instrumentation. Apply technical and professional protocols and practice scientific techniques, procedures, and measurements.	⇔	• Flexible learning • Active participation • Hands-on learning	Independence Active Learning

Note: The quality indicator defining components were extracted from Chapter 4: Tables 4.5 and 4.10.

6.2 Stakeholders' Evaluation of the Effectiveness of Science Online

After the interview data were re-analyzed through the lens of the laboratory learning objectives outlined above (Table 6.1), stakeholders' perceptions were filtered out and interpreted, exposing which objectives were perceived as essential. The use of learning objectives to filter and categorize participants' language, verbiage, and expressions describing laboratories created a more comprehensive and clear interpretation of participants' overall views of online science learning. Stakeholder perceptions became better defined, illuminating particular views beyond the generalized discussion of science learning quality.

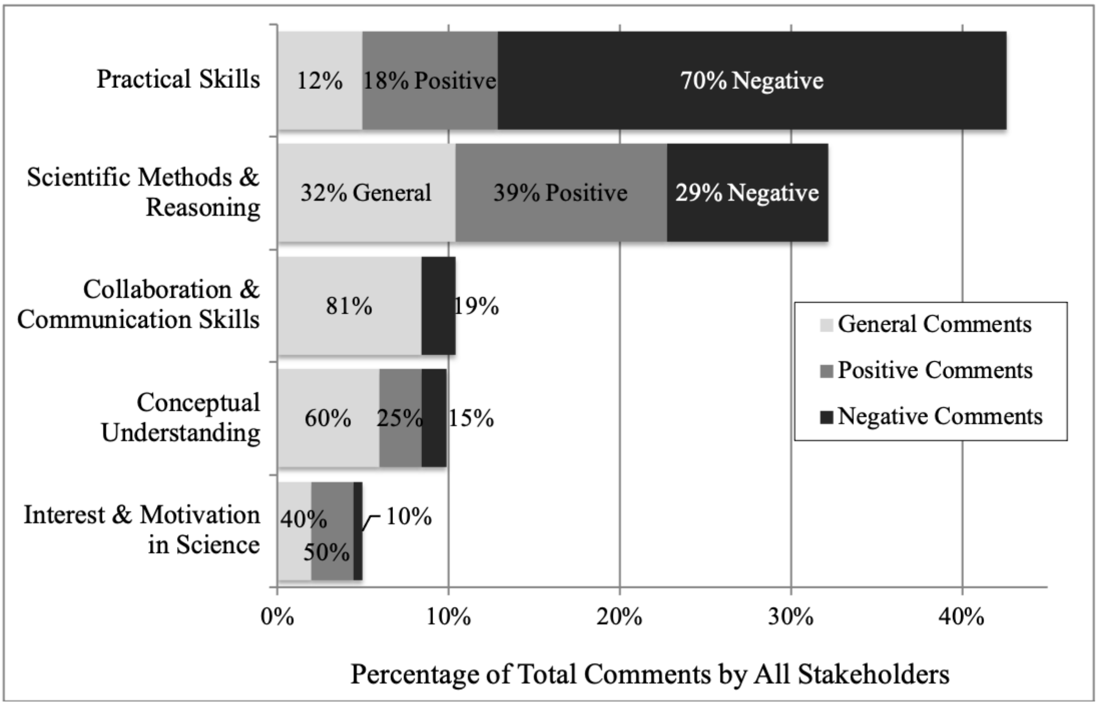
6.2.1 Overview of Stakeholder Perceptions

Participants from the three university stakeholder groups in this study considered laboratories to be a fundamental aspect of science and one of the most limiting factors for the success of online science courses. About half of the administrators had science backgrounds but none had direct experience with online science laboratories. Half of the instructors had experience teaching science courses with an online laboratory component, such as simulations, workbook-type laboratories, and take-home laboratories. About two-thirds of the student participants took online science courses with a laboratory component. Generally, it was believed that without a laboratory component, students would miss the fundamental experience of science. Identifying how participants emphasized the various learning objectives for laboratories helped to clarify participants' specific views towards effective or ineffective aspects of online laboratories, thus identifying indicators of quality unique to science online and addressing research question four. In addition, through analysis of perceptions specific to science online in this chapter, sources of skepticism began to be revealed, further addressing Research Question 4, presented in section 6.3.

Out of the total 202 comments the participants in this study offered regarding laboratory learning objectives (tabulated via NVivo coding as described in Section 3.4.3), the most frequent were about acquiring practical laboratory skills (43%), followed by scientific reasoning (32%), collaboration (11%), conceptual understanding (10%), and interest and motivation (5%). The percentage of positive and negative comments within each learning objective were identified from all stakeholders combined. This summary analysis gave a starting point for further investigation into participants' views on the effectiveness of online science laboratories. The most frequently mentioned learning objective, *Practical Skills*, drew the most negative responses (70%), while the second most frequently mentioned objective, *Scientific Methods and Reasoning*, was discussed more positively (only 29% negative). In general, the negative responses focused on the inability of online science laboratories to provide hands-on, practical experiences combined with collaborative learning experiences. On the other hand, *Scientific Methods and Reasoning*, *Interest and Motivation in Science*, and *Conceptual Understanding* were addressed positively for online laboratories. These details are presented in Figure 6.1.

FIGURE 6.1

Participants' Proportion of Discussion and Viewpoint of Each Learning Objective



Note: Positive, negative and general comments are expressed as percentage of the total frequency discussed for the individual learning objective.

Taken together, the participants in this study addressed all laboratory learning objectives identified from the review of the literature. *Practical Skills* and *Scientific*

Methods and Reasoning were discussed most frequently so may be considered more significant for providing quality learning experiences online. Analysis of each stakeholder group separately revealed that administrators discussed *Practical Skills* most frequently while instructors and students discussed *Scientific Methods and Reasoning* more than other learning objectives. In addition, administrators' perceptions regarding the ability of online science courses to achieve the laboratory learning objectives were much more negative overall than instructors' and students' perceptions. Figure 6.2 provides an overview of stakeholders' evaluation of online science laboratories showing how many participants expressed positive, negative, mixed (both positive and negative) or only general comments of online laboratories in relation to each learning objective. Below is a brief overview of the data in Figure 6.2 for each stakeholder group:

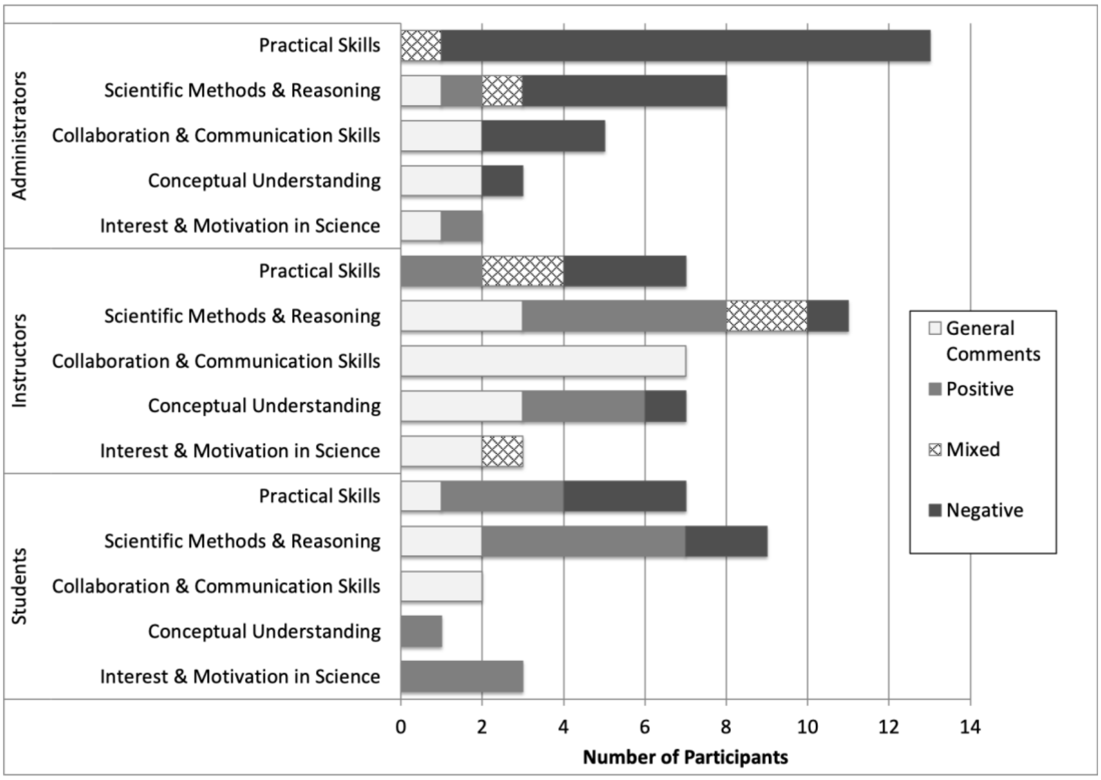
***Administrators* –** The majority of administrators (13 out of 14) primarily discussed the practical skills learning objective with a definite negative outlook for online science laboratories. Their comments about scientific reasoning and collaboration objectives were in a negative tone as well. Regarding all learning objectives, administrator responses were predominately negative (67%), with only 8% positive comments overall and from only one or two administrators.

***Instructors* -** Instructors, on the other hand, shared their ideas across various learning objectives in positive (29%), negative (14%) and mixed (14%) tones. While administrators expressed negative responses regarding the practical skills, the conversations with instructors regarding this objective were more divided and mixed: two instructors presented a noticeably decisive positive view, three presented a negative view, and two held mixed perceptions. More instructors (11 out of 13) discussed *Scientific Methods and Reasoning* than any other objective with a positive tone. They discussed the *Collaboration and Communication Skills* learning objective without sharing positive or negative views of online science labs.

***Students* -** Students were less vocal about laboratories, only addressing one or two objectives in their discussion. Generally, students' discussion of the objectives was positive, especially for the scientific reasoning objective, except for practical skills, which were discussed both positively and negatively.

Figure 6.2

Stakeholders' Evaluation of Online Science Labs in Relation to Learning Objectives



The detailed perceptions of stakeholders regarding each learning objective are presented below, including the quality indicator *Active Learning* as it was the online quality indicator addressed separate from laboratories.

6.2.2 Stakeholders' Perceptions – Can the Learning Objectives Be Met Online?

While online laboratories were not necessarily a new addition to online science courses at the participating universities, they were regarded as a challenge still to overcome. Participants discussed both advantages and limitations of online science laboratories in achieving learning objectives. However, university administrators were overwhelmingly more negative than instructors and students towards the ability of current online laboratories to accomplish any of the learning objectives discussed. Many of the negative views concentrated on the need for physical, hands-on experiences; whereas, most of the positive perceptions concentrated on *Conceptual Understanding*, *Interest and Motivation in Science* and especially the necessity of *Scientific Methods and Reasoning*.

The opinions of each stakeholder group shown in Figure 6.2 are expanded upon in the following sections, outlined by the learning objectives. Participants' perceptions of the effectiveness of online laboratories were examined in more detail to determine whether they thought laboratories are fulfilling, or failing to fulfill, each learning objective. As simulation-based online laboratories were the most frequently discussed, they were used as the primary basis for discussion of online laboratories.

Practical skills – Most Frequently Mentioned and Perceived Most Problematic. From all stakeholders combined, acquiring practical skills was discussed most frequently regarding the effectiveness of online laboratories (Figure 6.1). While all stakeholders addressed this objective, administrators dominated the discussion (Figure 6.2).

Administrators - Administrators' discussion centered on the physicality or hands-on aspects as being the core of laboratories. This view greatly contributed to the negative perception of putting science courses online. Many participants (63%) who discussed this objective explained that the online environment is ineffective for acquiring physical, practical laboratory skills. For this particular learning objective, they believed that students needed to come to campus and physically hold and use laboratory equipment.

> [In] science lab courses, I do think there is some benefit in actually, physically manipulating materials rather than doing it through online simulations. (*Amber, administrator at LittleU*)

Most administrators (71%) expressed the view that the skills components are more than just a learning objective; they are the essential part of the identity of science laboratory. Common phrases such as "hands-on is how you learn science" were well ingrained into many participants' perceptions of what science laboratories should be.

> [T]he actual hands-on lab experience is such a fundamental part of the discipline and the learning experience in the sciences that you really can't substitute for it. (*Arleen, administrator at RedBrickU*)

For any student striving to obtain jobs in which they need to be familiar with a laboratory environment and work with or operate specialized equipment, the practical skills learned in a science laboratory can be essential for their future. Half of the administrators explained that experiences with professional scientific equipment or models, such as using an oscilloscope or mass spectrometer, are essential in science laboratories. These administrators were pessimistic of the ability of the online environment to effectively provide these experiences for students, since they would not have physical access to real laboratory equipment online. However, they noted that physical skills may not be as necessary for introductory science courses and those geared towards non-science majors.

Additionally, there was concern that students in online laboratories would miss out on important fieldwork experiences that can provide students insight and experience into the working environment of scientists. Administrators with scientific backgrounds were the primary discussants of the necessity of field experiences as integral to the overall science laboratory experience. They believed that immersion experiences would be ineffective online because students would miss learning practical skills of dealing with science in its natural environment. Similarly, instructors expressed that online laboratories limit their ability to guide students in the hands-on aspects of learning how scientists gather data in the real world.

Instructors - While most participants discussing this objective (74%) primarily considered practical skills as purely tactile, five instructors discussed the hands-on aspects of laboratory under a more generalized interpretation, including "learning by doing." For these participants, hands-on can include manipulating software or collecting and analyzing digital data, as part of developing scientific practical skills. They expressed that laboratory simulations can provide opportunities to practice organizational and investigative skills and learn the ways in which scientists would use laboratory equipment or materials to perform experiments. However, being able to handle equipment as well as gain an understanding of how equipment works provides a holistic experience for students.

***Students* –** Students' discussion of practical skills was evenly split regarding to negative and positive comments. Some students believed the virtual laboratory experiences helped their learning, but others commented on missing being able to physically work with materials. Many students shared the feeling of administrators, voicing that the laboratory is where hands-on learning takes place.

> That's why it's called lab. You're supposed to touch it … you have to be able to touch them and turn them over and count how many paws they have. (*Shiela, student at PCU)*

The *Practical Skills* learning objective was the most frequently discussed objective among all stakeholder groups. The discussion was focused on hands-on or physical manipulation skills, thus highlighting the inability of online laboratories to directly meet these needs. While physical skills were viewed as ideal for all students, participants expressed more concern about the inability of online laboratories to provide physical experiences for students majoring in science than for non-science majors (this is expanded upon below in section 6.3). A summary of the primary viewpoints expressed by each stakeholder group regarding the *Practical Skills* learning objective is provided in Table 6.3.

Table 6.3

Summary of the Stakeholder Groups' Perceptions of Practical Skills

Stakeholder group	Primary perceptions
Administrators	• Online environment is ineffective for providing physical skills • Students should attend laboratories on-campus • Students aiming for science careers need experience with equipment • Students need fieldwork
Instructors	• Simulations allow learning-by-doing • Practical skills can include organization and investigative skills • Hands-on laboratories can provide a more holistic experience
Students	• Laboratories are defined by hands-on learning

Scientific Methods and Reasoning – Most Positive Response Among Learning Objectives. *Scientific Methods and Reasoning* was the second most frequently mentioned learning objective among participants in their discussion of science laboratories online. The ability of this learning objective to be met in the online environment was viewed more optimistically overall, particularly among instructors and students.

Administrators - Without direct experience and knowledge of the capabilities of simulated laboratories, administrators remained negative and skeptical regarding this objective. They were dubious of the ability of simulations to provide the realistic environment and appropriate guidance in which scientific methods and procedures can be effectively understood and practiced.

> We once had a comment on the virtual labs, 'and the good thing about virtual labs is that they always work' … I don't like the idea that from an online lab everything works all the time and that the data is reasonable, because real science isn't like that…it's very easy to go astray. *(Andy, administrator at BigU)*

Three administrators also expressed the view that scientific reasoning was directly linked to manipulative skills and practices during laboratories. As such, these participants were more doubtful that this objective could be effectively achieved online.

On the other hand, instructors and students were very positive about online science laboratories meeting the learning objective of building scientific reasoning skills as they go through scientific processes.

Instructors - Instructors were the primary stakeholders highlighting this learning objective as part of science laboratories. Three instructors expressed a view that online environments are doing a better job of supporting students to practice scientific methods and scientific reasoning more thoroughly than traditional face-to-face labs, going beyond cookbook style laboratories.

> I think science is about critical thinking … looking at data and interpreting it. And so, that's what I've tried to do with my [online] labs. [W]ith face-to-face, sometimes we get lost in 'oh we could do

> a microscope lab' … and spend so much time trying to get the experiment right, that we don't focus on interpreting the experiment. (*Ivy, instructor at Little U*)

Many instructors (54%) stressed the unique suitability of the online environment to provide learning opportunities to promote scientific reasoning and problem-solving skills. They shared how students are presented with scenarios based on real scientific situations in their discipline and students must problem-solve their way through the situation to come to a solution. These instructors also stressed the unique suitability of various online simulation programs developed by private companies, universities and other educational organizations to guide students in the methods of science.

> [A] Medical Institute has one [simulation program] that I use in physiology … [students] love it. They get to diagnose a heart patient, decide what test to do and … figure out if they could diagnose the patient. (*Irene, instructor at BigU*)

Students **-** Half of the students had positive experiences with simulated laboratories that allowed them to develop and perform experiments. They enjoyed seeing how their experimental designs influenced the data and results. A student with experience in a simulated biology laboratory described her excitement of being able to conduct a large-scale scientific experiment in her online course, something she would not be able to do physically.

> You actually get to do the experiment by yourself. [In] a pollution [experiment], we put nitrogen and phosphorous in the lake water and saw what happened to different types of algae, plankton and trout. I really liked that one because you experiment multiple [times]. (*Samantha, student at LittleU*)

Some instructors and students (21%) also talked positively about simulated laboratories that allow students to not only collect and analyze data but to consider inaccuracies and natural variations. They discussed their simulated laboratory experiences that produced unexpected results, just as one might see in a physical laboratory or field experience. They had to change variables and try their simulated experiment again. Instructors who chose to implement such online laboratory simulations were impressed at the capability to provide effective learning experiences in scientific experimentation for their online students. Instructors and students expressed their excitement with simulated laboratories regarding scientific methods and reasoning. A summary of the primary perceptions expressed by each stakeholder group regarding the *Scientific Methods and Reasoning* learning objective is provided in Table 6.4.

Table 6.4

Summary of the Stakeholder Groups' Perceptions of Scientific Methods & Reasoning

Stakeholder group	Primary perceptions
Administrators	• Scientific reasoning is linked to manipulative skills • Scientific methods and procedures are not understood due to unrealistic online environment • Simulated laboratories do not portray reality
Instructors	• Online promotes scientific reasoning and problem-solving skills • Online environment supports students in practicing the methods of science
Students	• Simulated laboratories allowed for large-scale scientific experiments • Simulated laboratories allow the execution of scientific methods - collect and analyse data and conduct experiments multiple times

Collaboration and Communication Skills – The Objective Without Opinion. Participants highlighted that part of learning about science in the laboratory and how scientists conduct research is learning about teamwork. Both administrators and instructors stressed that students should experience working in groups as well as working individually. They acknowledged that the interactive components within science learning most often come during the laboratory.

Administrators – Among administrators, teamwork was noted as an essential component of the science laboratory experience but hard to achieve online. The ability for students to be able to discuss in real-time with a lab partner was noted as crucial for learning in the laboratory. Administrators noted that in the online environment this is difficult as online communication is not quick enough for effective collaboration.

***Instructors* -** While instructors’ discussion regarding collaboration remained neutral, like administrators, some instructors expressed worry that in the online environment, discussion between students would be delayed, resulting in a loss of real-time problem solving with others.

> Group work around a table, is what I have in mind…there's something to be gained learning how to push yourself and participate in a group. I'm not familiar with forums [online] and how that works with the time lag in interaction. (*Ibrahim, instructor at BigU*)

***Students* -** Students noted that while their online laboratories were designed for them to work through independently, their instructors encouraged them to work with partners, emphasizing collaboration as part of the scientific process. In addition to collaboration skills, participants discussed aspects of learning to communicate results from laboratory activities in written laboratory reports or during oral presentations.

While 19% of participants expressed hesitation (negativity) regarding the ability of collaborative and communicative skills to be accomplished effectively online, majority (81%) of the conversation regarding this objective was neutral (Figure 6.1). Participants discussed this objective as part of science laboratory learning but appeared to be relatively un-opinionated regarding the ability to accomplish this objective within the context of the online laboratory.

Communication and collaboration were identified as crucial for online learning outside of the context of the science laboratory within the quality indicator *Student-Student Interaction.* While participants’ perceptions of communication in the laboratory were neutral, stakeholders were skeptical of student-student interaction effectiveness online, commenting that such interaction is lacking in online learning (Chapter 5.2.2). Much of the discussion of collaboration and communication among students was addressed in the learning process as a whole, as opposed to something specifically unique to science learning online. Table 6.5 outlines the primary perceptions of each stakeholder group regarding *Collaboration and Communication Skills.*

Table 6.5

Summary of the Stakeholder Groups' Perceptions of Collaboration & Communication Skills

Stakeholder group	Primary perceptions
Administrators	• Teamwork is essential in laboratories • Real-time discussion is difficult online
Instructors	• Online environment delays communication • Lack of real-time discussion and problem-solving
Students	• Online laboratories designed for independent work • Communicate results through written or oral reports

Conceptual Understanding – An Assumed Objective. At a fundamental level, laboratories complement science lectures. Participants explained that laboratories reinforce the concepts learned in lecture and often add to that knowledge. They believed it was best when the laboratory activities match the concepts learned in class, so knowledge learned in one setting can be implemented in the other. While participants did not express extreme opinions about this objective for online laboratories, it was clear that conceptual knowledge learned and reinforced was an ingrained component of laboratories. The few (just three: 2 administrators, 1 instructor) negative comments involved the need for hands-on experiences as the method to strengthen conceptual understanding from lectures in the laboratories.

> Of course, they are designed so that the concepts that are discussed in the class are reinforced when they do hands-on [experiments]. (*Ian, instructor at WRU*)

Most of the participants, however, discussed conceptual understanding as being a part of, or resulting from, all aspects of laboratory engagement. The centrality of this objective to laboratories may have caused it to be overshadowed by participants' consideration of other objectives when considering online laboratories. Table 6.6

outlines the main viewpoints of each stakeholder group for *Conceptual Understanding*, showing similar perceptions across the groups.

Table 6.6

Summary of the Stakeholder Groups' Perceptions of Conceptual Understanding

Stakeholder group	Primary perceptions
Administrators	• Hands-on experiences strengthen conceptual understanding • Laboratory activities compliment concepts presented in lecture
Instructors	• Hands-on experiences strengthen conceptual understanding • Laboratories show examples of and reinforce concepts learned in lecture
Students	• Simulated laboratories help conceptual understanding • Best when laboratory activities match concepts learned in class

Interest and Motivation in Science – A Neglected Aspect of Laboratories? Increasing *Student Interest and Motivation in Science* during laboratories was discussed less than any other learning objective. The eight participants who did discuss this objective portrayed a positive evaluation of the ability of online laboratories to achieve the objective, especially students.

Administrators and Instructors - Much of administrators' and instructors' discussion focused on providing students with real-world context to their science learning. Participants explained that online laboratories could provide opportunities to work on current societal issues involving science, such as climate change, increasing students' attitudes and interest in science. One instructor explained that the excitement of science is often expressed during the laboratory through the physical senses. Virtual laboratories may be able to visually demonstrate laboratories. However, this instructor feared that without the physical experience, the excitement that is sparked through laboratory work would be lost.

Students - In contrast, students discussed their excitement regarding the ability of online simulations to allow them to not only visually see the scientific processes but to be able to interact with the content material, thereby learning through exploration. Regarding his online simulation program in biology, one student explained the fun he had learning about mitosis in laboratory.

> It uses models and examples to do on the mitosis lab. It showed us how the individual chromatids end up separating and all that good stuff (*Steven, student at LittleU*).

Almost half of the students in this study (47%) expressed positive evaluations of the ability of simulations to provide real-world experiences, linking their conceptual learning to current world events.

> This week, we are doing [a simulation] about climate change … I had no idea to what extent it was affecting us. I like learning about things that are actually going on right now and are relevant. (*Samantha, student at LittleU*)

The excitement in students' voices, as they described their experiences working on current issues, showed that while this objective may not have been discussed much among stakeholders overall, the online laboratory experience was clearly influential to students' positive outlook on science. Table 6.7 outlines the main views of each stakeholder group regarding the *Interest and Motivation in Science* learning objective.

Table 6.7

Summary of the Stakeholder Groups' Perceptions of Interest & Motivation in Science

Stakeholder group	Primary perceptions
Administrators	• Experiences with real-world applications engage students
Instructors	• Experiences with real-world applications engage students • Physical experiences prompt interest and motivation in science
Students	• Experiences with real-world applications and working on current issues enhance interest and motivation in science • Simulated laboratories promote excitement in science through exploration opportunities

The perceptions for each stakeholder group as presented separately in the sections above, answer Research Question 4 of this study, describing how each university stakeholder group evaluates online science courses in relation to each of the science learning objectives. Based on the results presented, Table 6.8 provides a brief overview of stakeholders' combined perspectives regarding the ability of online science laboratories to meet the learning objectives by presenting perceived advantages and disadvantages of conducting science courses online. This table combines the perceptions from all three stakeholder groups in an effort to provide a more holistic presentation of all stakeholders' perceptions (Section 2.4).

Table 6.8

Summary of Participants' Views of How the Learning Objectives Are Met Online

Learning Objective	Online Laboratories (*simulations*)	
	Advantages	Limitations
Practical Skills	• Virtual manipulation of materials and tools, equipment – learning by doing • Safety working with materials virtually • Access to simulated equipment/laboratories/tools that university might not normally have access to (*applies to remote experiences as well)*	• No physical touching/ manipulation of the equipment/tools/materials • Fieldwork and science career preparation limited • Accreditation requirements for science majors programs– need physical, practical skills experience
Scientific Methods & Reasoning	• Not restricted by the lab equipment/material setup – allows for more time for thinking and analysing • Can have many alternative lab setups in one place • Large-scale experiments can be completed in shortened timeframes • Students can repeat experiments – allows for deeper/more through learning • Can simulate realistic data/results	• Data and results can be too perfect – not portraying reality • Scientific reasoning is well fostered through physical experimentation • Real life research experiences teach scientific methods
Collaboration & Communication Skills	• Independent work is fostered	• Teamwork is limited – difficult real-time interaction, delay in communication
Conceptual Understanding	• Content learning can be practiced and applied in simulation activities – check conceptual understanding • Labs can match lecture content	• Concepts cannot be reinforced via hands-on experiences
Interest & Motivation in Science	• Socially relevant scientific issues can be explored • Interaction with models of concepts can spark excitement and interest • Advanced visual experiences	• No physical experiences - smell, touch, sounds

6.2.3 Active Learning in Lieu of Laboratories

Active learning is often integrated in discussion of laboratory learning. However, some participants in this study segregated their discussion of laboratory from active learning activities. These participants viewed active learning as activities done in class, whereas laboratories were viewed as a separate component of the course designed specifically around experimentation, but both achieving similar learning objectives.

Many of the learning goals described in active learning activities correlate with the laboratory learning objectives identified in this study. Participants' discussion of active learning in the online classroom was highly linked to the discussion of *Scientific Methods & Reasoning* to include scientific inquiry, critical thinking and reflective thinking. Online activities were discussed as being effective for allowing students the independence to work through the material and construct their own understanding. In addition, online activities were described as providing students with avenues to explore and be creative in learning the material, providing open-ended learning opportunities. Active learning was viewed as a way to ensure that online science courses were providing more than lectures and rote learning but rather, were providing avenues for inquiry learning.

> [S]ome of the more simulation type activities that we developed were really great … allows students to go in and play with the module and then if they don't understand it, go back and play with it again. I want them to play. (*Ingrid, instructor at WRU)*

Both administrators and instructors expressed the sentiment that lectures alone are not adequate for learning science and that active learning with the content is necessary, whether it be through laboratories or in the lecture course. Some geological, astronomical and biological science instructors believed that inquiry learning, critical thinking, problem solving, and real-life applications could be incorporated directly into their introductory-level online science courses. These instructors argued that through active learning activities in their classrooms, and using simulations if available, the need for a separate laboratory was unnecessary. Some instructors explained that these activities were used as the homework assignments for their online courses as opposed to separate laboratory exercises.

> I do kind of crazy things. I have them do ecological footprint calculators. Then, I have them research a person in a third world country and how they live. How they get around. And then they go and redo the ecological footprint calculator. Then, they have to analyze all [the data] and come up with conclusions. I can have them do more creation…it could be like a commercial or something. It could be a persuasive poster they make. Or whatever they want to do. They can be as creative as they want to. (*Irma, instructor at RedBrickU*)

As expressed in the participant interview above, active learning also incorporates the learning objective, *Collaboration & Communication* as part of the learning experience. Irma describes students practicing science communication through the presentation of their data.

Additionally, participants described the importance of active learning within online science courses as a way to help students internalize the course material. In active learning, students draw models of concepts, work on solving problems in groups and use simulations or active websites to interact with the material they are learning. Participants explained that active learning gives visual and tactile learners a way to better comprehend and engage with the course material.

Students discussed online activities as avenues to guide their learning of science concepts, matching the *Conceptual Understanding* learning objective. While some students described their experiences with active learning as tedious, or hard work, some students described active learning as an essential component that can aid in learning the material. They also expressed the view that activities should include real-world applications, thereby providing *Interest & Motivation in Science,* highlighting another laboratory learning objective. Steven, a student at LittleU, provided an insightful account of students' desire for more active learning:

> [In] the earth and astronomical science [course], I probably could have benefitted more from it if there were some small modules that actually simulated the water cycle for example. Had me learning

> more while reading, while doing more interactive type capabilities. I probably would have picked it up even better than I did from just pure reading and having the materials in front of me.
>
> So, the interactivity is an important element that takes place. I think material that's tailored to the real-world examples instead of just simply being a regurgitation of the book is definitely a good one. (*Steven, student at LittleU*)

Active learning in the online lecture course can facilitate many of the learning objectives of science laboratories. It is often in the online laboratories where the literature addresses and discusses active learning. However, as shown in this study, active learning conducted separately from a formal laboratory course, can meet many of the learning objectives. One instructor went as far to say that if laboratory type activities are where the learning is taking place, then these types of activities should be brought into the classroom. She argued that learning in science courses should be using the type of learning we see in laboratories, regardless if there is a formal laboratory available.

6.3 Themes Guiding Perceptions – The Educational Context

In the process of analyzing the interview data through the lens of laboratories and the use of explanation building (Section 3.4.3), the foundational assumptions guiding participants' perceptions of online science education were exposed, adding to the answer of Research Question 4 of this study. Perceptions of the ability of online science education to achieve the quality indicators and meet the laboratory learning objectives were based on the educational context considered, namely the specific science discipline and the education goals of students as science majors or non-science majors. While the educational context was not directly acknowledged by all participants, it is an overarching theme highlighting that perceptions of quality are based upon the situation considered.

The educational context shaped how participants addressed the quality of online science education and how effective they believed individual courses would be online. Identifying and understanding how the educational context guided perceptions exposed how stakeholders evaluated the realization of online science education, answering the last research question of this study. The discipline considered and the student audience (science majors vs non-science majors) were found to have a large impact on stakeholders' perceptions of quality in online science education.

6.3.1 Discipline Matters

Not all science disciplines are perceived equally suitable for the online higher education environment. Participants in this study indicated that the type of science matters when considering its success in an online format. The specific sub-discipline, particulars of the laboratory, and perceived overall difficulty of the discipline were primary factors that determined how participants assessed individual science disciplines. How disciplines were perceived made a significant impact in perceptions of quality.

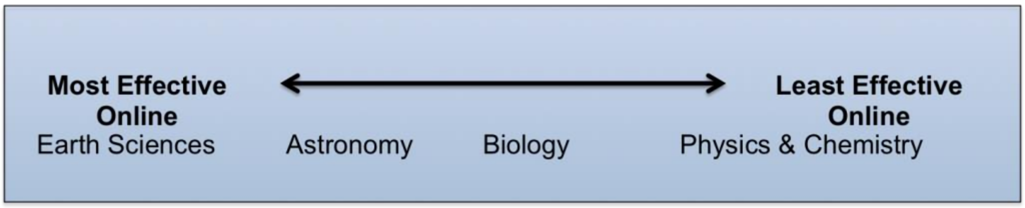
This study focused on participant perceptions of the effectiveness of the core sciences administered online: physics, chemistry, biology, astronomy, and earth sciences. Earth science is a diverse discipline without a consistent definition (Cloutis, 2010) but often includes the subjects of geology, meteorology, and oceanography. The discipline of biology includes general biology, as well as courses in ecology, genetics, mammalogy, and anatomy and physiology. The discussion of physics, chemistry and astronomy focused on core courses in these disciplines rather than specific sub-disciplines.

Each stakeholder group differed in how they judged and determined which science disciplines are best suited for online learning. Administrators relied heavily upon conversations with other academic staff across different science departments, in addition to any personal experience they had in specific disciplines of science. Instructors' comments concerning effective disciplines for online learning were based primarily upon their direct experience in teaching science courses. Students however, provided a mix of judgment based upon personal experience in science courses and pure speculation about disciplines in which they had no direct experience. Such speculation is often influenced by a discipline’s general reputation among a campus community.

Ranking of Science Disciplines. The rationale for why certain science disciplines may be better suited online than others varied between administrators, instructors, and students. However, there was a general consistency from all participants in the perceived suitability for online learning among the core sciences. Participants collectively identified the disciplines of physics and chemistry as being the least suitable online, and the earth sciences, astronomy and biological sciences as being the most suitable for online learning. These results are depicted in a linear representation in Figure 6.3. This figure shows the relative order of disciplines perceived to be most effective online to those perceived to be least effective online based on the combined perspectives of all three stakeholder groups. The disciplines of physics and chemistry are lumped together, due to lack of sufficient evidence from participants to delineate whether one is perceived to be more or less suitable online.

Figure 6.3

Ranking of Science Disciplines by Perceived Effectiveness Online



To summarize, participants reasoned that the difficulty of the subject matter and the need for hands-on applications in the disciplines of physics and chemistry make them less suitable online. These are also the disciplines in which instructors and students believed a face-to-face, personal interaction is particularly needed in order to succeed well online. The Earth sciences subjects of meteorology and oceanography were thought to do well in the online environment. Perceptions of biology were somewhat mixed when considering the efficacy of its courses online, but overall perceptions indicated that general introductory biology courses would be successful online. Participants held a positive perception towards the potential success of astronomy online, being considered a discipline already well suited to make an easy transition into online learning. These overall perceptions provide a general view of the perceived relative suitability of the core science disciplines in the online learning environment. Discipline matters in perceptions of quality for online science education.

Subject Matter and Sub-Disciplines. Instructor participants highlighted that the overarching discipline may be perceived as more or less suitable for online learning based on the suitability of the specific science subject matter and specific courses within the discipline. Instructors gave a detailed account of individual courses and sub-disciplines when thinking about the effectiveness of core sciences online. Ivy, an instructor of biology at LittleU, discussed in-depth the specific subjects within the science disciplines that she believed would work and not work well online. She dissected the discipline of her expertise, biology, into the specific courses and topics, candidly analyzing aspects unique to science in an effort to understand what makes one discipline more or less suitable online. Her thought process expressed in the interview provides a good example of the struggle most online instructors face in determining whether their discipline is suitable for online learning.

> You know, I think there actually are some areas of science that are better suited [online] versus others. Field botany for example…well actually as I say it, everybody can go outside, so I might actually be able to pull this off [as an online course]. Plant families are found everywhere, so you would have to structure the way you teach online. Ecology is the one I'm sitting on, especially because I'm trying to change that class [to] where they go out and collect data…it doesn't work online. I think Biology's that would be easy to do [online] would be organismal topics, like botany, animals, ones that are classification based, taxonomic based. Courses in Biology that I don't think you could do well [online], for example, I'm thinking of genetics. A lot of genetics is pipetting samples, taking DNA samples and running it. *(Ivy, instructor at LittleU)*

Much of the literature addresses online science education by focusing on a specific sub-discipline or specific content area. Lyle and Galwey (2017) explain that each discipline within science has a different set of assumptions, methodologies and objectives so techniques applicable to one discipline may be less successful in others. Downing and Holtz (2008) suggest that more research is needed to develop online best practices specific to the science discipline and its distinctive practical work. Data from this study confirm this sentiment.

It is evident that generalizing to all science disciplines is too broad for assessing overall quality of online science learning. It is therefore crucial when gauging quality of online science education to be mindful of the discipline, sub-discipline or specific subject matter before considering particular indicators of quality.

Need for Laboratory by Discipline. Among the differences in science disciplines is the inclusion of the laboratory, which is central to the perceptions of discipline effectiveness. Introductory chemistry, physics and biology lecture courses typically have an associated laboratory course that not only aligns with, but attaches to the lecture course. While these laboratories are offered at a separate time and typically taught by a different instructor, they are designed to be taken concurrently with the lecture course, making them a tethered unit.

As presented in this chapter, the laboratory is a significant factor in the perceived quality of online science education. Those disciplines that can be considered as a lecture course separate from the laboratory are often perceived as more suitable for the online learning environment. For example, it is generally perceived and accepted among the literature that the disciplines of earth science and astronomy can be effectively delivered online (Cloutis, 2010; Downing & Holtz, 2008; Radnofsky & Bobrowsky, 2005; Werhner, 2010). The disciplines of astronomy and earth sciences also typically offer a laboratory component, but at many universities, laboratories in these disciplines are offered untethered from an accompanying lecture course.

Disciplines such as chemistry and physics, which have a tethered laboratory course, are generally perceived as less effective online. The chemistry community, in line with the American Chemical Society (ACS), insists that the practical skills learned in laboratory are so essential to the learning of science that they cannot be viewed separately from the chemistry lecture course (American Chemical Society, 2017). Therefore, unlike the disciplines of earth science and astronomy, evaluation of chemistry, physics and biology are often tied directly to an evaluation of the ability of the laboratory to be conducted online. With the laboratory viewed as one of the most controversial aspects of online science education, disciplines with tethered lecture and laboratory courses are naturally viewed with more skepticism.

Need for Physical Practical Skills. Each discipline varies in how essential hands-on activities or laboratories are perceived to be for introductory science courses. As discussed by participants in Section 6.2.2, the hands-on nature of traditional laboratories is a primary factor contributing towards perceptions of quality in online science education. Hands-on primarily refers to physical practical skills learned in the laboratory. The necessity of physical practical skills, perceived as particularly prevalent in the disciplines of chemistry and physics, lead most administrators and many instructors to view these as least suitable in the online environment. Instructors with experience in introductory biology appeared to be more accepting of supplementing a hands-on laboratory with online simulations, accomplishing the practical skills learning objective virtually. However, they expressed that the need for hands-on laboratory experiences made biology sub-disciplines such as genetics, ecology and mammalogy less suitable for the online environment.

Astronomy was noted as having great potential to succeed online because of its predisposition in utilizing online and computer tools for imaging and learning about the subject. Several administrators and instructors acknowledged that astronomy is a discipline that would therefore translate well into an online learning environment where virtual practical skills suffice. Participants involved in the earth sciences appear to view hands-on laboratories as less essential towards the overall suitability of the discipline in the online environment. Participants' experiences in earth science laboratories involved active learning experiences with simulations or other online tools.

> In earth science we can't do as much experimentation and it's certainly not done in a typical introductory geology class, other than your basic hypothesis testing. And so, I get kind of frustrated when I hear the term lab because mostly what we do in geosciences are exercises, in my opinion. Now certainly they're using aspects of the scientific method, but you're not doing what most people think of as a lab where you do an experiment. (*Izzy, instructor at PCU*)

One exception appears to be the identification and classification of rocks and minerals in geology, often supplemented with take-home rock kits for online courses. It is evident that disciplines with greater perceived need for physical practical skills learned in the laboratory are perceived as less suitable for online learning (physics, chemistry and biology) than those perceived as less dependent on hands-on laboratories (earth sciences and astronomy).

Perceived Difficulty of a Discipline. From the students' perspectives, a disciplines' success in the online environment was based on the perceived difficulty or complexity of the subject matter. Science disciplines perceived to be hard were thought to be less successful online, whereas science subjects perceived to be relatively easy were thought to be better suited for online learning. Students regarded the disciplines of physics and chemistry to be the most difficult science subjects and therefore least effective online. One students' description of a course within the discipline of biology portrayed biology as a difficult subject as well.

> I know I have to take Anatomy & Physiology. It's not offered online, but if it was, there's no way in this world I would do it online! [laughs] I just think that it's way too complex, you know? *(Sarah, student at LittleU)*

The perceptions of students in this study align with student perceptions presented in a study by Jaggars (2014), reporting that students prefer to take "easy" disciplines online, but would rather take more "difficult" courses face-to-face. Lyle and Galwey (2017) explain that disciplines based heavily upon mathematics are conventionally accepted as being more fundamental and difficult. This view was reflected by students in this study, viewing the necessity of mathematics as a predictor of discipline difficulty and thus influencing its suitability for the online environment.

> There's no math in geology… that would be an easy one [online]. But I would say physics would be tough … [s]eeing one or two or three examples in a physics book is not going to let you know physics content. So, some classes…just need that teacher who's knowledgeable in that field to tell you stuff that's not in the book and can help you figure it out. *(Stuart, student at BigU)*

Stuart also introduced the finding that the more challenging the science content is perceived to be, the more students expressed a desire for further explanation on concepts and examples from the instructor, and less suitable for online learning. In general, students viewed online learning as a solitary method of learning, where the textbook is your primary instructor. This resulted in students feeling uncomfortable in their ability to learn on their own online in what are perceived to be the more difficult science disciplines. They conveyed that more instructor guidance was needed as the subject matter increased in difficulty. Since interaction with the instructor was itself perceived difficult to achieve online, students reasoned that these subjects would not be well suited for the online environment. This view was also shared by an administrator at PCU:

> [U]nless it's just balancing equations…you really have to be in the classroom with a professor to work through those formulas and be able to understand it. And that's why some sciences would be tough to actually have in an online curriculum. *(Amare, administrator at PCU)*

The science disciplines perceived to be more difficult by students are closely related to disciplines which society characterizes as difficult. Thus, student perceptions across the five universities in this study often reflect the overall perceptions of society in general.

6.3.2 Science Majors vs. Non-science Majors

Perceptions of online science education effectiveness are heavily weighted on course level and whether a course is designed for science majors or non-science majors. It became clear that in participants' minds, the suitability of online science education is directly related to whether one is considering students pursuing science degrees or students taking science to fulfill general education requirements. This different focus shaped how participants addressed the quality indicators of online science education and how effective they believed individual courses would be online.

Introductory undergraduate science courses are often geared towards students who are not pursuing science degrees, referred to as non-science majors. These introductory-level courses cover fundamental concepts within the discipline, designed to give an overview of the subject matter using a lower-level of scientific or discipline specific literacy (Klymkowsky, 2005). As was introduced in Chapter 2 (Section2.2.1), these courses are often referred to as general education courses, which fulfill requirements for degree completion in all disciplines. Students earning a bachelor's degree in science or other STEM disciplines (science, technology, engineering and mathematics), referred to as science majors, are often required to take a parallel introductory course designed specifically for STEM majors (Knight & Smith, 2010). Such courses cover the same fundamental concepts as the non-major courses, but often use higher-level mathematics, such as calculus instead of algebra. Lower-level or introductory courses designed for non-science majors are perceived from all stakeholder groups to be more effective online than those designed for science majors. Perceptions of online course suitability for science majors versus non-majors were based upon whether fully online degrees in science were considered, the need for hands-on laboratories, and the perceived need for more instructor interaction in upper-level courses.

Fully Online Science Degree Programs. In talking with university administrators, there was a general feeling that university instructors are hesitant or negative towards the idea of online science education. The stakeholder interviews revealed that much of this negative perception stems from instructors limiting their view of online science education to full degree programs online. Initially, when asked about their views of the effectiveness of online science education, many participants only considered entire science degree programs online. A full online degree program in science would require students to complete all lecture courses and laboratories in an online format for completion of their undergraduate degree. Most administrators expressed that students completing full degree programs need to obtain what they call the university experience. They supposed that a fully online science degree program would not adequately provide such experiences, adding to their hesitation for science major courses to be conducted online.

> If a student just does an online degree, they're missing something of the university experience. Being on campus, interacting with a scholarly community, attending university events. The Sciences continue to lag…they haven't gotten to the point where they've embraced a broad a spectrum of online courses across the curriculum, let alone complete online programs…I don't see any of them clamoring for a fully online program. *(Alan, administrator at RedBrickU)*

Administrators and instructors who were focused on the needs for science majors and those taking upper-level science courses generalized their perceptions, leading to a negative view of the effectiveness of online science courses overall. However, when shifting their focus to individual, lower-level science courses, instead of full degree programs, it became clear that instructors were more positive about the quality of online learning in the sciences. They reasoned that the limitations imposed on the upper-level courses for majors are less of a deterrent to online learning at the lower-level in courses for non-science majors.

The online courses offered at these universities at the time of data collection were primarily introductory, general education courses. No fully online degree programs in the sciences were offered. As participants considered these courses individually, they were able to focus their attention on particular quality indicators and away from generalized statements. These generalized perceptions were typically skeptical, as they were focused on full-degree programs and upper-level courses for science majors as opposed to the lower-level introductory courses actually being offered at their institutions. Administrators believed the lack of interest they perceived from the science departments in developing full degree programs and upper-level online courses was an indication that the instructors were unsure of the overall quality of online science. They attributed this to the difficulty of implementing science laboratories online and argued that they are only comfortable with their divisions offering non-science major courses online at the lower-level because they are often non-laboratory based.

Hands-on Laboratories Essential for Science Majors. As introduced in section 6.2.2 (practical skills), instructors and administrators were particularly adamant about the need for science majors to obtain at least some hands-on laboratory experience, rendering upper-level major courses and science degrees conducted fully online, to be impossible.

> [F]or the majors courses we felt there was no way we could go to a total online format for the labs. Their knowledge of how to handle glassware, how to handle instrumentation, and how to manipulate chemicals, is something they have to have as a progression, it can't be [all] online. *(Ivan, instructor at RedBrickU)*

It appears that few universities provide online laboratories in upper level-courses or courses geared specifically for science majors. Online science laboratories that are currently provided by universities in the United States tend to be geared towards general education, introductory courses that are populated primarily by non-science majors (Section 2.2.3). These students are typically taking a science laboratory course to complete their general education requirement and do not necessarily have a career goal in the sciences. Participant's discussion of the differences in effectiveness of online laboratories for science majors versus non-majors focused on the practical skills learning objective for laboratories. The practical skills needed to be able to physically manipulate laboratory equipment were considered critical for upper-level science student's career preparation. Administrators and instructors insisted that such laboratory skills are needed for careers in the sciences and could only be effectively obtained through a hands-on learning approach, by physically using equipment and practicing safety procedures while working with materials.

> In a lab course some outcomes involve the skill of using a particular instrument. How are you going to use an oscilloscope online? [laughs] … part of the assessment of our majors program depends on students graduating with certain skills … because a lot of them are going to be doing [jobs] related to lab and hands-on. (*Arthur, administrator at WRU*)

In addition, participants expressed that if online laboratories cannot provide effective practical skills, they would be unable to provide science majors with the accreditation requirements needed to complete their science degree programs. While hand-on skills were viewed as ideal for all students, participants expressed more concern about the inability of online laboratories to provide physical experiences for students majoring in science.

> To get an accredited degree a student has to have like 900 hours in the lab so for chemistry [majors] at least, the online labs are going to be problematic. [But], for the general [non-major] organic chemistry and biochemistry online course and lab, it really does satisfy what that population of students really does need. They're not going to be working in labs and they're not really going to have that much interest in a science background ... for that I can live with it. *(Alexander, administrator RedBrickU)*

In considering non-science majors in general education science courses, two instructors specifically acknowledged that physical, hands-on experiences might not be as essential. They expressed that online laboratory could be effective due to the different focus of skills taught in laboratories for non-majors, especially less need for physical practical skills.

Mirroring instructor and administrator views, students indicated that at the upper-level, science courses would be less effective in the online environment. Students recognized the need for laboratory skills in upper-level science courses, as a necessity for science majors. However, other students noted that in the lower-level, non-major science courses in which they were enrolled, learning these hands-on skills was not as necessary, making these courses well suited for online learning. Most of the students expressed that the online laboratory experiences they received in their non-majors courses were effective. Steven, a student at LittleU, provided an insightful analysis of how online courses can accommodate the differing needs of majors and non-majors.

> You know, if I were a science major, I would say I'd probably be missing a little bit [online]. If I did an entire science major [online], and all my major classes were based upon what these [online introductory biology] labs have brought me, I'd say there would probably be something missing. I would need to have the hands-on with the tools, actually be in the field, do the necessary work, and research. But, as a business major, and fulfilling some of the basic science [requirements]…you know I'm not sure that there's a significant amount of loss there… So, I think, overall, at the end of the day, I've been able to grasp the important points of…the introductory class without missing anything. *(Steven, student at LittleU)*

Issues with Upper-level Science Courses. All students in this study had experience in online science through non-major, lower level, introductory science courses. Students were very positive regarding the effectiveness of lower-level science courses online. A majority of students however, expressed that upper-level science courses would be least suitable online because as the course level increases, the concepts become more difficult. Student's perception matched the work of Klymkowsky (2005) who explains that courses for science majors are commonly viewed as harder, more rigorous and more comprehensive. Thus, as exposed earlier in the Discipline Matters context (Section 6.3.1), as the perceived difficulty of a course increases, students suspected there would be more need for direct interaction with instructors. Participants recognized a need for an increase in student-instructor interaction in more difficult, upper-level courses and for students majoring in science. This feeling that science majors need more one-on-one interaction was agreed upon across stakeholder groups. Upper-level courses are perceived as requiring more instructor interaction and students claimed that the presumed lack of interaction in online learning would render these upper-level courses unsuitable online. For some students, more direct and personal instructor interaction is particularly necessary in their major courses. Such interaction with instructors helps them succeed in their degree program and prepare them for careers by providing future references or career counseling.

> I don't think I would want to try those [upper-level courses] online … I would want to learn more of those in-class [face-to-face] and actually have a teacher to talk to…be able to know my professor on an actual level. (*Sonya, student at WRU*)

A few instructors saw some potential for future upper-level science courses being implemented online. However, these instructors noted that although they can see the feasibility, the content and tools are not readily available at the upper-level for online science learning. This highlights participants' consideration of the quality indicator, *Technology Adequacy* (Section 5.4) in the context of course level. In order to develop quality online materials for teaching upper-level science major courses, instructors would need resources and necessary skills most believed they lacked.

> I think the burden for upper-level classes is developing materials. Whereas for a 100-level class…there are such amazing resources already out…that I'm not finding for the upper-level. So, I have a really hard time doing the upper level online, but I absolutely think it can be done, if you've got the right resources. *(Ingrid, instructor at WRU)*

Thus, as represented in this study, at this point in the evolution of online science education, online courses tend to be at the undergraduate level and typically represent introductory classes (Downing & Holtz, 2008).

Generalizations to fully online degree requirements, hands-on laboratory experiences and perceptions of difficulty associated with upper-level courses aided in the perceived differences between suitability of online courses for science majors and those for non-majors. All stakeholder groups agreed that the success of online learning for the sciences is highly dependent on the course level and whether it is designed for majors or non-majors. Therefore, it is essential that we take into consideration the specific learning goals for both majors and non-majors science courses for assessing the effectiveness of these courses in the online environment. Clarification of explicit needs, goals and outcomes for both types of courses can help determine whether they are attainable online. Just as was revealed when considering the science discipline in understanding perceptions of quality in online science education, considering the course level and whether a course is for science majors or non-majors, highlighted that laboratories and instructor interaction are integral components to perceptions throughout consideration of online science courses.

In the process of re-analyzing the interview data through the lens of science laboratory learning objectives, the foundational premises guiding participants' perceptions were exposed. Perceptions of the quality of online science courses varied based on the educational context considered. This included the specific science discipline considered and the education goals of students as science majors or non-science majors. The educational context was not directly acknowledged among all participants, but was the basis of many perceptions regarding the ability of science to be conducted online and uphold the indicators of quality. These results added depth to the answer of Research Question 4 of this study, providing more insight into how university stakeholder groups evaluate online science courses.

6.4 Chapter Summary

This chapter presented the results from qualitative interviews with three stakeholder groups regarding their perceptions of quality in online science education through the context of science laboratories. The results presented in this chapter addressed the quality indicators unique to science as they aligned with identified learning objectives for laboratories. This chapter answered the final two research questions of this study, identifying science laboratory learning objectives (Research Question 3) and addressing how the university stakeholder groups evaluate online science courses in relation to the science learning objectives (Research Question 4).

Science laboratories continue to be viewed as part of the bedrock of science education. Stakeholders' discussion of science online was concentrated on laboratories to the extent that extraction of quality indicators unique to science was difficult. Thus, this chapter presented the results from analysis of interview data through the lens of learning objectives for science laboratories. The most common learning objectives for science laboratories were identified through a review of the literature: *scientific methods and reasoning, conceptual understanding, interest and motivation in science, collaboration and communication,* and *practical skills.* The *Science Learning* quality indicators from the initial focused literature review (Section 4.2.4) are directly integrated within the definitions of each laboratory learning objective. Identification of these learning objectives for science laboratories answered the third research question of this study. Laboratory learning objectives provided a more focused framework to analyze perceptions of quality for science online education.

Addressing the fourth, and final, research question of this study, participant data revealed that practical skills and scientific methods and reasoning were the two most influential learning objectives fueling discussion of the effectiveness of online science. University administrators were significantly more negative than instructors and students towards the ability of online laboratories to accomplish any of the learning objectives discussed. Generally, the perceptions of instructors and students were positive and optimistic regarding the effectiveness and potential of online science laboratories, especially in the ability of online laboratories to excel at meeting the scientific methods and reasoning objective. However, all participants agreed that more advanced simulations, providing realistic laboratory environments, are desired. Embracing the possibilities of how each learning objective can be accomplished in the online environment is key to providing successful online science learning and laboratories. Participants identified that many of the learning objectives could also be accomplished as part of active learning in the lecture portion of a science course.

This chapter concluded by presenting overarching themes influencing perceptions of quality and identifying a more tangible cause of the skepticism surrounding online science courses and laboratories. In examining all stakeholder perceptions, it was found that the perceived need for practical skills is often seen as a barrier to effective online science education. This learning objective was the most frequently discussed and the primary source of skepticism towards the advancement of online science learning and laboratories. Further analysis revealed that perceptions of quality are highly influenced by the educational context considered.

The results of this further analysis added depth to the answer of the final research question of this study, gaining insight into how stakeholders evaluate the realization of online science education in relation to the science learning objectives. The data from this study distinguished unique aspects of the core science disciplines, which determine their perceived suitability to be taught online at the university level. The specific science disciplines, and even the sub-disciplines, are the first important identifiers of educational context in the discussion of online science effectiveness. Following the classification of discipline, the identification of the level of the course and whether the course is designed for students majoring in science or not influences perceptions of online effectiveness. Without first acknowledging the educational context, discussion of the quality and effectiveness of online science courses becomes too dispersed and overly generalized, often fueling negativity and skepticism.

Chapter 7.

Discussion - Addressing the Challenges of Online Science Education

The purpose of this qualitative interview study was to investigate the effectiveness of online science courses from the perspectives of three primary stakeholder groups – instructors, students and administrators. Indicators of quality were identified and sources of skepticism towards online science education were revealed. Perceptions of quality indicators for online education and those unique to science online from stakeholder groups correlated with those identified in the literature. Those most frequently discussed and highlighted as particularly challenging by participants in this study were *Interaction, Instructor Support, Technology Adequacy, and Online Laboratory - Practical Skills*. Participants identified an additional indicator, *Accountability*, that was not included in the focused review of the literature and was perceived to pose a challenge for online learning.

Interaction (Section 5.2) – All stakeholder groups agreed that interaction with the instructor and among students is important, but quality interactions are often lacking in online science courses. Participants expressed that it is challenging to provide the social and more personal interactions online which often establish the community among learners. Instructor interaction was described among stakeholders as one of the more challenging aspects to online science learning, as interaction with the instructors was shown to be essential in all aspect of learning, from creating the course community, providing feedback, assisting in the laboratory and for guiding students towards their futures in science.

Instructor Support (Section 5.5.2) – Instructors highlighted that a major challenge to successful online science education is their personal ability to design and develop effective online courses. Many instructors generally felt they were inadequately prepared, and lacking the knowledge to design quality online courses. Instructors indicated that there is a need for additional time for the development and active management of the course, creating online presence and facilitating interaction. In addition, instructor support for online course development and learning to use and integrate technology was perceived as essential to overcome this challenge.

Technology Adequacy (Section 5.4) – Participants conveyed two technological challenges to providing quality online science education: 1) the technological tools exist but instructors and universities are not capitalizing on them, and 2) the technological tools don't exist yet for science disciplines and at the level of learning needed. The challenge of providing effective interaction was also perceived to be related to technology, as stakeholders were at a loss concerning how to foster such interaction online without either new technological tools or the use of synchronous communication.

Accountability (Section 5.9) – Instructors and Administrators expressed a wide range of concern toward maintaining academic integrity in the online learning environment. Some saw the ability to maintain academic integrity online as a major challenge to providing quality online education, while others viewed it as manageable in the online environment. Those who viewed this as a major challenge, expressed concern that without maintaining academic integrity, online science courses could not be considered quality.

Online Science Laboratories (Section 6.2) – The results presented in Chapter 6 revealed that much of the negativity towards online science education resides in the perception that laboratory learning cannot be conducted effectively online. Stakeholders addressed the learning objectives for laboratory as essential to science learning as a whole, and perceived most objectives to be effectively accomplished online. However, the majority of the skepticism towards online science education, was focused on the inability of the practical skills learning objective to be effectively accomplished online. While most participants viewed laboratories as an essential part of all science learning, some instructors explained that the learning objectives can be accomplished in a variety of modalities, such as virtual simulation or through active learning in the classroom instead of in a formal laboratory. This key contextual foundation to perceptions highlighted that perceptions of quality are based upon the situation considered.

In Chapter 6 (Section 6.3), the educational context was addressed as a source of differing perceptions and aiding the skepticism surrounding online science education. The discipline being considered, the course level, and the student population (science majors vs. non-science majors) were found to play a role in the challenges that participants noted for achieving quality online science education.

This chapter includes a discussion of these major findings as related to the literature pertaining to quality in online science education and what implications may be valuable for use by university educators, researchers and policy makers who plan to develop, implement or evaluate online science courses. This chapter provides a discussion of challenges participants identified, how these challenges are addressed in the literature and suggested ways forward in light of these challenges. It should be noted that the discussion is based upon participants' perceptions, and not necessarily representative of actual practice or official university policies.

7.1 Defining Interaction in Online Science Education

In any discussion of online learning effectiveness, interaction is a key player. Indeed, interaction is often viewed as a major issue in achieving effective online learning (Buffington-Adams et al., 2017) and thus is an instigator of the development of new pedagogies in online teaching and new online learning tools to facilitate communication. It is commonly believed that high levels of interaction are needed for students to have a positive attitude and achieve satisfaction in learning (Desai et al., 2008). The interviews in this study confirmed that the term "interaction" is used broadly among university stakeholders and often generalized as an important factor in determining quality. While all components of interaction were discussed under the premise of being specific to science education in the online environment, much of the discussion concerning interaction was generalized and not focused solely on the sciences. The importance and identification of the defining factors of interaction are consistent with what the research and best practice literature has established. Prompt and personal feedback, providing office hours, creating a community online, and instructor presence are fundamental pillars of quality student-instructor interaction in any online course. One component addressed specifically towards science instruction and learning was the necessity of adaptive interaction between students and instructors (Section 5.2.1).

Stakeholders' discussion of student-student interaction focused on the necessity of group work and the use of discussions to foster communication and community, despite most students perceiving online learning as an independent endeavor (Section 5.2.2). The importance placed on providing opportunities for interaction and collaboration among students indicates alignment to a constructivist, specifically a social constructivist, perspective on science education (Agarkar & Brock, 2017; Ross & Scanlon, 1995; Scager et al., 2020). In addition, the importance placed on the necessity of interaction in learning has led to the perceived importance of a learning community culture (Luo et al., 2017; Ross & Scanlon, 1995).

Participants were clear in what is needed for quality interaction and just as clear in their perceptions that such interactions are lacking in the online environment. Ross and Scanlon (1995) suggest this is a common perception. Reimagining the building of science learning communities in the online environments has challenged educators to rethink how interaction is fostered and maintained. As Buffington-Adams et al. (2017) suggest, the work to provide quality interaction online is not as impossible as some might believe, but "strangely remains the same while looking different" (p. 245). Online learning can provide a social context for learning science within constructivism, as long as the aspects necessary in interaction are considered within the contexts of an online community of learning (Ross & Scanlon, 1995). The perceptions revealed from this study indicate that re-considering how interaction is accomplished may be a key towards the success of online interactions.

7.1.1 The Role of the Instructor in Interaction

Interaction with the instructor was perceived to be lacking in online science education even when, as administrators in this study attested, multiple avenues of communication tools and opportunities are provided (Section 5.2.1). The expectations of student-instructor interaction may differ from what can actually be provided. As online science courses continue to be developed and instigated at the university level, adaptations in teaching practices are necessary (Desai et al., 2008). Online instructors must take on new roles such as mentors, coordinators, and facilitators of learning, in addition to disseminating course content (Hardy & Bower, 2004). A shift in roles such as this is a challenge for many instructors, especially those who typically rely on traditional lecturing (Desai et al., 2008; Gratz & Looney, 2020).

As identified in this study, successful online education requires active interaction with the instructor because it sets the foundation for a sense of community environment for learners (Section 5.2.1). Participants stressed that interaction is multi-faceted, including direct virtual interaction, indirect via feedback, a sense of community and online presence. Effective interaction heavily depends on the multitude of roles and actions of the instructor because they foster interactions in the online environment (Aldrich et al., 2017; Harasim, 2012). It is the human connection created and facilitated by the instructor that fosters the interactions seen as foundational in quality online education (Buffington-Adams et al., 2017; Downing & Holtz, 2008).

Ross and Scanlon (1995) advise that a common understanding of interaction as 'learner support' in online education is distinctly different from interactive techniques and devices embedded in learning materials, as they cannot respond to the learner as an individual person. This type of desired interaction, takes significant foresight, effort and time on part of the instructor. The instructor must design, moderate and scaffold the interactions in their online course (Downing & Holtz, 2008). Participants in this study noted that small class sizes were a component to ensure quality online science learning (Section 5.3.5). Small class sizes could aid in providing a more manageable situation for instructors to be successful in providing and structuring such quality interaction in their online courses (Bates, 2000; Orellana, 2006). In line with this, results from this study highlighted that the course structure must be designed to facilitate multiple avenues for communication between students and instructors, in addition to providing methods in which the instructor can effectively convey online presence (Section 5.3.1).

The work of the online instructor is crucial for establishing and maintaining both student-instructor and student-student interaction. Nicholson (2005) proposes that it is less about the available tools and more about the ability and efforts of the instructors, starting with instructional design and continuing throughout the course. How interaction occurs is important (Abrami et al., 2011). In the traditional classroom, students are able to develop relationships due to proximity of other students and their instructor. In the online classroom, these relationships and an established community must be fostered and facilitated by the instructors (Buffington-Adams et al., 2017; Harasim, 2012). Successful online teaching incorporates instructor guidance and interaction (Desai et al., 2008). Consequently, the variations of interaction type have a direct effect on the role of the instructor, in some cases making them moderators of learning, and in others, facilitators of relationship building.

Instructor Support is Essential. The amount of interaction required during online teaching takes a lot of work on the part of the instructors and thus, support for instructors becomes essential when linking this quality indicator with instructor satisfaction (presented below in Section 7.2). The support administrators claim they are providing appears to not match the need of instructors or the demand and expectations for providing quality interactions online. Perhaps administrators are not thinking as deeply about the work involved in the interaction. As was presented in this study, when instructors are given the support and guidance to provide effective interaction, they are more satisfied with their online teaching (Section 5.5.2). Instructor preparation and support is a vital component of designing an online science course and should involve opportunities to learn the technology and consider appropriate pedagogical techniques (Downing & Holtz, 2008). Recognizing this vital instructor role of creating quality interaction can vastly increase both student and instructor satisfaction, thus increasing the positive perception of online science course quality.

7.1.2 Physical versus Virtual Instructor Presence

As participants in this study have indicated, instructor presence and student-instructor interaction are directly related; interaction is presence (O'Reilly, 2009). Interaction involves direct communication with students but conveyed presence in an online course can add depth to direct communication. Presence includes showing the instructor’s personality, knowledge (content and technology), and an understanding of student needs (Wood, 2002). Instructors in this study acknowledged that instructor presence is important to the success of students in an online course, interpreted as “being real” with their students (Richardson et al.,

2016) (Section 5.2.1; 5.3.7). Instructor presence is a feeling of support and guidance from the instructor that students see as an essential component in online learning and is integral in the discussion on student-instructor interaction (Hung & Chou, 2015). Support and guidance can allow students to perceive that they are seen and to feel that the instructor is more than just a name on a page or an unknown person grading assignments. Frequent and productive communication between students and instructors removes some of the feelings of disconnect in online courses (O'Reilly, 2009), providing students with a sense that they are being taught by an individual who cares about their success in the course. Conveying presence and incorporating interaction in online courses not only increases students' positive perceptions of their online courses, it increases instructor satisfaction as well, creating a learning community (Shea et al., 2006).

Participants in this study stressed the need for guidance and instruction during science learning, immediate feedback, and the ability to ask questions as they worked through modules, activities and the laboratory. While most participants considered that a physically present instructor best achieved these needs, the way students described their experiences (Section 5.2) began to reveal that the computer-generated guidance and feedback was satisfying some of the desire for instructor presence as described above. This finding raises the question: Is a physically present instructor essential for learning, or can virtual presence suffice?

There is strong agreement in the literature that instructor presence in online learning is an essential element for student success and satisfaction (Joo et al., 2011; Ladyshewsky, 2013; Richardson et al., 2016). As part of instructor presence, students desire timely feedback, guidance and interaction as key to their learning satisfaction (Vesely et al., 2007). Simulations can provide automated feedback to students as they design virtual experiments and work through the simulation activities. In addition, Ryoo and Linn (2016) found that automated feedback and guidance during an online inquiry based activity effectively aided student learning. Similarly, some students in this study noted that the simulated feedback they received was very useful in helping them learn and as a result made them feel that an instructor was present (Section 5.2). However, in line with the research literature, most students in this study still felt that instructors need to make a concerted effort to engage with them during the laboratory by providing concurrent guidance and assistance (Stuckey-Mickell & Stuckey-Danner, 2007).

Suggestions from the Literature – Providing Virtual Instructor Presence. Live text chat sessions or synchronous online audiovisual conference sessions can be used to provide such concurrent feedback and guidance, either within simulations or using parallel software programs such as Skype or Zoom (Ladyshewsky, 2013). In addition to synchronous communication, interaction can include announcements, emails, feedback, asynchronous chat, and developing a personalized rapport with students (O'Reilly, 2009). Even the simple addition of visuals of the instructor imbedded in lectures are perceived by students to be more enjoyable, interesting and believed to facilitate learning (Wilson et al., 2018). When instructor interaction is perceived to be lacking online, often one or more of these elements is missing. With frequent and constructive interaction, students often report that they feel they are receiving the support they desire (Swan et al., 2000), even if this interaction is automated. Thus, instructor presence is portrayed through automated feedback and software guidance. Student-instructor presence and interaction can be converted to student-content interaction in the online environment (Anderson, 2010). Therefore, if a high level of such virtual presence is provided in online science courses, perhaps the need for physical presence becomes less essential.

Participants desire for more instructor interaction in their online science courses may be addressed with careful consideration of the tools and techniques to provide effective online presence. “If the ability to develop community in virtual learning spaces hinges upon the strength of an instructor’s presence, then ensuring one can construct a clear and consistent presence across the virtual learning space becomes the first concern in designing online learning experiences” (Buffington-Adams et al., 2017, p. 237). In addition to considering the technological aspects of providing instructor presence, it is important to be mindful of the multiple roles instructors hold (Hofstein & Kind, 2012).

7.1.3 Adaptive Learning – What Interaction is Desired?

While all aspects of interaction are relevant for science learning online, adaptive teaching and learning was addressed by participants in this study with science specifically in mind (Section 5.2.1). Adaptive learning includes the ability of the instructor to interpret the current level of students' understanding, typically via visual and verbal cues, in order to aid in the learning process by adapting the learning pace or content covered accordingly. While not originally identified as an indicator of quality, a concern voiced among both instructors and students is that adaptive teaching and learning is essential, but is limited in the online environment. One of the major complaints about online interaction is the lack of social cues and physical gestures which guide learning. This situation leads to more task oriented and less personal interaction (Downing & Holtz, 2008; Hill et al., 2009). As science primarily deals with problem-solving, not being able to observe the process or interact with students can hinder an instructor's ability to gauge student development (Jeschofnig & Jeschofnig, 2011).

Data from this study indicates that instructors and students find static online learning ineffective and request more adaptive and dynamic learning (Section 5.2.1; 5.3.1). Students describe adaptability within the broader context of interaction, noting the desire to be able to stop the learning process to reflect and ask questions of their instructor, and feel that they are guided in the learning process through a personal connection (Section 5.2.1). Once again, students reflect the desire for spontaneity through instructor presence in their learning. Instructors added that the common interactions that cannot readily be transferred online are the real-time interactive components of teaching, specifying Socratic dialog through questioning and probing, adapting the material spontaneously, and understanding students' current levels of progress or confusion. Although recognized as important for success, many of these behaviors which create instructor presence in the face-to-face classroom are difficult to emulate online (Buffington-Adams et al., 2017).

Some instructors in this study attempted to integrate adaptive learning technologies (Section 5.4; 6.2.2). These included companies which offer a version of adaptive teaching and learning through use of homework and laboratory systems (e.g., SimBio - online biology laboratories) that can be scaffolded and give immediate feedback and helpful hints for students as they work through the material. One adaptive learning technology company called Smart Sparrow, advertises that their programs aim to emulate and support instructors in providing the best learning situations for students and aid instructors in achieving ‘one-on-one style’ adaptive teaching with tens to hundreds of students in a classroom (Smart Sparrow, 2018). Such computer learning systems aim at achieving a common learning goal for learners of differing achievement, aptitude, or learning styles.

It is unclear from the results of this study whether is it the actual need for adaptive feedback and guided learning as could be provided by learning management programs, or simply the instructor presence and interaction that is specifically perceived to be missing online. Further exploration is warranted. While it is not surprising that instructors discussed the lack of adaptability in teaching and learning online, it was notable that students were also wary of the lack of adaptability in their online science course (Section 6.2.2). As Abrami et al. (2011) points out, designing online courses with adaptive attributes aids in student motivation and thus, overall satisfaction.

7.1.4 Students Would Rather Learn Science Online Alone, Should They?

Student participants expressed a view that online learning was typically an independent endeavor (Section 5.2.2). They did not expect to make friends or have the interaction they expect from face-to-face courses, although some expressed the view that it might be enjoyable. Generally, the students explained that the group work and discussion opportunities provided in online learning lacked any real collaboration between students and often was difficult to accomplish. Students were left believing that online learning is independent and self-directed, requiring self-motivation and working alone. This view is shared by Radnofsky and Bobrowsky (2005) who remarked that online courses in the physical sciences require students to be independent and self-directed in their learning. Many students in this study expressed the opinion that they specifically choose online courses to work independently. Should online science education consider addressing student-student interaction as optional, allowing students to work independently? Downing and Holtz (2008) suggest that online collaboration is not a learning strategy embraced by all due to personal learning styles and the specific nature of working with others. In addition, instructors indicated that group work and facilitating student-student interaction is difficult to achieve.

Embracing student learning independence as the way of online science education contests the social constructivist learning philosophy embraced in science education. Most learning is a socially constructed activity (Vygotsky, 1978). There will always be students who choose online learning because they prefer to work alone and remotely from others, but a vast majority want or need the interaction with others and with the instructor (Anderson & Carta-Falsa, 2002; Asoodar et al., 2016; Lee et al., 2011; Ross & Scanlon, 1995). Research has shown that designing student-student interaction into online courses positively impacts student learning (Bernard et al., 2009; Kurucay & Inan, 2017). Group learning on average has significantly more positive effects on student achievement than individual learning, but it is important to note that effective group work and student-student interaction hinges on instructor facilitation and effective use of technology (Lou et al., 2001). Finally, collaboration contributes to understanding material, developing critical thinking skills and retaining learning (Garrison et al., 2001). These studies resonate with the desire of instructors and administrators, from this study, to provide student-student interaction, hinging on the support for instructors to design and facilitate effective collaboration.

Following a social constructivist model for learning, the research and best practices literature suggest that students should be encouraged to collaborate in online science courses instead of working entirely independently. Consequently, it appears essential to consider those avenues to best foster collaboration online to support students in learning science.

7.1.5 Course Structure with More Interaction

The basic elements of online course structure outlined by participants mirrors that of best practices literature (Section 2.3.5; 4.2.2). Organized content, outlined expectations and clarity of objectives are necessary structural components in quality online courses. The structure of the online science courses which participants in this study experienced contained four basic components: reading, lecture notes, discussion and examinations. There were some variations such as the addition of homework assignments and activities or laboratories, but most followed a fairly basic course structure often seen in face-to-face science courses (Section 5.3.1).

Online course structure is often compared to and designed by trying to mimic the course structure common in face-to-face classrooms. However, when a course is taught online there are new structures to consider and understand (Major, 2015). The online education literature suggests that traditional face-to-face instructional designs need to be adapted to provide the same benefits in online courses (de Caprariis, 2000; Soffer & Nachmias, 2018). How lectures are delivered and students complete activities and interact with their classmates must be re-evaluated for the online environment, particularly in attempts to follow a social constructivist model for science learning online (Downing & Holtz, 2008). One approach to the development of online courses uses what is called the Learning Design methodology, where instructors make more informed decisions about how they design their courses based on the application of pedagogically informed learning theories to the creation of learning experiences and materials with effective use of resources and technologies (Conole, 2012; MacLean & Scott, 2011). Toetenel and Rienties (2016b) report that online courses designed following this approach are found to be less focused on traditional teaching patterns and instead focus on enabling students to develop a range of skills. Another study analyzing 157 learning designs across multiple disciplines at a distance education university found that courses using a Learning Design approach also include less assimilative activities such as reading, watching videos and listening to audio, which if extensively relied upon, were found to be negatively associated with student performance (Toetenel & Rienties, 2016a).

While the course structure provided at the universities in this study was viewed as adequate, participants confirmed that these basic components needed improvement to achieve a quality structured online course. Participants suggested improvements such as adding audiovisuals to lecture notes and providing more engaging content or activities (Section 5.2.1, 5.3.1 & 5.3.4). This recommendation indicates a desire for more instructor presence, interaction and active learning. Active learning instruction that includes inquiry activities and group discussions has been shown to increase learning outcomes and retention in tertiary level science courses (Idsardi, 2020; Phipps, 2013). Participants voiced a clear idea of what makes quality online science education that distinctly parallels the research literature. Online courses designed to include interactive learning activities, incorporation of audiovisual multimedia and real-life applications are suggested to replace traditional lectures (Radnofsky &

Bobrowsky, 2005; Sit & Brudzinski, 2017; Trinidad et al., 2005). Such structure reforms allow students to find value in their online courses (Velayutham et al., 2011).

The online course structure provided at the universities in this study appears to fall short of the expectations of the stakeholders involved. If stakeholders know what is desired and needed for quality, why is it not provided? Phipps (2013) explains that one of the most difficult tasks in designing online science courses is to “adequately communicate complex concepts in the sciences” (p. 572). Active learning, use of multimedia, and communication can help achieve this, but actual implementation is not straightforward. It is believed that it takes twice as long to develop and implement an online course as it does a face-to-face course (Radnofsky & Bobrowsky, 2005). It is possible to provide an effective online science learning environment, yet significant forethought and planning is necessary (Phipps, 2013) and perhaps a fundamental paradigm shift in teaching is needed (Radnofsky & Bobrowsky, 2005). As discussed in the sections above, it appears the task of such reform and effort lie on the shoulders of instructors. Instructor satisfaction is further discussed in Section 7.2.

What Dictates Course Design and Delivery? The overall design and subsequent structure of an online course is fundamentally dictated by the delivery type: asynchronous, synchronous or hybrid/blended. Downing and Holtz (2008) advise that ideally, the design of an online science course should be pedagogically based and settle into one of the delivery types on its own merits instead of being driven by the method of delivery itself. In line with this philosophy, administrators and some instructors from this study asserted that a hybrid or blended delivery type would pedagogically best suit science in the online environment (Section 5.3.6). These participants viewed a hybrid design as best for learning science compared to asynchronous because the perceived nature of the design allowed for more interactive time with the instructor, hands-on laboratory experiences and an environment for proctored examinations. This hybrid design is what Combs (2004) described as the best approach for learning in the sciences, embracing the best of both online and traditional learning opportunities. According to one research study, hybrids are perceived as a better fit for learning science, maybe even better suited than traditional, face-to-face teaching (Riffell & Sibley, 2005). This point was echoed by Allen et al. (2016) who reported that academic leaders view a hybrid online course design as superior to both asynchronous and face-to-face instruction. However, such a course structure is not what was offered at most of the universities at the time data were collected.

Participants in this study determined the delivery type of their online science courses based primarily upon the direction outlined by the institution (Section 5.3.6). In line with this decision, Ross and Scanlon (1995) suggest that the choice of instructional design and delivery is more likely to depend on logistics than on pedagogy. Chau (2010) argues that universities have begun to realize that ignoring online education is no longer strategically sound and if not considered in some fashion, may be detrimental to the success of the university. Much of the course design and delivery of university online science courses is based upon a myriad of different logistical factors and drivers, including timing, money, resources, length of course term, student enrollment numbers, course type and discipline (Major, 2015). While hybrid designs may better fit science courses pedagogically, key advantages of providing asynchronous online science courses include the ability to reach underserved student populations (Radnofsky & Bobrowsky, 2005) and provide an avenue of inclusiveness for those unable to attend courses on campus (Downing & Holtz, 2008; Jeschofnig & Jeschofnig, 2011).

University administrators from this study acknowledged that their universities are adding online courses as a tool to maintain financial sustainability (Section 5.8). The higher education market is highly driven by student enrollment and the resulting revenue associated with it. “Even in its purest form, education and particularly higher education is a business similar to any other business” (Chau, 2010, p. 183). Higher education in this respect reflects a traditional, short-term economic model, where more students enrolling in courses creates an immediate output of profit (Bowen, 2013). Students, as consumers, are enrolling in more online courses each year at four-year public and private non-profit universities in the United States. On the national scale, the number of undergraduate students taking at least one online course increased 15.2% from 2012 to 2016 (Seaman et al., 2018). The growth of online education is accelerating past other segments of higher education in the

United States, with 6.9 million students enrolled in online courses, representing 35.3% of all higher education students as of 2018 (Gallagher, 2019; U.S. Department of Education, 2019a). Student enrollment increases as the university increases its learning opportunities, to include offering more online courses across disciplines which fit into students' schedules and lifestyles.

Many universities that avoided online learning have started to be persuaded by the benefits of online education in increasing financial security and making the institution more competitive and marketable to students (Chau, 2010). Due to the COVID-19 pandemic, universities were left with little choice except to embrace online courses in order to keep their institutions open. A survey conducted in May, 2020 reported that 89% of US universities had already adopted more online courses or were considering increasing the number of online courses for the Fall 2020 semester (AACRAO, 2020). According to the same survey, 69% of these universities were considering going to a fully online course delivery for Fall 2020.

This competitive higher education market now includes online education from the course level to the degree level. More universities across the United States are beginning to offer Bachelor degree programs completely online and the universities in this study are no exception. Every university in this study offered at least one online degree program at the time of data collection. Online degree programs adhere to the same fundamental set of requirements for degree completion as on-campus degree programs. At many universities, undergraduate students have to successfully complete general education courses in addition to subject-specific courses (Bolliger & Wasilik, 2012). General education courses are typically introductory, lower-level, undergraduate courses structured as part of complete undergraduate degree programs. Seaman et al. (2018) define these distance education programs (an umbrella term which includes online education) as programs for which all the required coursework for degree completion can be completed via distance education courses. With full undergraduate degrees being offered online, the necessary general education courses need to also be offered online, and in modalities conductive to the learners' needs.

Participants from this study confirmed that most of the online science courses offered at their universities were chosen to be delivered in an asynchronous format due to the fully online degree programs being asynchronously delivered. Science courses count towards general education requirements for most undergraduate degrees regardless of the discipline. Science courses typically fulfill the critical thinking or laboratory competency requirements all students need as part of the fundamental general education courses. Each university requires one to three science courses, typically a choice between a natural science or a physical science. At the time of data collection, all of the universities in this study offered at least one fully online degree program, necessitating the need for online introductory-level science courses.

The decision regarding which science courses to place online for fulfilling general education requirements was not particularly strategic. Administrators announced a need for online science courses and each science department determined which, if any, courses they would offer online. The decision ultimately fell to the science instructors, based on their willingness to develop and teach courses online within their discipline. This willingness ultimately determined which science courses were placed online. Instructors understood the need to provide the necessary general education courses for students, prompting many to continue to offer online courses in their specific discipline in the asynchronous format. Online science education supplies a crucial component for allowing these universities to keep current and competitive in the higher education market.

7.2 The Demand on Instructors for Quality Online Courses

7.2.1 Instructor Satisfaction: Need for Time

As discussed in the previous section, the instructors' role in providing quality online interaction is multi-faceted and may require instructors to re-consider how they provide interaction. Thus, it is not surprising that additional time and support were the most common requests among instructors to improve their satisfaction in online science teaching and the overall quality of their courses. Results from this study indicate that instructors primarily desire additional time for the development of online courses to improve quality aspects such as interaction, audiovisual additions to lecture notes, activities and more advanced simulated laboratories (Section 5.5.2).

In summarizing observations from the literature, Palloff and Pratt (2001) explained that instructors are afraid of feeling “overwhelmed and overloaded” in teaching online. While results from this study confirm such findings (Section 5.5.3), the research literature presents somewhat conflicting results on whether teaching online actually takes more time and effort than teaching face-to-face. The literature which methodically recorded time, used time-log data collection, as opposed to comparing instructor reflections of time spent. These studies analyzed instructor time spent teaching online per student compared to face-to-face, reporting conflicting results: some reported that teaching online takes less time per student (DiBiase, 2000; McKenney et al., 2010; Van de Vord & Pogue, 2012; Visser, 2000) while others reported that online teaching takes more time per student (Bender et al., 2004; Cavanaugh, 2005; Tomei, 2006; Worley & Tesdell, 2009). Additional studies reported time teaching online as comparable to that of face-to-face delivery (Hislop & Ellis, 2004; Lazarus, 2003; McLain, 2005). The question of how much total time and effort is involved in the delivery of online courses is not a new one (Moore, 2000). However, after more than a decade of research, there is no clear conclusion from the literature concerning actual time difference between online and face-to-face delivery.

Overall time comparisons, such as many of those cited above, are surface level findings and do not tell the whole story (Van de Vord & Pogue, 2012). Instructor time and effort vary widely among categories of how time is spent teaching online to include: interacting with students, evaluating students’ work, submitting feedback and grades, lecture preparation, course modification, technical support and initial course development (Bender et al., 2004; Van de Vord & Pogue, 2012; Visser, 2000; Worley & Tesdell, 2009). In line with these categories, instructors in this study identified the active management of the course, creating online presence and facilitating interaction as primary tasks that take more time in teaching online (Section 5.5.2). The addition of such aspects correlates with indicators of quality for online science courses. Palloff and Pratt (2007) warn that not all instructors are providing these aspects and that instructor accountability is something that universities should consider when striving to offer quality online courses. Instructors who find an online course to take little preparation and time may be offering a minimal course design, excluding interaction, presence or timely and detailed feedback.

While results from the literature remain inconclusive about actual time expenditures, educational research supports the idea that most instructors *believe* teaching online is more time-intensive than teaching face-to-face (Major, 2015). The perceptions that teaching online takes more time and effort may be related to differences in how instructors interact with students throughout the course. As there is no set scheduled meeting time for students in asynchronous online courses, there is a feeling of expectation that instructors must be available 24 hours a day, seven days a week (DiBiase, 2000; Lazarus, 2003). Results from this study support such perceptions from instructors and students in that there is more continual attention required in an online class, aiding in the perception of more time and effort, irrespective of actual time expended (Hislop & Ellis, 2004; Worley & Tesdell, 2009). Even studies that found online teaching to take the same or less time as teaching face-to-face found that the number of days instructors spend with students is greater (DiBiase, 2000; McKenney et al., 2010; McLain, 2005).

When analyzed separately from delivery, data from the literature, using time-logs, found the initial design and development of an online course takes considerable time and effort on the part of the instructor (Palloff & Pratt, 2007; Visser, 2000; Worley & Tesdell, 2009). Participants in this study echoed these results (Section 5.5.2). However, even if allocated enough time for developing a quality online course, instructors remained concerned about their ability to actually develop simulations and more advanced online teaching techniques. Educational research on perceptions identifies this as a common feeling among online instructors, and a primary factor influencing instructors' willingness to adopt technology in their online teaching (Butler & Sellbom, 2002; Koehler & Mishra, 2009; Shreaves et al., 2020). Many instructors generally felt they were inadequately prepared, and lacking the knowledge to design quality online courses (Section 5.5.3).

7.2.2 Instructor Satisfaction: Need for Support

Teaching the same online course over time is believed to become less work, with the design and development of each successive class taking less time and effort (Pachnowski & Jurczyk, 2003; Palloff & Pratt, 2007). Once a course has gone through the growing pains of initial development, instructors may find that they don't have to devote as much time and effort to their online courses. However, since technology changes so rapidly, it may be difficult for instructors to feel they can keep up with modifications to their course without additional support and training (Brinkley-Etzkorn, 2018; Pedro & Kumar, 2020). Teaching online means re-conceptualizing and re-designing courses (Rubens & Southard, 2005). Instructors in this study noted a desire for additional support particularly for online course development and learning to use and integrate technology (Section 5.5.2). Two avenues of support that administrators outlined are pre-designed templates and professional development workshops on designing and teaching online courses (Section 5.5.2). These may help to ensure quality aspects are included in future online science courses (Pedro & Kumar, 2020; Smith, 2014). While administrators felt this support was appropriate, instructors felt the support was lacking.

Pre-designed templates can lessen the time and effort in developing an online course for instructors that teach the course later (Smith, 2014), yet one instructor is still tasked with the initial development upfront. Most of the instructors interviewed in this study, were in the position of initial developers, not benefiting from pre-designed templates. Instructors may not consider templates to be as supportive as administrators think they are. The instructors designing the first online science templates still need adequate time and support to do so (Gratz & Looney, 2020). It is unclear from the data collected in this study how many support workshops were offered to instructors and what they entailed. Successful professional development workshops offer support to instructors in overcoming feelings of insufficient knowledge in technological tools, in addition to guiding instructors in how to integrate the tools with pedagogy (Brinkley-Etzkorn, 2018). An instructors' ability to teach with technology differs from knowing how to use technology in general (Mishra & Koehler, 2006). Palloff and Pratt (2007) explain that too often instructor training in online teaching involves an introduction to the technological tools with no emphasis on integrating pedagogy with technology, allowing instructors to feel more confident teaching online. A common fundamental barrier to the adoption of technology in online courses is a lack of support for instructors. For online courses to be successful, universities must adequately address these barriers (Butler & Sellbom, 2002; Mitchell & Geva-May, 2009; Pedro & Kumar, 2020).

Throughout discussion of the various indicators of quality, instructor time and support for instructors have shown to play a crucial role. Instructors' satisfaction is heavily determined by how well they believed their online courses are developed and how much time they have to devote to teaching online.

7.3 Does Technology Drive Pedagogy?

The issues presented by participants in this study echo those addressed in the research literature. To reflect on these issues, it is fruitful to consider the purpose, use and implications of technology in online science education. The primary use of technology in online science education is to provide a digital platform for the online course, as well as avenues for interaction, activities and laboratories.

7.3.1 Learning Platforms and Online Pedagogy

Today, most universities deliver online courses through the use of a digital platform called a Learning Management System (LMS) which supports the basic components of online learning. The LMS provides the online environment upon which instructors manage the content, interactions and assessment of students and where instructors can link access to other applications or technological tools. The LMS provides a basic platform from which instructors can facilitate their online courses, but how they use it, is up to them.

Online education is rooted in technology, whether it is facilitated through an LMS, website or other learning platform, and will continue to be "coupled and constrained by innovations in communication and information technologies" (Downing & Holtz, 2008, p. 159). The tie of online learning to the technological tools available can heavily drive pedagogical choices and the direction of online course design, structure and content. Champion and Novicki (2006) advise that the decision to use instructional technology or any technological tool should be carefully chosen and centered on student learning. They explain that technology which is thoughtfully chosen and properly used can increase student learning and interest, but poorly used instructional technology can do the opposite. Learning should be grounded in fundamental pedagogical principles and not entirely driven by technology (Downing & Holtz, 2008). However, technological tools, including LMSs, often have "intentions" or specific purposes built in which can drive how institutions and instructors design and facilitate online courses (Major, 2015; Verbeek, 2006). Ideally the design intentions of a chosen learning platform are pedagogically based. However, the intentions may differ from what the instructors believe is necessary for quality online science learning.

Most of the LMSs used at universities provide some type of discussion forum where students asynchronously interact with other students through back-and-forth text-based posts. Discussions are an effective avenue to foster interaction in online learning (Aldrich et al., 2017; Asbell-Clarke & Rowe, 2007). The type of interaction participants in this study experienced in their online science courses was primarily based upon these types of asynchronous discussions (Section 5.2.2). The incorporation of text-based discussion forums embedded in the LMS promotes the use of this tool as the primary avenue for interaction. This may discourage the implementation of other types of interaction tools such as audiovisual, or other "everyday" technology (e.g. mobile devices), thus contributing to perceptions that quality interaction and technology are lacking in online science learning (Downing & Holtz, 2008).

While learning platforms and other technological tools are the vehicle through which online science learning occurs, they should not serve as the primary driver of the learning process (Palloff & Pratt, 2007). Abrami et al. (2011) suggest that the challenge for the future of online education is for instructional design and technology applications to unite to achieve a more interactive online environment.

7.3.2 Yes, the Technology is Available – An Additional Role for Instructors

The enormous increase in the capabilities of and access to technology provide opportunities to change how teaching is conducted online, making learning more effective and hopefully more efficient (Wieman, 2017). As with the addition of any new tool in teaching, instructors must first learn how to use the technology and implement it into their classroom. One issue noted by participants in this study is that effective technological tools are available, but that instructors do not know how to use, access or incorporate them in their online courses (Section 5.4). Instructors may be experiencing what Major (2015) refers to as the addition of another knowledge base which often differs from their current instructor role in face-to-face teaching. Mishra and Koehler (2006) developed the Technological Pedagogical Content Knowledge (TPACK) model, suggesting that teaching online requires the integration of technology with content and pedagogical knowledge (Shulman, 1986).

For instructors new to teaching online, integrating technological knowledge with their current content and pedagogical knowledge may be challenging (Brinkley-Etzkorn, 2018). There are four pedagogical shifts which online instructors are thought to experience: a shift in role, a shift in instructional design and possibly course content, a shift in how time is viewed and accounted for and finally, a shift in use of technology (Worley & Tesdell, 2009). Instructor workload is generally believed to already be high, without adding additional roles and technological challenges (Bender et al., 2004). However, as discussed previously, much of the work to provide quality in online science education is placed on the knowledge and drive of the instructor. Instructors need support and guidance to effectively incorporate technological tools to best support learning (Palloff & Pratt, 2007; Pedro & Kumar, 2020; The Institute for Higher Education Policy, 2000). As results from this study confirm (Section 5.4; 5.5), limitations of available technology (cost and access) and technological support for instructors and students can affect perceptions of quality in online science education (Downing & Holtz, 2008).

7.3.3 The Dream Technology is Still Unavailable for Science Education

The second issue participants noted with technology adequacy is that perhaps quality technology does not yet exist for the learning goals within the sciences (Section 5.4; 6.3.2). Wieman (2017) explains that "generally the educational information technology currently available is quite limited in both quantity and quality, in part because its design and use are not adequately guided by good pedagogy" (p. 10). The research literature indicated that many technological tools exist to facilitate learning in online science, including simulations, interactive activities and even full online laboratories (Downing & Holtz, 2008; Kennepohl & Shaw, 2010; Khurana & Sabine, 2017).

When innovative technology is properly applied, it can propel the efficacy of online science education forward (Downing & Holtz, 2008). However, much of the hope is for haptic design technologies in online laboratories and learning activities, where students give and receive physical responses to the virtual reality or simulation software (Ahmed et al., 2016; Ustunel & Keles, 2019). In this regard, the technology is not yet available for educational uses due to cost and accessibility. Linn, Davis, et al. (2004b) warn that while many technologies can aid in the teaching and learning of science, others can distract. Therefore, even when new technology becomes available, the efficacy of such new technologies must be explored and evaluated for usefulness in meeting particular science learning objectives. Innovative technologies will only see broad use in online science education if they are cost effective for the university and students, and also seen as being beneficial by instructors and students (Downing & Holtz, 2008).

7.4 Accountability Online

There is always a concern about academic honesty at universities but how to handle this issue in the online environment has opened the door to a new set of challenges. In quality courses, students are held accountable for their own academic work. The same expectations are necessary in online science courses.

7.4.1 Perceived Pervasiveness of Academic Dishonesty

Despite continuous research and reminders that academic dishonesty is unacceptable, such dishonesty is actually quite common within the academic setting (Miller & Young-Jones, 2012; Scanlon, 2003). Research suggests that students continue to cheat on examinations and other graded assignments (Hard et al., 2006; McCabe et al., 2001). With the additional increase of online courses at universities, it is commonly believed that cheating is more prevalent among students in online courses than face-to-face courses (Burgason et al., 2019; Fask et al., 2014; Miller & Young-Jones, 2012). Many participants in this study shared this perception, noting that cheating may be worse among online students due to easy access to the internet and unproctored assessments (Section 5.9). Yet, just because it may be easier to cheat online, does that mean students are actually more likely to cheat?

Do Online Students Cheat More than Face-to-Face Students? Many studies have embarked on answering this question. The research literature investigating how many students actually cheat online versus face-to-face has reported mixed results. Some studies conclude that students in online courses cheat more than those in face-to-face courses (Arnold, 2016; Fask et al., 2014; Lanier, 2006), while others find lower rates of cheating online (Kidwell & Kent, 2008; Peled et al., 2019; Stuber-McEwen et al., 2009; Watson & Scottile, 2010). Yet, another study reveals no significant difference between the amount of cheating online versus face-to-face (Grijalva et al., 2006). Results lead to evidence and speculation among the literature that non-traditional, older, more mature students are less likely to cheat and show more academic integrity than traditional, younger students (Jeschofnig & Jeschofnig, 2011; Lanier, 2006; Miller & Young-Jones, 2012; Stuber-McEwen et al., 2009). This aligns with current research suggesting that students with higher intrinsic motivation to learn and those able to learn independently are less likely to participate in academic dishonesty (Peled et al., 2019).

Regardless of whether or not there is more or less academic dishonesty in online courses, academic integrity at universities must be upheld. While participants did not explicitly discuss whether they thought online students cheat more than face-to-face students, their discussion of various actions to uphold accountability indicated their concern about online students' likelihood to cheat (Section 5.9.1; 5.9.2). Jeschofnig and Jeschofnig (2011) suggest that it is necessary for online educators to protect the integrity of their courses and institutions by using every means possible to discourage and detect academic dishonesty.

7.4.2 How to Ensure Accountability Online?

As with the results from this study, the literature reveals a spectrum of effort and strictness applied to deterring cheating in online courses: from proctoring services (Jeschofnig & Jeschofnig, 2011; Richardson & North, 2013) to setting time limits on assessment (Grijalva et al., 2006; Jeschofnig & Jeschofnig, 2011). Much of online education still struggles with constraints imposed by the online environment. Being present in the classroom is ingrained in the nature of traditional teaching and assessment. As such, acceptable levels of accountability seem more defined in traditional classrooms. Fask et al. (2014) noted that they were unable to perform a true experimental design to examine whether students cheat more or less online because leaving a group of students "unattended during the exam for the purpose of a research study would invite scandal" (p. 105). However, administering an unproctored examination online was deemed acceptable for research.

Why does administering an unproctored examination to a class of online students not invite "scandal" as well? There appears to be differing levels of acceptability between online and face-to-face accountability, supporting the spectrum of methods used to prevent cheating. The desire to take familiar teaching components from face-to-face courses and implement them directly into the online environment presents an obstacle to preserving accountability. Many instructors continue to simply try to replicate their in-class teaching methods in their online courses (Paullet et al., 2016). New forms of assessments may be necessary for the online environment, depending less on traditional summative assessment techniques and more on formative and low-stake assessments.

Assessment Considerations. For science education, traditional empirical assessment is common (Downing & Holtz, 2008). Customarily, face-to-face science courses include midterm and final examinations which usually account for a large portion of a students' final grade. Many university science instructors highly value the use of such written conceptual tests through which students show their scientific understanding of the fundamental concepts in the discipline. This situation, however, presents an issue in unproctored examinations, where answers can be copied from a textbook, or easily searched on the Internet. However, in the humanities and social sciences, students are more often assessed through interpretation and application of knowledge, such as in essays. These types of assessment may be better suited to the online environment and thus have contributed to the relatively early adoption of online education in humanities and social sciences compared to the sciences.

McMahon (2012, p. 202) encourages education to consider that the real fault in students being able to “copy and paste answers without internalizing any information,” lies not in the nature of the ease of access to the Internet, but in the nature of the assignment itself. Summative assessments in science too often reinforce piecemeal science learning and are composed of memorization type of questions which are easier for students to cheat on (Howard, 2020; Linn, Davis, Bell, et al., 2004). There is a desire for more inquiry-based learning and formative assessments to replace high-stakes examination in the sciences (Hackling, 2012; Linn, Davis, et al., 2004a). While traditional assessments can work in the online environment, Downing and Holtz (2008) insist that there is little need to rely on them when inquiry-based assessments can perhaps better accomplish science educational goals. However, Linn, Davis, et al. (2004a) warn that inquiry assessments demand new technology and teaching methods to be successful in the online environment.

As many instructors directly apply assumptions and practices from face-to-face science courses to those in the online environment, the issue of accountability and academic integrity becomes highly problematic. The discussion of academic integrity in online science courses opens up an opportunity for critical discussion and examination of the purpose and use of assessment in science learning.

Clear Guidelines for Accountability are Needed. Discussing issues of academic dishonesty in online learning, and communicating integrity policies to instructors and students is essential in providing quality online science courses. Clearly defined and articulated policies regarding academic integrity and how students are held accountable may substantially reduce academic misconduct (Lowe et al., 2018; McCabe et al., 2002). Research indicates that online students view cheating differently than their instructors, categorizing their actions as trivial, whereas from the instructor or institution view the actions would be considered as cheating (Burgason et al., 2019). Students in this study reported a similar view in regards to their actions during online assessments (Section 5.9.3). Educators may need to more clearly outline the boundaries of academic misconduct for online learning, setting the ground rules for what constitutes cheating (Downing & Holtz, 2008; Peled et al., 2019).

Şendağ et al. (2012) found that online academic dishonesty is greater in engineering and physical sciences compared to the humanities and social sciences. Their research, conducted at one university, found that science students cited minimal institutional policies as a reason for participating in academic dishonesty. This response included insufficient penalties for academic dishonesty, easy access to resources on the internet and instructors turning a blind eye towards academic misconduct (Şendağ et al., 2012). Students in this study articulated a similar rationale (Section 5.9.3).

Clarification of academic integrity may help students to better understand what is expected of them in the online environment. The literature recommends that instructors and administrators take affirmative action in addressing accountability in online science courses in order to provide a fair assessment of learning and ensure students' grades are truly reflective of their own learning (Arnold, 2016; Fask et al., 2014; Miller & Young-Jones, 2012).

7.5 Online Laboratories

This research study found that perceptions of science laboratories directly influence perceptions of quality in online science education as a whole. Two fundamental issues emerged from perceptions of online laboratories: the need for instructor interaction (Section 6.3.1) and the importance of hands-on or practical skills (Section 6.3.2). Thus, these components are also foundational to the perceived success of online science education. As instructor interaction is thoroughly discussed in the first section of this chapter (Section 7.1), the challenges of providing online practical laboratory skills are discussed here.

7.5.1 The Physical Necessity of Practical Skills

The general consensus among participants from this research study was that hands-on physical laboratory experiences are best for learning science (Section 6.2). Science educators agree, viewing hands-on laboratory experiences as an essential component of science course curricula (American Chemical Society, 2017; National Academies of Sciences Engineering and Medicine, 2015). In addition, physical laboratory skills are critical to prepare students for careers in the sciences (Ma &

Nickerson, 2006), and physical laboratory work is typically a graduation requirement for undergraduates in science disciplines. It is well recognized that students majoring in science need a hands-on or field-based laboratory experience with real equipment or environments (Potkonjak et al., 2016; Rivera, 2016). In addition, simulated experiences are often perceived as being unable to properly train students on the use of specialized laboratory equipment for skills that students majoring in science may need (Flowers, 2011).

An introductory non-majors course may be the only college course where a student is exposed to science (Cotner et al., 2017; Phipps, 2013), therefore the needs of non-majors may be fundamentally different from the needs of and learning objectives for science majors (Knight & Smith, 2010). For example, the practical skills objective of science laboratories, particularly in learning technical skills, is perceived as more crucial for science majors than non-science majors, a result shared by Johnson (2002) and thoroughly addressed in Sections 6.2.2 and 6.3.2. While physical experiences would be ideal for non-science majors, the practical skills opportunities provided in simulated laboratories may provide a close alternative to adequately suit their needs. As reported in Section 6.3.2, the extent to which laboratory goals are implemented depends on the level of the course and the student population (American Association of Physics Teachers Committee on Laboratories, 2014). While simulations are not the only methods for providing online laboratory experiences (workbook activities and take-home lab kits are other examples), they are discussed most often in this study and in the literature, so remain the focus of this discussion.

Practical Skills Through Virtual Manipulation. Discussion and evaluation of the learning objective for laboratory practical skills is often limited to the physical, tactile or hands-on skills. However, practical skills are more than just the physical skills and include linking the understanding of the tools that scientists use to take data, the purpose of various equipment or techniques and how to gather and interpret data. Laboratory simulations can provide online students with the ability to achieve the practical skills objective through the use of virtual experiments, virtual equipment or instrumentation and by developing skills related to the conduct of laboratory work. Virtual equipment cannot, however, provide tactile experiences.

Just as face-to-face laboratories can provide practical skills using physical manipulatives (physical materials and apparatus), online laboratories can provide practical skills using virtual manipulatives (virtual apparatus and materials in simulations) (Zacharia et al., 2008).

Online laboratories using virtual manipulatives have been found to be comparable to traditional physical experiences in both student comprehension and mastery of laboratory practical skills (Finkelstein et al., 2005). Simulated laboratories can provide students with unique "opportunities to manipulate conceptual objects" (Olympiou & Zacharia, 2012, p. 22), allowing students to visualize processes and objects beyond normal perception (Winn et al., 2006), making the phenomena under investigation more accessible. Understanding that various types of measurement errors can exist in scientific explorations and learning to account for them is an essential part of experiencing science (Toth et al., 2009). Online laboratories, using virtual manipulatives, can provide opportunities for such authentic experimentation for students, but without the restrictions of physical laboratory requirements.

Simulated laboratories can go one step further by allowing for ease of repeating failed experiments (Tatli & Ayas, 2013) and providing the unique ability to alter the normal time scales, making long time-frame science experiments achievable by students (Olympiou & Zacharia, 2012). The modern world of scientific industry in which many students gain employment, increasingly relies on computers and technology for experimental research and development. Simulated laboratories provide real-world preparation for scientific and engineering jobs (Wiesner & Lan, 2004), such as using computers to simulate, monitor and control experiments in chemical process industries where time spent manipulating physical equipment is becoming less frequent (Scalise et al., 2011). Astronomical data collection at large observatories serve as another example, where data are gathered and analyzed using computer software, as simulated in online laboratories.

Both physical and virtual laboratories provide unique learning opportunities and therefore need to be assessed for their relevance in catering to each student's needs (Ma & Nickerson, 2006; Olympiou & Zacharia, 2012; Zacharia et al., 2008). Online laboratories should not be discounted based solely on their inability to provide physical experiences, especially for non-science majors. Practical skills such as the use of technology, following technical and professional protocols and practicing laboratory techniques, procedures and measurements have shown to be accomplished successfully virtually (Brinson, 2015). Considering the educational contexts (as presented in Section 6.3) helps to determine whether physical experiences, virtual experiences or a combination of both will best achieve the learning objectives for science courses and laboratory (de Jong et al., 2013; Rivera, 2016; Scheckler, 2003).

Realistic Simulated Laboratories are Currently Limited. Instructors and students in this study reported that they valued the laboratory simulations they had experienced (Section 6.2.2). However, even those participants with experience using effective simulations discussed the potential for improvements as the technology advances. The administrators and instructors who were more negative towards online laboratories commented, “the technology is not there yet”, meaning that simulations were nowhere near where they need to be for effective online laboratory experiences (Section 5.4). Downing and Holtz (2008) echo this view, suggesting that there is a significant number of basic visualizations and simulations produced by research that could be transformed for use in online science learning and laboratory but are seldom realized for this purpose. The sense is, that for online laboratories to be most effective, the simulations must catch up to the requirements and expectations of its users.

Authentic laboratory experiences are desired where students can carry out investigations using equipment and apparatus that function as they would in a physical classroom. As addressed by participants in this study, authentic scientific inquiry includes not only the basic duties of performing a series of experiments, but learning how to deal with inaccurate data, poor apparatus, or difficulties in controlling factors within the laboratory itself (Section 6.2.2). It is argued that by replacing physical laboratories with simulations currently available, this approach may be hindering student’s scientific thinking and problem-solving abilities by providing oversimplified experiences (Chen, 2010). However, a few of the simulated laboratories used by participants in this study, were described as providing students with opportunities to develop their own experiments, and see if they work or not. Participants explained that some simulations even allowed students to record inaccurate data or results, but then guided students in troubleshooting and revising their experiments (Section 6.2.2). It is recommended that online science laboratories be designed using simulated reality based upon real situations and occurrences, including the implementation of small random equipment errors as one would encounter in real life (Chen, 2010).

While simulations are making strides in improvements every year, there is yet to be a wide availability of effective online laboratories for university students. Simulations are made for specific disciplines and cover only certain topics within those disciplines. Without readily available online laboratories, instructors are left with the task of developing their own, which many feel they are not qualified or have the extra time and resources available to accomplish (Garcell et al., 2007). Effective online laboratory simulations are being developed but more consideration is needed to accommodate all disciplines and more realistic experiences for undergraduate online students. While simulation and virtual reality laboratories are making huge strides in improvements every year, there is yet to be a “one fits all” solution to providing effective online laboratories to university students. Skepticism of online science laboratories is likely to continue until more robust simulations are developed and tested across disciplines and for all levels of students.

7.6 Chapter Summary

This chapter provided a discussion of the main results of this research study, focusing on the challenges participants identified in providing quality online science education. The findings were discussed in relation to the current literature, implications were addressed and any potential steps identified as ways to address the challenges were presented.

How interactions and the role of the instructor in the online environment is viewed may need to be reconceptualized beyond the familiar interactions common in face-to-face learning. While conventional student-instructor and student-student interactions are still much desired, additional components such as conveying online instructor presence should not be overlooked. Students may report that advantages of online learning can include being able to work independently, but following a social constructivist framework for science learning, collaboration among students is thought to be beneficial for overall student success online. A hybrid or blended online design was viewed as the best solution for maintaining quality interaction in online science courses. However, the course design is often dictated not by pedagogy but by policies set by the university. Online science courses fulfill a general education requirement needed for fully online degree programs offered at the participating universities, pushing many science courses to be delivered asynchronously.

The role of instructors in the online environment becomes multi-faceted, leading to requests for more time for course development and more university support for instructors. The amount of time and support required to develop and implement new online courses is agreed to be substantial. While the literature is inconclusive regarding differences in required time to teach online verses face-to-face courses after they are established, instructors believe teaching online takes more time. The support provided to instructors concentrates on technology, but support in developing sound online pedagogy may better support instructors teaching online.

While there is no consensus on whether students cheat more in online courses versus face-to-face courses, academic integrity in the online environment should not be ignored. Alternative assessments may need to be considered, depending on the level of accountability decided necessary. Clear guidelines are proposed to help students understand their role and responsibility pertaining to academic integrity online.

Online laboratories remain a primary focus of the skepticism surrounding online science education. Consideration of the need and purpose of practical skills can be beneficial in providing quality education online. Practical skills do not necessarily have to be physical, that is, have a tactile component. Depending on the educational context, particularly whether science majors or non-science majors are the focus, practical skills learned through virtual manipulation may be able to provide a quality online science learning experience.

This research study identified quality indicators for online science education and shed light on the sources of skepticism regarding teaching and learning science online. Understanding what is perceived as necessary in providing a quality online science learning experience is just a first step in helping educators develop and implement quality courses. A careful analysis of the challenges within the various quality indicators, as started in this discussion, provides the insight needed to move forward and either embrace or work through these challenges. However, as shown through the results and discussion of this study, the importance of identifying the educational context in which perceptions of quality are based is an essential step in the discussion, debate or recognition of quality online science education.

Chapter 8.
Conclusion

This study investigated the quality of online science courses at the tertiary level from the combined perspectives of students, instructors and administrators. In an effort to investigate the rationale behind persistent skepticism of quality online science courses, this study identified indicators of quality for online education and science learning objectives and then interviewed three stakeholder groups to understand their perceptions, experiences and challenges in providing quality online science courses. This chapter presents a summary of the major findings of this research. The significance of this study is presented, followed by limitations and recommendations for future research. This study provides the data to ground the understanding of quality and guide decisions about how to implement quality online science courses.

8.1 Summary of Major Findings

The number of online courses offered at universities across the United States have been increasing over the last decade (Seaman et al., 2018). This increase in course offerings applies to all disciplines, including the sciences; however, the science disciplines have grown at a much slower rise. In the year 2020, with the COVID-19 pandemic, universities have been forced to rapidly increase their online course offerings across all disciplines and have required the science disciplines to rapidly catch up. In the current pandemic, the question of whether or not we should offer science courses online has reoriented to how we are going to offer quality science courses and laboratories online.

Much of the research conducted on examining effectiveness of online science education compares student learning outcomes from online and face-to-face courses (Brinson, 2015; Flowers, 2011; Lee et al., 2011). Moving beyond comparisons with face-to-face courses, research has started to focus on the unique aspects of online learning through the perspectives of instructors and students, but without including the perspectives of administrators (Smidt et al., 2017). Amongst the studies of stakeholders' perspectives on the quality of online education, few report on science courses compared to other disciplines (Nennig et al., 2020). This study fills this gap in the research literature by analyzing the perspectives of all three primary stakeholder groups in online science courses - students, instructors and administrators – thereby gaining a more holistic view of what makes quality online science courses and the rationales behind skepticism.

This study used a qualitative analysis of interview data to gain insight into perceptions of quality in online science courses. Fifty participants, from five universities in the Midwestern United States participated in this study. First, a focused review of the literature was conducted identifying an initial list of eight categories of quality indicators for online education. The list of quality indicators was used to guide the data collection from the stakeholder groups. A qualitative analysis of semi-structured interviews provided detailed insight into the perceptions of quality in online courses. To investigate the quality features specific to online science courses, a second literature review was conducted identifying science learning objectives through the science laboratory. The interview data was analyzed again in relation to meeting those science learning objectives to offer the stakeholders' evaluation of online *science* courses. A further analysis was conducted to probe reasons for the skepticism surrounding the effectiveness of online science courses.

8.1.1 Indicators of Quality for Online Education

The first two research questions guiding this study addressed the quality of online education generally.

Research Question 1 - What does the literature identify as quality indicators for online education? Quality indicators were identified in the focused review of the literature and were used to guide the analysis of stakeholder perceptions on online education. Eight major categories of quality indicators were identified from the review of the literature: *Interaction, Course Design, Technology Adequacy, Science Learning, Satisfaction, Student Learning Outcomes, Instructor Competency* and *Cost Effectiveness.* Excluding *Science Learning,* all of the indicators identified in the review of the literature are directly applicable to online education more generally.

Research Question 2 - What indicators do the university stakeholders use to evaluate the quality of online education in the context of university science courses? Many of the perceptions among the three stakeholder groups aligned with the identified quality indicator results presented from the literature. The most frequently discussed indicators of quality for online education, among all participants, involved *Interaction*, *Course Design*, *Satisfaction* and *Technology Adequacy*.

Stakeholders addressed student-instructor interaction more frequently than student-student interaction but both were defined as foundational to quality online education. Participants emphasized that both types of interaction are generally lacking in the online environment. Participants explained that quality online courses are designed to include engaging content, interactive learning activities, incorporation of audiovisual multimedia and real-life applications. Participants indicated a desire for clear expectations for both students and instructors, more instructor presence, interaction and active learning. Overall, participants expressed satisfaction with the course learning management systems used to facilitate their online science courses. However, they felt that other technological tools used for online learning and facilitation of interaction are either not being used to their full potential or are not yet at the level necessary for the most effective level of learning needed.

Consistent with much of the literature in online learning, participants expressed the belief that students with high self-efficacy and maturity will be more satisfied learning online. Instructors expressed hesitation regarding their ability to provide the most effective science courses online, that more technical support and time to develop, maintain and conduct online courses was desired. An indicator of quality added by participants, but not outlined in the focused review of the literature, was academic integrity. Administrators and instructors emphasized the importance of maintaining academic integrity in the online environment. While the methods described to achieve accountability spanned a full spectrum, participants agreed that in order for an online course to be considered quality, it must be able to preserve academic integrity.

8.1.2 Perceptions of Quality Aspects Unique to Online Science Courses

Two research questions of this study addressed the unique quality aspects of online science courses, specifically focusing on the science laboratory.

Research Question 3 - What does the literature identify as science learning objectives, especially for science laboratories? The learning objectives for science laboratories were established through a review of the literature: *scientific methods and reasoning*; *conceptual understanding*; *interest and motivation in science*; *collaboration and communication*; and *practical skills.*

Research Question 4 - How do the university stakeholder groups evaluate online science courses in relation to the science learning objectives? The interviews were re-analyzed through the lens of science laboratory learning objectives. This analysis enabled extraction of participants' perceptions of science learning and exposed the sources of skepticism surrounding online science courses. Participants addressed all the laboratory learning objectives, but the majority of discussion of quality centered upon the necessity of *scientific methods and reasoning*, and *practical skills*.

Administrators were notably more negative than instructors and students regarding the ability of science to be conducted effectively online. The majority of the negativity was centered upon the challenge of providing practical skills experiences. The other learning objectives were perceived to be accomplished effectively online. For example, instructors described simulations and other online activities that promoted critical thinking and practicing scientific methods and reasoning. While all of the learning objectives for laboratories were recognized by participants, they were discussed as being essential to all of science learning, not necessarily restricted to the laboratory setting. Discussion of laboratories was typically generalized to all of science learning, as it is a primary method to conduct active learning in the sciences.

Through further analysis of participants' interviews, this study was able to identify and understand the sources of skepticism regarding online science education effectiveness. Participants identified the most challenging aspects as the ability to conduct effective interaction and provide the practical skills experiences. Perceptions, regarding these challenges, were heavily influenced by the educational context in which participants were thinking of online science learning. Two themes were identified: 1) the science discipline matters when considering quality and 2) courses for non-science majors are perceived more suitable for the online environment than those for science majors.

Some science disciplines were perceived to be better suited for the online environment than others. The particular aspects unique to each discipline or sub-discipline of science determined whether that discipline was perceived to be effectively taught in the online environment. For example, some disciplines such as physics and chemistry have a laboratory course tethered to the lecture course for introductory level courses. Thus, discussion of physics and chemistry disciplines was heavily influenced by perceptions of the ability of the laboratory to be conducted effectively online. This view is in contrast to disciplines such as astronomy where the laboratory is typically a separate course all together. However, the acknowledgement of the difference in disciplines was not explicitly identified by most participants but their perceptions were framed within the discipline in which they had experience. Analysis of all stakeholder groups combined, showed that the respective science discipline is important with regards to perceptions of quality for online science education.

There was a difference in the perceived acceptance of online courses for non-science majors compared to those intended for students majoring in science. Courses for science majors were perceived to be less suitable online. This perception was grounded primarily in the view that learning practical skills in the laboratory are necessary for science majors. In addition, upper-level courses, intended for science majors, and considered to be more challenging, were perceived to have a greater need for quality interaction with instructors. However, courses intended for non-science majors, were perceived to be a better fit for the online environment as the need for practical skills was perceived less important or effectively supplemented with virtual simulations.

Both the discipline considered and the intended student audience are educational contexts that frame perceptions of quality. Discussion of quality online education are seldom prefaced with a clear grounding of the educational context under consideration. Much of the skepticism regarding online science education was found to be derived from a lack of clarification of the education context and importance of specific quality indicators. This study found that the educational context is an important factor to consider when analyzing perceptions of quality of online science education.

8.2 Significance

This study has both practical and theoretical implications for university online science courses. The recent development and execution of online courses in higher education are being investigated, evaluated, and scrutinized in extreme detail, being held to arguably higher standards of quality than their corresponding face-to-face counterparts. In response, this study provides a foundational understanding of the quality factors specific for online science education. The quality indicators, along with science learning objectives, presented in this study provide a practical and comprehensive resource for gauging the effectiveness of online science courses. These indicators can be implemented for use in the development of future research, in the design of online science courses or programs, and for use in the development of quality standards boards and assessments. Identification of these quality indicators gives all stakeholders in higher education insight into what is necessary for the effective implementation of science courses in higher education online learning environments. They provide the building blocks upon which tertiary institutions can establish reasonable goals for implementing and assessing the unique aspects of science online education.

Even with a clear understanding of the aspects needed to provide quality, assumptions are being made regarding science online. Understanding different perceptions has helped to clarify assumptions and revealed that stakeholder group perceptions are similar yet different in specifics. Through analysis of the perceptions of each stakeholder group, this study provides insight into the rationales of the continued skepticism of online science courses and helps to bridge the gap between the differing results of research and general perceptions. The educational context in which perceptions of quality are based were found to be contributing factors driving skepticism of online science education effectiveness. The discipline considered, the course level and whether a course is aimed for science majors or non-majors impacts perceptions of whether various quality indicators can be accomplished online. Perceptions of quality were found to be divided when the educational contexts underlining the discussions were different. Thus, this study shed light on the source and rationale behind skepticism of online science courses and serves as a reminder that when considering online science courses, the educational context should be clearly defined and stated. Understanding these foundations of perceptions provides a theoretical groundwork for further research.

8.3 Limitations and Recommendations for Future Research

A noted limitation of this study is that the sample size was relatively small, with only 50 participants interviewed. A larger sample size would provide more data in identifying the perceived quality of online science courses and in identifying indicators of quality. For the practical nature of the data collection, the study was localized to the Midwest United States. A larger study including participants from universities across all the major regions of the U.S. could ensure that the location is not adding a particular bias to the data. In addition, the interview time constraints may have limited the depth of participant’s answers. More time with each participant would allow for more exploratory investigation in answers given and expansion on participants’ initial reactions and comments, thus providing more robust data for deeper interpretation. The limited number of participants also created some cases where there was only one participant representing combined categories, such as one student who took one mammalogy online course at a medium sized university. Findings unique to the individual stakeholder or university are sometimes difficult to generalize across stakeholders. For example, findings from RedBrick University were limited since there were no student participants, resulting in a lack of representation of the student perspective within the context of this university. As the findings are tied to the context of the universities and the individual participating stakeholders, any further generalizations from the findings of this study should consider these limitations.

Another limitation was the lack of inclusion of university technology support staff or those involved in online course design (instructional designers) as an additional stakeholder group. Participant interviews took place during a period of rapid change in online learning and at the time of data collection, not all of the universities in this study had designated technology support staff specific for online courses. Thus, it was decided to exclude this stakeholder group from the current study in order to retain uniformity among the universities. These support positions are becoming more prominent at universities as the number of online courses increases. Since 2004, the demand for instructional designers at universities has risen by more than 20% across the United States (Decherney & Levander, 2020). In addition, according to the U.S. Bureau of Labor Statistics, the instructional designer occupation (referred to as instructional coordinator) is projected to grow 6% from 2019 to 2029, faster than the average for all occupations in the United States economy (Bureau of Labor Statistics, 2020). Thus, it may be beneficial to add the perspective of instructional designers or other technology support staff to future research investigating perceptions of quality in online science education.

Excluded from the results of this study is consideration of the use of remote laboratories, particularly in regards to perceptions of the efficacy of acquiring practical skills online. Remote laboratories were not included in participants' discussion of practical work as none of the universities in this study were conducting remote science laboratories at the time of data collection. Instead, findings from participant interviews primarily focused on simulated laboratory experiences in providing practical skills for science students. As a result, findings such as the ranking of the science disciplines perceived best suited for the online environment (Figure 6.3) and perceptions regarding efficacy of an online course based on the course level are missing consideration of the use of remote laboratories for attaining practical skills. As universities continue to offer more online science courses and laboratories, stakeholders are likely to obtain more experience with remote laboratories, providing opportunities for future research regarding perceptions of online practical work.

A final limitation of this study was that participants were not directly asked to comment on quality indicators previously identified in the literature. Participants were asked open-ended questions about what aspects they considered to be necessary for effective online science courses, not individual indicators specifically. The information provided in interviews for this study was derived from what participants chose to address on their own. While this was done intentionally, so that participants would not be biased with a pre-determined list, participants' insight on specific indicators could add depth to those indicators addressed less often.

There is further need to closely examine what is being offered as online science education, what are the real versus imagined ideals of online science education, and what expectations are engrained in science education as they affect our perception of quality online. A suggestion for future research is to confirm the quality indicators established in this study, validating them with a larger sample and a robust analysis of the impact and importance of each indicator across all disciplines and levels of science. In addition, future research on the differences in accomplishing learning goals for science majors and non-science majors in the online environment may help science researchers to gain a deeper understanding of how best to move forward with online science education, particularly online laboratories.

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Appendix A: Formal Participation Request Email Example

<u>University Administrator – Recruitment Email</u>

My name is Stephanie Colby. I'm a graduate research student at Curtin University. I am beginning an investigation of perceptions of quality in online science education for my PhD thesis in science education. The research project is titled, "An Investigation of the Quality of Online Science Education at the Tertiary Level from the Perspectives of Students, Faculty, and University Administrators."

I am looking at the overall perceptions of online science education from the viewpoint of university administrators, instructors and students. I see that PCU offers some online science courses and I would like to interview you to hear your views about the effectiveness of online science education at the undergraduate level. Your experience as a university administrator would be very valuable to this study! This research study has officially been approved by the PCU IRB (please see attached letter of support).

I am looking to schedule an interview session with you (about 60min) this week on any of the following days to discuss your perceptions of online science education:

Wed Oct 8 - anytime
Thurs Oct 9 - anytime except 10-11:30am
Fri Oct 10 - anytime

Please let me know if you would be able to participate and which day and time would work best for you!

Thank you for your time and consideration. I hope to hear from you soon!

Sincerely,
Stephanie Colby

Appendix B: Online Student Recruitment Email

RECRUITMENT for ONLINE STUDENTS

Hi There! I am looking to interview students to hear your views about the quality of online science education.

My name is Stephanie Colby, and I'm a graduate research student at Curtin University conducting research for my PhD thesis. Since you have experience as a student in an online science class, I would really appreciate your participation in this study! I would like to hear your views about the effectiveness of online science education.

Participation would consist of a 45–60-minute, one-on-one interview session with me to discuss your perceptions of online science education. The interview can be conducted online via Skype or Phone.

This interview will have no effect on your academic standing, is voluntary, and is not directly related to RBU or your online science class. Instead, the study is just about your overall experience, opinions, and perceptions of online science courses as an undergraduate student. This research project is an investigation of perceptions of quality in online science education from the viewpoint of students, faculty, and university administrators. Your views as a student would highly benefit this study! Overall, my hope is that this study can supply a better understanding of how universities can provide quality online science courses.

Please email or call me if you are interested in participating or would like further information about the study!

Phone – 618-589-1947
Email - stephanie.colby@postgrad.curtin.edu.au

The information gathered for this project will be kept confidential and private, and personal identifying information such as your name will NOT be attached to the data in my thesis or publications. I have been granted permission by the RBU Human Subjects Review Committee to contact you in regards to participation in this study (Office of Research & Projects - XXX-XXX-XXX or *email address*).

Thank you for your time and consideration. I hope to hear from you!

Sincerely,
Stephanie Colby

Appendix C: Interview Information Sheet and Consent Form (Instructor Version)

Curtin University
Science and Mathematics Education Centre

My name is Stephanie Colby, and I am a graduate student at Curtin University. I am conducting research involving online science education for my PhD thesis. This research project is an investigation of perceptions of quality in online science education from the viewpoint of students, faculty, and university administrators. This study will describe current interpretations of quality in online education and investigate effectiveness specific to online science education. In addition, this study intends to supply a better understanding of how universities can provide quality online science education.

Since you are currently teaching an online science course, I would like for you to participate in this study. I am asking for around 60 minutes of your time to partake in a face-to-face interview session to discuss your perceptions of online science education. I would like to conduct the interview session in-person, on your university campus. The interview session will be recorded using a voice-recording device. I will ask you a few questions regarding your perceptions of quality in online science education, but nothing specific to you personally. Only a reference number and designation as 'instructor' will identify your interview data in data analysis. No personal identifying information will be used in any published materials. Risk of participating in this study is no greater than that experienced in normal daily activities.

Your involvement in this project is completely voluntary. You have the right to withdraw your consent to participate at any stage without consequences to you or your university. The information gathered for this project will be kept confidential and private. Only my advisor, Professor David Treagust, and I will have the access to the data. The interview transcripts will be identified by a number and will not contain your name or any other personal identifying information. No aspect of this research will be used in determining employment status, course offerings, or judgment of quality in your online courses. In adherence to Curtin University policy, the interview recordings and transcripts will be kept in a locked cabinet for seven years before a decision is made as to whether it should be destroyed. When you have signed the consent form, I will assume that you have agreed to participate in the interview session.

This research has been reviewed and given approval by Curtin University Human Research Ethics Committee (Approval Number SMEC-11-14). If you would like further information about the study, please feel free to contact me at 618-589-1947 (USA) or by email stephanie.colby@postgrad.curtin.edu.au . Alternatively, you can contact Professor David Treagust on +61 8-9266-7924 (AUS) or email D.Treagust@curtin.edu.au .

Thank you very much for your involvement in this research.
Your participation is greatly appreciated.

INTERVIEW CONSENT FORM

• I understand the purpose and procedures of the study.

• I understand that in order to participate in this study I must be teaching or have already taught an online science course, and I must be at least 18 years of age.

• I have been provided with the interview participation information sheet.

• I understand that the procedure itself may not benefit me.

• I understand that my involvement is voluntary and I can withdraw at any time without problem.

• I understand that once my interview is complete my name will be removed as an identifier and the interview transcript will be assigned a number.

• I understand that no personal identifying information will be used in any published materials.

• I understand that all information will be securely stored for at least 7 years before a decision is made as to whether it should be destroyed.

• I have been given the opportunity to ask questions about this research.

• I agree to allow the researcher to audio record the interview session.

• I agree to participate in the study outlined to me.

Name: ____

Signature: ____

Date: ______________________

Appendix D: Interview Questions for Each Participant Group

University Administrator Interview Questions:

1. To your knowledge, about how many online science courses are offered at your university? Are any of these a laboratory class?
   a. What kind of online courses are offered: asynchronous, synchronous, or blended/hybrid?
   b. In what science disciplines?
   c. Which students take these online science courses?
   d. Who are the instructors?

2. Describe your overall experience in regards to online science courses.
   a. Have you taken or taught an online course? Describe your experience.

3. In general, what are faculty perceptions of online science courses at ____ university?
   a. What are students' perceptions?

4. How do you see the future of online science education at your university?
   a. Does the school plan to offer more online classes or less?
   b. What prevents or encourages the addition of online science courses?

5. Thinking of university education in general, what in your opinion makes quality education?

6. Do you think that online science education in general rates as quality education? Why or why not?

7. In your opinion what makes "quality" online science education?
   a. *If needed - List a few of the identified indicators of quality:* From these aspects of online science education, which do you think is most important for providing quality education? Explain why.

8. What support is provided for online instructors?

Instructor Interview Questions:

1. To your knowledge, about how many online science courses are offered at your university? Are any of these a laboratory class?

2. How many online courses have you taught and in which subjects? Were any of these a laboratory class?

3. Describe your overall experience in online science courses. What works well and what doesn't work well?

4. What makes teaching science online unique?

5. Thinking of university education in general, what in your opinion makes quality education?

6. Do you think that online science education in general rates as quality education? Why or why not?

7. What made one online class better in your opinion than another online class you have taught? Why? Specifically, what was better about it?
    a. *If they have only taught one class* – Compare this online class to a face-to-face course.

8. In your opinion what makes "quality" online science education?
    a. What support do you receive for teaching online?

9. Do you choose to teach online or are you requested to teach online without a choice?
    a. Would you choose to teach online science again?

10. Have you taken an online course as a student? Describe your experience.

Student Interview Questions:

1. What is your grade level and major?

2. How many online courses have you taken and in which subjects? Were any of these a laboratory class?

3. Describe your overall experience in online science courses. What do you like/not like about online science education?

4. What made one online class better in your opinion than another online class? Why? Explain specifically what was better about it.
   a. *If they have only taken one class* – Compare this online class to a face-to-face course.

5. Thinking of university education in general, what in your opinion makes quality education?

6. Do you think that online science education in general rates as quality education? Why or why not?

7. In your opinion what makes quality online science education?
   a. *If needed - List a few of the identified indicators of quality:* From these aspects of online science education, which is most important for your overall satisfaction in a class? Explain why.

8. Do you think your online class is a quality course? Why or why not?

9. Would you choose to take additional courses in science online? Why or why not?

Appendix E: Interview Debrief Letter

An Investigation of Online Science Education Effectiveness – Looking at Perspectives from University Students, Instructors and Administrators

This research project is an investigation of perceptions of quality in online science education. Viewpoints from university students, faculty, and administrators will be included in the study. Your discussion and views of online education effectiveness in the sciences will be analyzed as part of this research. This study intends to supply a better understanding of how universities can provide quality online science education.

As outlined in the information sheet, your discussion within this interview session will remain confidential. Only my research advisor, Professor David Treagust, and I will have access to the recorded audio data. The audio recordings will be transcribed into text, upon which your name will be converted to a code number and designated by one of the following titles: Student, Instructor or Administrator.

Your participation in this study is greatly appreciated! If you'd be interested in obtaining a copy of the results once the study is complete, you may contact me, Stephanie Colby at stephanie.colby@postgrad.curtin.edu.au. If you have a more general interest in this area of research, you may also wish to consult the following references:

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If you have any concerns, questions, or complaints about this research, please feel free to contact, Professor David Treagust at +61 8-9266-7924 or email D.Treagust@curtin.edu.au.

Thank you very much for your participation!

Stephanie Colby

SMEC – Science and Mathematics Education Centre
Curtin University, Perth, Western Australia

Appendix F: Overview of Focused Literature Review Studies

Overview of the Focused Literature Review Studies

Author(s) and year	Study category	Purpose of study	Research method/ Design	Sample	Discipline/ Topic	Type of online	Instrument/ Study type	Instrument full name
Aldridge, Dorman & Fraser (2004)	Online Learning	To develop an instrument to investigate students' perceptions of their outcomes-focused, technology-rich settings via students' perceptions of actual class vs. preferred class environments.	Quantitative: Survey	1,249 secondary students	Mixed	Web-facilitated	TROFLEI	Technology-Rich Outcomes-Focused Learning Environment Inventory
Asbell-Clarke & Rowe (2007)	Online Science Higher Education	To examine the nature and variety of instructional methods and activities employed in online science courses for teachers, focusing on student and instructor's perceptions.	Mixed: Survey, Interview	35 instructors / 250 graduate students	Sciences and Science Education	Asynchronous	LSO	Learning Science Online (Study)
Bangert (2006)	Online Higher Education	To assess students' perceptions of online learning environments at higher education institutions. An instrument was developed to assess the quality indicators of online instruction represented by Chickering & Gamson's 7 Principles Framework.	Quantitative: Survey	807 students (graduate and undergraduate)	Mixed	Asynchronous / Blended	SEOTE	Student Evaluation of Online Teaching Effectiveness
Blake & Scanlon (2007)	Online Science Higher Education	To reconsider the use of simulations for undergraduate online science at an Open University. Developed a set of features for the effective use of simulations in distance learning.	Mixed: Survey, Interview	160 undergraduate students	Physics	Asynchronous	Theory	
Bright et al. (2008)	Online Laboratory & Computer Laboratory	Provides a discussion of the use of remote laboratories as a way to engage students in laboratory-based learning and effective factors that impact quality and learning outcomes in online learning.	Qualitative		Engineering	Synchronous (Remote)	Lit Review	
Chang & Fisher (2001/2003)	Online Higher Education	To develop and validate a new instrument to assess students' perceptions of web-based learning environments. The instrument is designed to be used by tertiary teachers who have their courses delivered as dependent and/or fully-developed Web-based learning applications.	Quantitative: Survey	344 undergraduate students	Mixed	Asynchronous	WEBLEI	The Web-based Learning Environment Instrument

Author(s) and year	Study category	Purpose of study	Research method/ Design	Sample	Discipline/ Topic	Type of online	Instrument/ Study type	Instrument full name
Chickering & Ehrmann (1996) / Chickering & Gamson (1987)	Online Higher Education	To discuss of the use of the 7 Principles of good practice in undergraduate education with computers, video and telecommunications technologies.	Qualitative: Theory development		Mixed	N/A	Theory: 7 Principles	Theory: 7 Principles of Effective Learning
Clayton (2011)	Online Higher Education	To report on the development, validity and reliability of a 7-scale, 35-item learning environment instrument designed to investigate student perceptions on the interactions occurring in their online learning environments in an economical and efficient manner.	Quantitative: Survey	284 undergraduate students	Mixed	Asynchronous	OLLES	OnLine Learning Environment Survey
Davis & Snyder (2012)	Online Science Higher Education	To present and discuss Science Education Online (SEO): an online, graduate-level program for elementary and middle school science teachers that fosters learning of science and science teaching. The paper describes effective qualities of online courses linked to increased students' subject matter knowledge and understandings of effective teaching.	Mixed: Survey, Interview	Graduate students: 124 (SRTI survey) / 16 (EEOI survey)/ 8 (interviews)	Sciences	Asynchronous	SRTI & EEOI	Student Response to Instruction / Elements of Effective Online Instruction
DeHaan (2005)	Science Higher Education	Review of the literature in cognitive sciences, instructional methods, student learning, educational policy, and assessment to shed light on how to improve science education at the undergraduate level.	Qualitative		Sciences	N/A	Lit Review	
Downing & Holtz (2008)	Online Science Higher Education	A pilot survey study of an instrument developed in order to determine emerging and current practices for online science learning at the undergraduate level. The instrument concentrates on trends in distance education for the physical, environmental, life, engineering, and mathematical sciences.	Quantitative: Survey	23 science educators	Sciences	Asynchronous / Blended / Web-facilitated	SUDSE	Survey of Undergraduate Distance Science Education
Fraser, Giddings & McRobbie (1992/1995)	Science Learning & Laboratory	To develop a class and personal form of an instrument for both actual and preferred environments, which can be used to assess students' perceptions of their science laboratory classroom environment. The questionnaire is intended for use in situations in which a separate laboratory class exists.	Quantitative: Survey	7,401 undergraduate students	Sciences	N/A	SLEI	Science Laboratory Environment Inventory

Author(s) and year	Study category	Purpose of study	Research method/ Design	Sample	Discipline/ Topic	Type of online	Instrument/ Study type	Instrument full name
Institute for Higher Education Policy (2000)	Online Higher Education	To bring reason and research data to the pro/con debate regarding online education, providing more tangible measures of quality in Internet-based distance learning. The study identifies 24 benchmarks, divided into seven categories of quality measures, considered essential to ensuring excellence in asynchronous online learning.	Mixed: Survey, Interviews, Lit review	147 total participants: 27 instructors / 62 administrators / 16 admin & instructor / 42 undergraduate students	Mixed	Asynchronous	Quality on the Line	Quality on the Line
Iyer (2011)	Online Higher Education	To examine the effectiveness of a newly-developed online course compared to a similar face-to-face course through the design, development and validation of a questionnaire comprised of two surveys. The surveys can be used to assess the relative effectiveness of an online course in terms of students' perceptions of the learning environment and attitudes.	Mixed: Survey, Focus group interviews	991 undergraduate students (survey) / 90 students (interviews)	Engineering	Asynchronous	COMPLEQ	Comparative Learning Environment Questionnaire
Jegede, Fraser & Fisher (1995)/ Williams (2003)	Online Higher Education	To develop, validate and use an 8-scale instrument designed to examine the effects of the learning environment on student outcomes and psychosocial interactions taking place. Williams (2003) adapted the instrument for use in a community college setting and added 7-scales for distance education environment dimensions.	Qualitative	165 undergraduate students	Mixed	Asynchronous	DOLES	Distance and Open Learning Environment Survey
Kerr, Fisher, Yaxley & Fraser (2006)	Science Learning & Laboratory	To investigate science students' perceptions of their actual and preferred psychosocial learning environment and correlate this data with student achievement and attitudinal data. The study also looked at why students take science and why some drop out.	Mixed: Survey, Case study	1,080 secondary students	Sciences	N/A	CSCES	College Science Classroom Environment Survey
Lee et al. (2011)	Online Science Higher Education	To examine the relevant research on Internet-based science learning. 65 papers are reviewed for 1) the role of demographics and learners' characteristics for Internet-based science learning and 2) the learning outcomes derived from Internet-based science learning.	Qualitative			Web-enhanced	Lit Review	

Author(s) and year	Study category	Purpose of study	Research method/ Design	Sample	Discipline/ Topic	Type of online	Instrument/ Study type	Instrument full name
Lowe et al. (2007)	Online Laboratory & Computer Laboratory	This review of the literature compiles the factors used in assessment of online laboratories and pedagogical frameworks used in studying online laboratories.	Qualitative		Engineering Remote Laboratories	Synchronous	Lit Review	
Maor & Fraser (2005)	Online Laboratory & Computer Laboratory	To describe the development, validation and use of an instrument to assess teachers' and students' perception of the science learning environment when students use online multimedia programs and teachers use constructivism in their teaching.	Quantitative: Survey	221 secondary students	Sciences	Synchronous	CMLES	Constructivist Multimedia Learning Environment Survey
Martz, Reddy & Sangermano (2004)	Online Higher Education	To identify key components of distance education satisfaction by using potential variables for satisfaction from previous research to develop a questionnaire administered to students in an MBA distance education program.	Quantitative: Survey	341graduate students	Business	Asynchronous	DEQ	Distance Education Questionnaire
Maryland Online (2011-2013 Ed)	Online Higher Education	A set of eight general standards and 42 specific review standards used to evaluate the design of online and blended courses in higher education.	Qualitative			Asynchronous / Blended	Rubric	Quality Matters Rubric
McGorry (2003)	Online Higher Education	To investigate the distance education and information technology literature in an attempt to develop a model to measure quality and learning in online courses. Identified nine constructs indicated by a total of 60 items proposed to demonstrate quality and learning effectiveness in online programs.	Quantitative: Survey	82 graduate students	Business	Asynchronous	Model	N/A
Newby & Fisher (1997/2000)	Online Laboratory & Computer Laboratory	To describe the development, validation and use of two instruments to investigate associations between students' perceptions of aspects of their computing laboratory environment and students' attitudinal outcomes. The 1997 study reports on the development of the classroom environment instrument. The 2000 study reports on the use of both the learning environment and attitudinal instruments.	Quantitative: Survey	208 undergraduate students	Business	N/A	ACCC /CLEI	The Attitude towards Computers and Computer Courses Questionnaire / The Computer Laboratory Environment Inventory

Author(s) and year	Study category	Purpose of study	Research method/ Design	Sample	Discipline/ Topic	Type of online	Instrument/ Study type	Instrument full name
Online Learning Consortium (2015)	Online Learning	To help institutions identify goals and measure progress towards them by providing building blocks to support successful online learning through a quality framework.	Qualitative		Mixed	All Types	5 Pillars	5 Pillars of Quality Online Learning
Perry (2003)	Online Higher Education	To develop, validate and use a 30-item survey instrument to examine relationships between instructor beliefs and instructor perceptions of what students believe about instruction, content, and use of technology in distance education.	Quantitative: Survey	120 instructors	Online Education	Asynchronous	QDES	Quality Distance Education Survey
Rovai (2002)	Online Higher Education	To develop, validate and use an instrument to measure the sense of community in a learning environment for university students taking online courses. The study explores factors that influence students' community experiences.	Quantitative: Survey	375 undergraduate students	Mixed	Asynchronous	CCS	The Classroom Community Scale
Slagter van Tryon & Bishop (2012)	Online Higher Education	To develop and validate an instrument for measuring students' perception of the social connectedness that leads to the development of group social structure among participants in online courses.	Quantitative: Survey	50 graduate students	Educational Leadership	Asynchronous	SPLCI	Social Perceptions in Learning Contexts Instrument
Swan (2004)	Online Learning	To explore interesting themes in the recent research literature on online learning effectiveness. In this paper, the effects of interface design, teaching presence, and learner characteristics on student learning in online courses were explored and found to be both significant and meaningful.	Qualitative			Asynchronous	Lit Review	
Trinidad, Aldridge & Fraser (2005)	Online Higher Education	To develop, validate, and use an 8-scale, 52-item survey instrument for assessing students' perceptions of their e-learning environments and their enjoyment of e-learning. A second form of the instrument was developed to assess teachers' perceptions of the e-learning environment.	Mixed: Survey, Interview	325 students (survey) / 21 students & 7 instructors (interviews)	Mixed	Asynchronous / Web-enhanced	OLES	Online Learning Environment Survey

Author(s) and year	Study category	Purpose of study	Research method/ Design	Sample	Discipline/ Topic	Type of online	Instrument/ Study type	Instrument full name
Veal, Brantley & Zulli (2004)	Online Science Higher Education	To explore previously identified instructional quality indicators for face-to-face courses and then evaluate improvements in effectiveness, usefulness, competency, assessment, communication and achievement by incorporating the quality indicators in an online course.	Mixed: Survey, Observations	34 graduate students	Geology	Asynchronous	Theory	
Velayutham, Aldridge & Fraser (2011)	Science Learning & Laboratory	To develop and validate an instrument, based on theoretical and research underpinnings, to measure salient factors related to the motivation and self-regulation of students in secondary science classrooms.	Quantitative: Survey	1,360 secondary students	Sciences	N/A	SALES	Students' Adaptive Learning Engagement in Science
Walker & Fraser (2005)	Online Higher Education	To develop and validate a 6-scale, 34-item learning environments instrument to measure the psychosocial learning environment in postsecondary distance education and investigate associations between the nature of the distance education learning environment and students' enjoyment of their studies.	Quantitative: Survey	680 undergraduate students	Mixed	Asynchronous	DELES	Distance Education Learning Environment Survey
Ward, Peters & Shelley (2010)	Online Higher Education	To explore the rationale for use of a particular technology, instructor conclusions regarding implementation of the technology, and the impact of the technology on instruction and learning in synchronous interactive online instruction. The online course medium was analyzed from both instructor and student perceptions regarding the quality of courses delivered via online instruction.	Mixed: Survey, Interview	95 undergraduate students (survey) / 7 instructors (interviews)	Educational Leadership	Synchronous	Theory	
Yeo, Taylor & Kulski (2006)	Online Higher Education	To adapt and validate the Constructivist OnLine Learning Environment Survey (COLLES) for use in the transnational online learning higher education context. Used to investigate student's perceptions of psychosocial characteristics of the online learning environment.	Quantitative: Survey	210 undergraduate students	Business	Asynchronous / Blended	COLLES	Constructivist On-Line Learning Environment Survey
Young & Norgard (2006)	Online Higher Education	To develop a survey based on the findings in existing research regarding students' perceptions and preferences related to online course delivery to assess the quality of online course delivery.	Quantitative: Survey	233 undergraduate students	Mixed	Asynchronous	Survey	

Appendix G: Quality Indicators Identified in the Literature

Interaction Quality Indicators Identified in the Literature

Author(s) and year	Instrument / Study type	Interaction			
		Instructor-Student Interaction	**Student-Student Interaction**	**Instructor Feedback**	**Equity**
Aldridge, Dorman & Fraser (2004)	TROFLEI	Teacher Support	1) Student Cohesiveness 2) Cooperation		1) Equity 2) Differentiation
Asbell-Clarke & Rowe (2007)	LSO	Nature of Communication: 1) Communication between instructor and students 2) Perceived Level of Support	Nature of Communication: 1) Online discussions, communication among students 2) Collaborative grouping	Assessment/Feedback	
Bangert (2006)	SEOTE	Student-Faculty Interaction	Cooperation Among Students		
Blake & Scanlon (2007)	Theory				Adapting to level of expertise
Bright et al. (2008)	Lit Review	1) Tutor Assistance 2) Interaction 3) Presence	1) Group work & Collaboration 2) Interaction		
Chang & Fisher (2001/2003)	WEBLEI		Interaction	Results	
Chickering & Ehrmann (1996) / Chickering & Gamson (1987)	Theory: 7 Principles	Principle 1: Encourages contact between students and faculty	Principle 2: Develops reciprocity and cooperation among students	Principle 4: Gives prompt feedback	1) Principle 6: High expectations 2) Principle 7: Respects diverse talents and ways of learning
Clayton (2011)	OLLES	Tutor Support	Student Collaboration	Active Learning	
Davis & Snyder (2012)	EEOI	1) Interaction between instructors and students 2) Instructors were accessible	1) Social & Professional Community 2) Interaction among students	1) Timelines for response 2) Feedback is prompt	
DeHaan (2005)	Lit Review	Interactions	Social Interactions & Collaboration		

Author(s) and year	Instrument / Study type	Interaction			
		Instructor-Student Interaction	Student-Student Interaction	Instructor Feedback	Equity
Downing & Holtz (2008)	Theory	1) Instructor to learner knowledge transfer 2) Collaboration	1) Peers and teams to learner knowledge transfer 2) Collaboration		
Fraser, Giddings & McRobbie (1992/1995)	SLEI		Student Cohesiveness		
Institute for Higher Education Policy (2000)	Quality on the Line	Teaching and Learning Interaction/Communication	Teaching and Learning: Interaction with other students	Teaching and Learning: Feedback	
Iyer (2011)	COMPLEQ		Computer usage: Used to communicate with others		
Jegede, Fraser & Fisher (1995)/ Williams (2003)	DOLES	Faculty support / Interactivity	Student cohesiveness / Interactivity	Faculty support	
Kerr, Fisher, Yaxley & Fraser (2006)	CSCES	Teacher support	Cooperation		
Lee et al. (2011)	Lit Review	Interaction	Interaction		
Lowe et al. (2007)	Lit Review	1) Interactivity / Chat function 2) Student-Instructor Interaction 3) Connection with Professor	1) Interactivity / Chat function 2) Student-Student Interaction 3) Quality of inter-student interaction 4) Support for multiple simultaneous student interactions 5) Teamwork	1) Feedback clear, timely and meaningful 2) Responsiveness of the system	1) Clear goal statement 2) User guide 3) Expectations clearly articulated
Maor & Fraser (2005)	CMLES	Learning to Communicate	Learning to Communicate		
Martz, Reddy & Sangermano (2004)	DEQ	Interaction with the Professor	Interaction: Group work	Timely and personalized feedback from instructor	Fairness
Maryland Online (2011-2013 Ed.)	Rubric	Learner Interaction & Engagement	Learner Interaction & Engagement	Learner Interaction & Engagement: Instructor clearly states plan for classroom response time and feedback in assignments	Accessibility

Author(s) and year	Instrument / Study type	Interaction			
		Instructor-Student Interaction	**Student-Student Interaction**	**Instructor Feedback**	**Equity**
McGorry (2003)	Theory	Interaction	Interaction	Responsiveness & Student support	
Newby & Fisher (1997/2000)	ACCC /CLEI		Student Cohesiveness		
Online Learning Consortium (2015)	5 Pillars	Learning Effectiveness	Learning Effectiveness	Student Satisfaction: Responsive	Student Satisfaction: Adequate and fair systems to access course learning objectives
Perry (2003)	QDES	Students interaction with the instructor	Collaboration among students	Timely comments from the instructor	
Rovai (2002)	CCS	Learning Items - #2 & #4	Connectedness Items: All 10 items	Learning Items #2, #4 & #6	Learning Item #18
Slagter van Tryon & Bishop (2012)	SPLCI	Persistent follow-up	Increased interaction		
Swan (2004)	Lit Review	Teaching presence	Interactivity and support for collaboration		
Trinidad, Aldridge & Fraser (2005)	OLES	Teacher Support	Student Interaction & Collaboration		Equity
Veal, Brantley & Zulli (2004)	Theory	Student-Instructor contact	1) Interaction 2) Cooperation among students	Evaluation and assessment	
Walker & Fraser (2005)	DELES	Instructor Support	Student Interaction and Collaboration	Instructor Support	
Ward, Peters & Shelley (2010)	Theory	Good social and communication	Good social and communication		
Yeo, Taylor & Kulski (2006)	COLLES	Facilitator Support	1) Student Interaction 2) Peer Support 3) Communicating Online		
Young & Norgard (2006)	Survey	Interaction	Interaction		

Course Design Quality Indicators Identified in the Literature

Author(s) and year	Instrument / Study type	Course Design			
		Course Structure	**Clarity of Objectives**	**Time on Task**	**Relevance & Task Value**
Aldridge, Dorman & Fraser (2004)	TROFLEI		Task orientation		
Asbell-Clarke & Rowe (2007)	LSO	Intellectual Difficulty			
Bangert (2006)	SEOTE			Time on Task	
Blake & Scanlon (2007)	Theory	Multiple Representations	Tailor activities		Real world
Bright et al. (2008)	Lit Review		1) Understanding Procedures 2) Clear Instructions: Social & instructional resources	1) Time on Task 2) Convenience & modest time required	
Chang & Fisher (2001/2003)	WEBLEI	Information structure & design aspects	Results		
Chickering & Ehrmann (1996) / Chickering & Gamson (1987)	Theory: 7 Principles		Principle 6: Clarity of objectives	Principle 5: Emphasizes time on task	Principle 4: Uses active learning techniques, Relevance
Clayton (2011)	OLLES	Information Design & Appeal	Information Design & Appeal		
Davis & Snyder (2012)	EEOI		1) Clarity of directions from instructor 2) Assignments and instructions were clear	Discussions respect students' time	
DeHaan (2005)	Lit Review	Multiple modes of representation	Clear objectives		
Downing & Holtz (2008)	Theory	Disciplinary Content Object Model (DCOM) and pedagogical considerations	Learning objectives are a key consideration		1) Use Vale and Conservation Value of science education 2) Pragmatic purpose of science education for the individual

Author(s) and year	Instrument / Study type	Course Design			
		Course Structure	Clarity of Objectives	Time on Task	Relevance & Task Value
Fraser, Giddings & McRobbie (1992/1995)	SLEI	Material Environment	Rule Clarity		Integration
Institute for Higher Education Policy (2000)	Quality on the Line	1) Course Structure 2) Course Development	Course Structure: Learning outcomes, rubrics and expectations		
Iyer (2011)	COMPLEQ	Information design and appeal	Task orientation		Authentic learning
Jegede, Fraser & Fisher (1995)/ Williams (2003)	DOLES		Task orientation	Personal involvement	
Kerr, Fisher, Yaxley & Fraser (2006)	CSCES	Leadership	Leadership	Task orientation	1) Relevance 2) Integration
Lowe et al. (2007)	Lit Review	1) Website easy to navigate 2) Simple web delivery method 3) User friendliness 4) Ease of use	1) Clear goal statement 2) User guide 3) Expectations clearly articulated		
Maor & Fraser (2005)	CMLES				Relevance
Martz, Reddy & Sangermano (2004)	DEQ	Content of the course	Clear expectations and instructions		Value: Whether course was of value
Maryland Online (2011-2013 Ed.)	Rubric	Course Overview and Introduction: Clear introduction, purpose and structure of the course	1) Course Overview and Introduction: Clear instructions 2) Learning Objectives		
McGorry (2003)	Theory		Student learning: Clear objectives		
Newby & Fisher (1997/2000)	ACCC /CLEI	Integration			1) Integration 2) Usefulness of Course

Author(s) and year	Instrument / Study type	Course Design			
		Course Structure	Clarity of Objectives	Time on Task	Relevance & Task Value
Online Learning Consortium (2015)	5 Pillars	1) Learning Effectiveness: Course design 2) Student Satisfaction: Course design			
Perry (2003)	QDES	1) Clear organization of the course 2) Uses a variety of instructional techniques	1) Clear organization of the course 2) Clear criteria for student assessment	Time required to complete course is reasonable	
Swan (2004)	Lit Review	Teaching presence			
Trinidad, Aldridge & Fraser (2005)	OLES				1) Authentic Learning 2) Personal Relevance
Veal, Brantley & Zulli (2004)	Theory	1) Course development and structure 2) Content presentation	Learning goals		
Velayutham, Aldridge & Fraser (2011)	SALES	Learning goal orientation			Task value
Walker & Fraser (2005)	DELES				1) Personal Relevance 2) Authentic Learning
Yeo, Taylor & Kulski (2006)	COLLES				Relevance
Young & Norgard (2006)	Survey	1) Online course content 2) Online course design	1) Online course content 2) Online course design	Preference for online vs. face-to-face: Time required online	

Technology Adequacy Quality Indicators Identified in the Literature

Author(s) and year	Instrument / Study type	Technology Adequacy		
		Technology Type & Use	**Access**	**IT Technical Support**
Aldridge, Dorman & Fraser (2004)	TROFLEI	Computer usage	Computer usage	
Asbell-Clarke & Rowe (2007)	LSO	Media to Communicate: Email, discussion board, synchronous chat.		
Blake & Scanlon (2007)	Theory	Multiple Representations		Student Support
Bright et al. (2008)	Lit Review	Social & Instructional Resources	Ease of Access: Student preferences for laboratory formats	
Chang & Fisher (2001/2003)	WEBLEI		Access	
Chickering & Ehrmann (1996) / Chickering & Gamson (1987)	Theory: 7 Principles	Principle 3: Uses active learning techniques using technology		
Clayton (2011)	OLLES	1) Material Environment 2) Computer Competence		
Davis & Snyder (2012)	EEOI	1) Variety of modes for interaction 2) Platform consistency across courses		Tech Support
DeHaan (2005)	Lit Review	Computer simulations	Computer simulations	
Downing & Holtz (2008)	Theory	1) Optimize technology available 2) Technology available and deployment		Technical Support for Students
Institute for Higher Education Policy (2000)	Quality on the Line	Institutional support: Technology reliability & Classroom management system/structure	Course Structure: Access to technology tools	Institutional & Student Support: IT technical support
Iyer (2011)	COMPLEQ	Computer usage	Access	
Jegede, Fraser & Fisher (1995)/ Williams (2003)	DOLES	Technology resources	Technology resources	Technological support

Author(s) and year	Instrument / Study type	Technology Adequacy		
		Technology Type & Use	Access	IT Technical Support
Lowe et al. (2007)	Lit Review	1) Incorporation of leading-edge technology 2) Reliability of System 3) Leading edge technology	1) Accessibility 2) System availability 3) Anytime, anyplace learning 4) Learning at any time 5) Learning at any place	Help available
Maor & Fraser (2005)	CMLES	Ease of Use		
Martz, Reddy & Sangermano (2004)	DEQ	Technology use and Value: Quality of technology		
Maryland Online (2011-2013 Ed.)	Rubric	1) Instructional Materials 2) Course Technology	1) Course Technology: Students can readily access the technologies required 2) Accessibility	Learner Support
McGorry (2003)	Theory	1) Technology usefulness 2) Ease of use	Flexibility	Technological Support
Newby & Fisher (1997/2000)	ACCC /CLEI	1) Technology Adequacy 2) Usefulness of Computers	Availability	
Online Learning Consortium (2015)	5 Pillars	1) Learning Effectiveness: Resources 2) Access: Technical 3) Student Satisfaction 4) Faculty satisfaction: Technological infrastructure	1) Access 2) Student Satisfaction: Access	1) Access: Student support services 2) Student Satisfaction: Student support services
Perry (2003)	QDES	Technology used enhances student learning		Technical assistance is easily accessible
Slagter van Tryon & Bishop (2012)	SPLCI			Technology Support
Swan (2004)	Lit Review	Interface issues		
Trinidad, Aldridge & Fraser (2005)	OLES	Computer Usage	1) Asynchronocity 2) Computer Usage	
Ward, Peters & Shelley (2010)	Theory	Technology adequacy	Ease of access	Good IT support
Young & Norgard (2006)	Survey			Technical support

Science Learning Quality Indicators Identified in the Literature

Author(s) and year	Instrument / Study type	Science Learning				
		Active Learning	**Reflective Thinking**	**Scientific Inquiry & Critical Thinking**	**Independence**	**Open-endedness**
Aldridge, Dorman & Fraser (2004)	TROFLEI			Investigation	Young Adult Ethos	
Asbell-Clarke & Rowe (2007)	LSO	Hands-on	Minds-on	Minds-on		
Bangert (2006)	SEOTE	Active Learning	Cooperation Among Students			
Blake & Scanlon (2007)	Theory	Active Learning		Hypothesis testing	Adaptability and tailoring for individual needs	Tailoring for individual needs
Bright et al. (2008)	Lit Review				Prior Learning & Experience	
Chickering & Ehrmann (1996) / Chickering & Gamson (1987)	Theory: 7 Principles	Principle 3: Uses active learning techniques	Principle 4: Reflection			
Clayton (2011)	OLLES	Active Learning	Reflective Thinking			
Davis & Snyder (2012)	EEOI	Hands-on activities		Inquiry based activities		Course platform provides flexible environment
DeHaan (2005)	Lit Review	1) Active Learning 2) Conceptual change and constructivism		Constructivism	Independence	Open-ended
Downing & Holtz (2008)	Theory	1) Activities that stimulate and optimize hypothetico-predictive reasoning 2) Science community of learners to the learner (practice to the learner) knowledge transfer				
Fraser, Giddings & McRobbie (1992/1995)	SLEI					Open-ended
Institute for Higher Education Policy (2000)	Quality on the Line	Course Development: Designed to engage students in analysis, synthesis and evaluation		Teaching and Learning: Instructed in effective research		

Author(s) and year	Instrument / Study type	Science Learning				
		Active Learning	**Reflective Thinking**	**Scientific Inquiry & Critical Thinking**	**Independence**	**Open-endedness**
Iyer (2011)	COMPLEQ	Active Learning			Responsibility & Independence	
Jegede, Fraser & Fisher (1995)/ Williams (2003)	DOLES		Negotiation			Flexibility
Kerr, Fisher, Yaxley & Fraser (2006)	CSCES				Independence	Open-ended
Lee et al. (2011)	Lit Review			1) Conceptual understanding 2) Conceptual change 3) Skills for scientific inquiry	General cognitive skills	
Lowe et al. (2007)	Lit Review	Facilitation of active learning			1) Self-paced schedule 2) Appropriate engagement for self-motivation and self-assessment	Opportunities for learners to test theories
Maor & Fraser (2005)	CMLES		Learning to Think	1) Learning to Investigate 2) Challenge		
Martz, Reddy & Sangermano (2004)	DEQ			Technology use and Learning: Thinking critically		Content of the Course: Customize learning
Maryland Online (2011-2013 Ed.)	Rubric	Learner Interaction & Engagement: Learning activities provide opportunities for interaction that support active learning				
McGorry (2003)	Theory	Student learning: Actively engaged				
Newby & Fisher (1997/2000)	ACCC /CLEI					Open-endedness
Online Learning Consortium (2015)	5 Pillars	Student Satisfaction: Use IT technology to support active and constructive learning				

Author(s) and year	Instrument / Study type	Science Learning				
		Active Learning	**Reflective Thinking**	**Scientific Inquiry & Critical Thinking**	**Independence**	**Open-endedness**
Perry (2003)	QDES	Active class participation required				
Swan (2004)	Lit Review		Support for reflective inquiry		Learner characteristics	
Trinidad, Aldridge & Fraser (2005)	OLES		Asynchronicity		Student Autonomy	
Veal, Brantley & Zulli (2004)	Theory	Active learning				
Velayutham, Aldridge & Fraser (2011)	SALES			Learning goal orientation	Self-regulation of effort	
Walker & Fraser (2005)	DELES	Active Learning			Student Autonomy	
Yeo, Taylor & Kulski (2006)	COLLES		Critical Thinking	Critical Thinking		

Satisfaction Quality Indicators Identified in the Literature

Author(s) and year	Instrument / Study type	Satisfaction	
		Student Satisfaction (Self Efficacy)	**Instructor Satisfaction & Support**
Aldridge, Dorman & Fraser (2004)	TROFLEI	Involvement	
Bright et al. (2008)	Lit Review	Learning Style of Student	
Chang & Fisher (2001/2003)	WEBLEI	Response: Enjoyment, confidence, accomplishments, success, frustration and tedium.	
Chickering & Ehrmann (1996) / Chickering & Gamson (1987)	Theory: 7 Principles		Faculty Support
Clayton (2011)	OLLES	Computer Competence	
DeHaan (2005)	Lit Review	Student satisfaction	Instructor Satisfaction
Downing & Holtz (2008)	Theory	1) Student Type / Learning Styles 2) Motivation	Support for faculty in their instructional design
Institute for Higher Education Policy (2000)	Quality on the Line		Faculty Support
Iyer (2011)	COMPLEQ	1) Student Enjoyment / Anxiety 2) Academic Efficacy	
Jegede, Fraser & Fisher (1995)/ Williams (2003)	DOLES	Personal involvement	
Kerr, Fisher, Yaxley & Fraser (2006)	CSCES	Involvement	
Lee et al. (2011)	Lit Review	1) Self-efficacy 2) Attitude	
Martz, Reddy & Sangermano (2004)	DEQ	Student Satisfaction	
McGorry (2003)	Theory	Student Satisfaction	
Newby & Fisher (1997/2000)	ACCC /CLEI	1) Anxiety 2) Enjoyment	
Online Learning Consortium (2015)	5 Pillars	Student Satisfaction	1) Faculty Satisfaction 2) Learning Effectiveness: Faculty development

Author(s) and year	Instrument / Study type	Satisfaction	
		Student Satisfaction (Self Efficacy)	Instructor Satisfaction & Support
Perry (2003)	QDES		Enthusiasm in distance education teaching
Rovai (2002)	CCS	Learning Items #18 & #20	
Veal, Brantley & Zulli (2004)	Theory	Student support	
Velayutham, Aldridge & Fraser (2011)	SALES	Self-efficacy	
Ward, Peters & Shelley (2010)	Theory	Good social and communication satisfaction	1) Good introduction to teaching of online learning system 2) Given more time to make classes
Young & Norgard (2006)	Survey	Preference for online vs. face-to-face	

Cost, Outcomes and Instructor Competency Quality Indicators Identified in the Literature

Author(s) and year	Instrument / Study type	Cost	Outcomes	Instructor Competency	
				Competency in Content	**Competency in Technology**
Bright et al. (2008)	Lit Review	Cost Effective	Learning Effectiveness	Tutor Assistance	Presence
Chickering & Ehrmann (1996) / Chickering & Gamson (1987)	Theory: 7 Principles			Faculty experts and enthusiastic	
Downing & Holtz (2008)	Theory		Assessment of student learning in the online environment	Instructor preparation should involve pedagogical best practices	Instructor preparation should include familiarization with technology
Institute for Higher Education Policy (2000)	Quality on the Line	1) Evaluation and Assessment: Enrollment 2) Evaluation and Assessment: Costs	Evaluation and Assessment: Intended learning outcomes		
Lee et al. (2011)	Lit Review		Learning outcomes		
Lowe et al. (2007)	Lit Review		Accomplishment of goals verified by student test results		
Maryland Online (2011-2013 Ed.)	Rubric		Assessment & Measurement		
Online Learning Consortium (2015)	5 Pillars	1) Scale: Capacity enrollment 2) Scale: Affordable tuition	1) Learning Effectiveness: Learning outcomes and retention 2) Learning Effectiveness: Learning outcomes, achievement and performance		
Perry (2003)	QDES			Expertise of faculty in course content	Faculty competency using technology
Ward, Peters & Shelley (2010)	Theory	Minimization of costs			