MATH SKILLS IN BIOLOGY EDUCATION: A NEEDS ASSESSMENT OF COMMUNITY COLLEGE BIOLOGY FACULTY

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(Original signatures are on file with official student records.)
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A Needs Assessment of Community College Biology Faculty

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Sondra Marie LoRe
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Thank you to my wonderful husband and best friend Greg
whose love and support makes all things possible.
And thank you to my wonderful children Sarah and Michael
who fill my life with pure joy.

If you don’t get out there and define yourself, you’ll be quickly
and inaccurately defined by others.

—Michelle Obama
Abstract

Despite the long history of Community Colleges (CCs) in the United States, the needs of faculty and students in these institutions remain underexplored and underrepresented in literature. Our society’s increasing need for a data science literate STEM-ready workforce, particularly in the areas of biological and health sciences, increases the urgency to understand and support students and faculty in CCs. This study included a needs assessment of math and quantitative skills in CC biology education. An exploratory, sequential, mixed methods design, infusing an interview phase and inventory survey phase framed this needs assessment. Phase 1 of the research included interviews with 20 CC biology educators recruited from national conferences. Findings from Phase 1 of the research formed the basis for the design of an inventory survey of math/quantitative skills in CC biology courses. An expert panel supported the revisions of the inventory survey through a modified Delphi Method. Phase 2 of the research included nearly 300 inventory survey responses from CC biology faculty in 45 states. Integrated findings from both phases of the research informed the needs assessment and recommendations. Results of the needs assessment support findings that CC biology faculty are challenged by the diversity of student needs including weak math/quantitative skills. Increasing curricular and certification requirements combined with little institutional support compound these challenges. High rates of adjunct faculty are being offered low salaries, few benefits, and unsupported time for curriculum development and student mentoring. Findings also demonstrate the need for professional development for all faculty regardless of their full-time or adjunct status. Recommendations for professional development aimed at infusing active learning, collaborative practices, and interdisciplinary curriculum design conclude the study.
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Chapter 1: Introduction

This chapter examines the need for quantitative/math skills in undergraduate biology education and introduces a mixed method approach to identifying the unique challenges community college (CC) faculty experience when employing math or quantitative skills in biology classes. This introductory chapter begins with a demonstration of the need for examining quantitative skills in CC biology education supported by mass media reports about the value of CC education. The chapter concludes with a plan of action for conducting a needs assessment of math and quantitative skills in biology courses.

Math/quantitative skills, such as the ability to perform basic algebraic calculations, reason with numbers, interpret graphical representations, use and interpret basic statistics, and use and create models are an important competency for biology students emphasized by *Bio2010* (National Research Council, 2003) and *Vision and Change* (American Association for the Advancement of Science [AAAS], 2011). These skills are integral for conducting scientific investigations and communicating the results. Moreover, they are increasingly in demand with the rise of fields such as bioinformatics and data science. To ensure biology students master quantitative skills, it is argued that these skills should be incorporated into all biology courses (Feser, Vasaly, & Herrera, 2013). Research on the implementation of quantitative curricula content has largely focused on 4-year institutional settings and not specifically on the culture and needs of CC biology faculty and students. Despite the importance of CCs in postsecondary education, we have little understanding of the landscape of quantitative/math skills in instruction at these institutions. A detailed needs assessment of CC biology faculty regarding the challenges of teaching quantitative/math skills is necessary.

On March 30, 2018, Walter G. Bumphus, the president and CEO of the American
Association of Community Colleges (AACC) released the following statement, which reads in part, “The beauty of the community college is its ability to evolve in support of its citizens. As the country and world evolved, so did the needs of its citizens” (Bumphus, 2018). One might wonder why such a statement would need to be released in this day and age. Perhaps Dr. Bumphus’ editorial was in response to statements made by President Trump the day before at the Infrastructure Initiative speech at the Richfield Training Site in Ohio: “…when I was growing up, we had what was called vocational school. They weren’t community colleges, because, I don’t know what that means—a community college” (Trump, 2018). The president prescribes a suggestion for referring to community colleges in the future, “and I tell people, call it ‘vocational’ from now on. It’s a great word. People know what that means. We don’t know what community college means” (Trump, 2018).

If the leader of our nation has an unclear definition of CCs and their role in society, then perhaps other citizens may need help understanding as well. Dr. Bumphus’ editorial continues in an effort to enlighten readers: “

Classes that were offered in support of learning the skills to be an automotive technician in the 1980s would certainly be lacking in today’s technologically advanced vehicles that are largely run by computers. The technology evolved. So did the education. (Bumphus, 2018)

For a more concrete description and a better understanding of today’s CC culture and importance to industry and society, it is helpful to look at the role of community college as it has evolved over time.
The Emergence of the Community College

At the turn to of 20th century, “junior colleges” emerged. Mt Joliet, located near Chicago, is considered to be the first CC opening its doors in 1901 to six students. The vision of the first junior colleges was to expand the community in which residents lived by offering postsecondary courses that mirrored nearby 4-year institutions (Cohen & Brawer, 2008; Harbour, 2015). Early junior colleges were housed in high school buildings and were designed, much like today’s community colleges, to offer courses to community residents at low cost in the evenings to allow for students to work during the day, support families, and prepare for further education (Beach, 2011; Cohen & Brawer, 2008; Cohen, Brawer, & Kisker, 2013). Over the next 30 years, from 1965-1999, the number of community college enrollment expanded from approximately 1 million enrolled students to 5.3 million (Kasper, 2002).

Several events during the Great Depression of the 1930s further expanded development and enrollment in community colleges. With high unemployment rates and a need for skilled workers, “emergency community colleges” (Cohen et al., 2013; Harbour, 2015) were funded under the Federal Emergency Education Relief Act (FERA). This period in American history also helped to usher in the vocational skills offered at junior colleges to meet the needs of society during the Great Depression (Cohen et al., 2013; Harbour, 2015). In addition, student loans were introduced during this time and young adults graduating from high school with little workforce skills and opportunities for employment began to consider the vocational and associate degrees offered by community colleges (Beach, 2011; Cohen & Brawer, 2008; Cohen et al., 2013; Harbour, 2015). Following World War II, the Servicemen’s Readjustment Act of 1944 (the GI Bill) led to the emergence of over 300 new community colleges, expanded offerings, and development of new courses to support the servicemen returning to American society (Harbour,
As Baby Boomers came of age in the 1960s and 1970s, community colleges experienced increased growth. In 1963, the Vocational Education Act increased the funding for and availability of occupational education (Beach, 2011; Cohen & Brawer, 2008; Harbour, 2015). In 1992, the American Association of Junior Colleges changed its name to the American Association of Community Colleges (AACC) to reflect the collaboration of adult education, occupational, and associate degrees offered in community colleges. During the Great Recession from 2007-2009, community colleges experienced a dip in state and federal funding, causing an increase in tuition and a move toward increasing the number of adjunct faculty over the more expensive, permanent faculty positions (Juszkiewicz, 2015). In 2010, the White House hosted a summit on community college education organized by Jill Biden, an adjunct professor at the nearby Northern Virginia University. Following the summit, the National Academies Press issued a report: *Community Colleges in the Evolving STEM Education Landscape: Summary of a Summit* (Olson & Labov, 2012) where

President Obama called community colleges the “unsung heroes” of American education and emphasized the critical role they play in sustaining the nation's competitiveness. He pointed out that in the coming years jobs requiring at least an associate’s degree are projected to increase twice as fast as those requiring no college experience. (Olson & Labov, 2012, p. 10)

In 2015, President Obama shared his goals for a tuition-free model for American citizens called “America's College Promise” in his state of the union speech. This brought increased attention to community colleges who at the time had more than 7 million students enrolled in the US (Ginder, Kelly-Reid, & Mann, 2016). At the time of this writing, two states offer free CC
tuition to residents. The state of Tennessee offers tuition-free community college and technical school programs, and New York state offers free 2-year and 4-year education through its state higher education network. While our current administration may struggle to describe and understand CCs, a brief look into its history demonstrates their steadfast success toward reflecting the rapidly changing needs of our society in an inclusive and forward-thinking way.

Mission of Community Colleges

Since their inception, the mission of community colleges has remained consistent: 1) provide open access, 2) offer a comprehensive curriculum, and 3) maintain a commitment to the communities in which they reside (Cohen et al., 2013; Harbour, 2015; Hardré, 2012). In the first mission element, open access, CCs have what is often referred to as “an open-door policy,” meaning anyone with a high school diploma or GED is accepted. Placement examinations typically align students with remedial courses, online modules, and/or academic coaches to support prerequisite course benchmarks. Open access also refers to lower costs, financial assistance, and flexible scheduling of courses, making CCs more accessible to the general population of the United States. The second mission element, comprehensive curriculum, describes the diversity in available degrees and certificates offered in CC (Olson & Labov, 2012; Provasnik & Planty, 2008). A person can graduate with an associate’s in arts (AA), an associate’s in science (AS), an associate’s in applied sciences (AAS) from a 2-year vocational program, or a vocational certificate from a 1-year program (“Community College Research Center (CCRC),” n.d.; Harbour, 2015). The third mission element of CCs, pledging commitment to their communities, “means that even though all community colleges offer a wide range of instructional programs, they tailor these to meet the education needs of the communities they serve” (Harbour, 2015, p. 12). It is the needs and challenges of communities and our society that
drive the direction of this paper.

**Challenges for Students in STEM-Ready Workforce**

In its mission to prepare students for postsecondary studies and careers, CCs have been mindful of the societal needs of a STEM-ready workforce (Malcom et al., 2016; Olson & Labov, 2012). CCs typically offer “two major categories of STEM programs: science and engineering programs (and a small number of mathematics programs) and technical degrees” (Malcom et al., 2016, p. 41). As mentioned, the pathway to achieving associate’s degrees in these fields may require students to take developmental courses in science or math before beginning core classes (Malcom et al., 2016; Olson & Labov, 2012; Provasnik & Planty, 2008). The increasing diversity of students in community college as well as needs for a STEM-ready workforce increased the urgency and need for inclusive practices in CC education (Kasper, 2002; Malcom et al., 2016).

Researchers of undergraduate student persistence in STEM education offer two competing perspectives for student success: 1) those who believe success is reliant on innate ability and 2) those who believe student success is reliant on mathematics skills (Cohen et al., 2013; Kasper, 2002; Malcom et al., 2016; Provasnik & Planty, 2008). Those who argue that persistence in STEM is innate say, “The overall message conveyed is that success in STEM fields requires either a natural ability in mathematics or science or very early exposure to high-quality training” (Malcom et al., 2016, p. 63). Those who favor mathematics skills as a condition for success in STEM studies believe that whether or not a student takes calculus in high school (and not just pre-calculus) is the greatest predictor for student success in studies related to STEM (Chen, 2009; Malcom et al., 2016). It is this notion of mathematics skills related to student success in the sciences that helps guide the direction of this research.
Challenges for Faculty in Community College

To understand the discussion of the mathematics skills related to success for undergraduate students in STEM, one must also consider the role and challenges of CC faculty. During the early years of CC, a typical associate’s granting institution averaged around 60% of its faculty being in full-time or tenured positions. The makeup of faculty largely included former K-12 teachers with experience teaching and designing curriculum. Now, the opposite is true with nearly 70% of CC positions being held by adjuncts, many of whom have little or no teaching experience (Cohen et al., 2013; Harbour, 2015; Kasper, 2002). While a large number of adjunct faculty is not necessary and cause for concern, some research indicates that adjunct faculty in the sciences perceive CC instruction positions as a holding place, or a place to work while seeking out faculty positions at 4-year institutions (Grubb, 1999; Harbour, 2015; Spear, Seymour, & McGrath, 1992). Particularly in the areas of mathematics and sciences, CC adjunct faculty may be recent PhD or postdocs who were not hired by research institutions and are looking for ways to gain teaching experience (Cohen et al., 2013; Eagan, 2008; Grubb, 1999; Harbour, 2015; Levin, Kater, & Wagoner, 2006; Paths, Fugate, & Amey, 1996). In October of 2018 Inside Higher Ed published findings from the American Association of University Professors (AAUP) that showed that less than 20% of CC faculty are tenure track (AAUP, 2018; Flaherty, 2018) and that 50% of these faculty members hold doctorates with less than 5 years of teaching experience (AAUP, 2018; Malcom et al., 2016). To make matters worse, many CC faculty find themselves shuffling between multiple institutions, trying to piece together full-time employment (Grubb, 1999; Harbour, 2015). The breadth of student populations and preparedness is expanding while little attention is being drawn to the needs of faculty to take on these challenges.
Challenges for Undergraduate CC Biology Education

The importance of biology education in CC is critically evident (AAAS, 2011; National Research Council, 2003). In 2016, there were nearly 1,700 community and tribal colleges in the United States with more than 12 million students enrolled (McFarland & Pape-Lindstrom, 2016). No singular government agency or organization compiles course information from all of these CC institutions so precise numbers of students enrolled in all science area courses is difficult to determine (Kasper, 2002; Malcom et al., 2016; McFarland & Pape-Lindstrom, 2016).

Estimations of students in biology and biology-related courses can be made based on degree and course offerings. Biology is one of the primary sciences chosen by CC students for certifications in the health sciences, associate of science degrees, and for core-level general education in associate of arts degrees (Kasper, 2002; Malcom et al., 2016). For some, biology is a required course for an associate’s degree. Commonly awarded associate’s degrees include pharmacy, dental, or veterinarian assistants, phlebotomist, medical transcriptionist, EMT, and medical coders, all of which require biology or life science as foundational course (Carnevale, Strohl, Cheah, & Ridley, 2017; Musante, 2012). Some who enter community college on their path to undergraduate and graduate degrees may choose biology because it is perceived to have less math in the curriculum than other science courses such as chemistry or physics (Wyse & Soneral, 2018). In 2016, a case study of related biology courses at two CCs in Washington state found that related biology courses such as anatomy and physiology are being offered at a similar rate to nearby Washington State University (McFarland & Pape-Lindstrom, 2016). The frequency of biology courses at CCs is similar to that of 4-year institutions, yet the needs of CC students taking related biology courses are largely underrepresented in national statistics.

Gaining a better understanding of current CC STEM faculty needs and values can drive
meaningful change (House & Howe, 1999; Patton, 2012, 2018). Recent calls for reform in STEM education, particularly in the field of biology education, have emphasized the need for increased quantitative reasoning skills for biology students (Holm, Carter, & Woodin, 2011). A common way to promote change in pedagogy is professional development, but it has been shown that widespread change in community college and undergraduate biology teaching is difficult to achieve (Henderson, Beach, & Finkelstein, 2011). Frequently cited barriers to change include insufficient training, time, and incentives (Brownell & Tanner, 2012). Brownell and Tanner (2012) classify these barriers as the “Big Three” when it comes to changing the way undergraduate biology is taught. Taking faculty needs into account should help devise better buy-in to overcome barriers and create a significant learning impact in the classroom.

**Statement of the Problem**

As student enrollment in community colleges and the need for STEM-ready professionals who can work with data in science fields increases, educators are experiencing challenges to teaching quantitative concepts within their courses (Figure 1). Biology faculty in community colleges are faced with the unique challenge of addressing the math skills students need for success in their courses due to the broad variation of student math backgrounds and abilities (D’Avanzo, 2013; T. Park, Woods, Hu, Bertrand Jones, & Tandberg, 2018). This problem is compounded by large CC teaching loads and increasing adjunct faculty rates (Diegel, 2013; Hutto, 2017; Webb, 2007). These challenges, combined with zero to little input into curriculum design and few, if any, professional development opportunities, leaves faculty in need of an exploratory needs assessment to understand the value and use of quantitative skills in their courses (Ast, Mullen, & Mullen, 2018; Edwards, Sandoval, & McNamara, 2015; Herbert, Baize-Ward, & Latz, 2018).
As student enrollment in CC and needs for career ready professionals in STEM fields increases, biology faculty continue to experience challenges related to student math skills within courses.

The purpose of this study is to determine what quantitative/math skills CC biology faculty need and value in their curriculum.

An exploratory mixed methods approach is taken to assess the needs of math skills in CC biology courses.

Figure 1: Research plan for a needs assessment math/quantitative skills in community college biology education
**Purpose Statement**

The purpose of this study is to determine what quantitative/math skills CC biology faculty need and value in their curriculum. This study was embedded within a needs assessment framework of *use* and *value* in evaluation (Alkin, 2013). In order for a principle or core belief, such as the usefulness of quantitative skills in biology, to be advanced, evaluation efforts must include a needs assessment or assessment of the value added to the education program or curriculum (Alkin, 2013; Greene, Caracelli, & Graham, 1989; House & Howe, 1999; Stufflebeam, 2007). Identifying the needs, use, and utility of quantitative/math skills in biology contributes to the body of knowledge for CC curriculum design and institutional investment in faculty development and support in undergraduate education.

**Research Questions**

The research questions which guide this needs assessment are the following: 1) What quantitative/mathematics skills do CC biology faculty value in their courses? 2) What are the needs of CC biology faculty in teaching quantitative skills in their biology courses? 3) What challenges do CC biology faculty experience when including quantitative skills in biology courses? and 4) How do CC biology faculty perceive their efficacy and skill level in teaching quantitative/math skills to their student population?

**Needs Assessment Framework**

As Dr. Patricia Leavy describes in *Research Design* (2017), in a pragmatist worldview, “researchers value utility and works in the context of a particular research question” and “any of the methods or theories … may become a part of a pragmatic design” (p. 14). The value to the user of an education evaluation is paramount to its success and pragmatism, as it applies to the usability of mathematics in biology curriculum, and frames this qualitative study (House &
Howe, 1999; Nowakowski, 1983; Scriven, 1996, 2007; Tyler, 1967, 1977). To advise and support CC biology faculty we must first understand their needs and what is valued from the perspectives of faculty and their multiple realities of academic institutions.

Needs assessments help to define the gap between what is currently known about a population or program and the desired outcome (Altschuld & Watkins, 2014; Gupta, 1999). In this research, the gap that was examined was space between current level of math/quantitative skills in CC biology and the expected skill level to meet the expected outcomes of institutions, society, and industry. Needs assessment researcher Kavita Gupta writes about four main types of needs assessment: 1) strategic needs assessment (for businesses and organizations), 2) competency-based assessment (for management or supervisory roles), 3) job and task analysis, and 4) training and needs assessment (Gupta, 1999). It is the fourth type, training and needs assessment that guided this exploratory research. Needs assessment with regard to training should focus on “who needs to be trained” (Lepicki & Boggs, 2014, p. 68) as well as how it would be valued by the intended group. The population informing this research was CC biology faculty, with the understanding that they are the influencing population for change.

Needs assessments in education programs are often measured against norm-based guidelines and although CC biology courses can be measured against associate’s or technical degree certification requirements and their alignment to Vision and Change (AAAS, 2009) and Bio2010 (National Research Council, 2003), these are not necessarily a measure of value. A need is “a context dependent word” (Scriven & Roth, 1978, p. 10). What is a need to one educator, program, or institution may not be of value to another. Authors Scriven & Roth (1978) encourage discriminating between “performance needs” and “treatment needs” (p. 17).
Performance needs are practical and grounded in “what would be possible and not merely wonderful” (Scriven & Roth, 1978, p. 7). These needs are situated in values and usability of the population being served. Treatment needs for education include the potential added value of the insertion of new models for curriculum, methods, and faculty development. These treatment needs in education are situated in the core beliefs of and value added to the population (Patton, 2018; Scriven & Roth, 1990). It was the intention of this exploratory needs assessment to determine the performance needs of students and faculty to make determinations for treatment needs.

**Delimitations: The Boundaries of the Study**

This study, conducted in two phases (Figure 2), began with 20 interviews with community college faculty recruited from the following conferences or workshops in 2017: the Society for the Advancement of Biology Education Research Annual Conference (SABER), the Gordon Research Conference on Undergraduate Biology Education Research, the National Association for Biology Teachers Annual Conference, BioQUEST Curriculum Consortium, and CC-BIOME (Community College Biology Master Educators). The analysis of the Phase 1 interviews with CC biology education in collaboration with an expert panel informed the design of the second phrase of research, an inventory survey to assess the needs of CC biology faculty. A modified Delphi method was used to validate the needs assessment inventory survey, which was widely distributed to the aforementioned associations as well as members of the communities such as the Quantitative Undergraduate Biology Education and Synthesis (QUBES) and the National Institute for Mathematical and Biological Synthesis (NIMBioS). An extensive online search of CC in the US with open faculty directories was also conducted to
Figure 2: Timeline of research, data collection, and analysis
expand the distribution of the survey across the United States. At the conclusion of the inventory survey, a total of 44 states were represented in the data.

**Significance of the Study**

This mixed method approach to determining the needs of CC faculty to assist in the design of a best-practices design for future online PD models can be extrapolated to other disciplines and institutions in STEM education. As access to community college and undergraduate education is made available to more students, especially through tuition-free incentives, this study aided in the preparation, improvement, and sustainability of biology faculty who are tasked with meeting the needs of a broad spectrum of skills and experiences of students.
Chapter 2: Literature Review

Introduction to Literature Review

The purpose of this literature review is to offer an expanded view of research and studies in community colleges to demonstrate a need for assessment of postsecondary quantitative/math skills in biology education. CC can be described as a tapestry of interwoven threads as shown in Figure 3 (Risser, 2012). The structural core, or warp of the weaver’s loom, represents the students, faculty, curriculum, and society’s expectations about community college. The warp pieces on a loom are pulled taut and are held tight, much in the same way a person’s values are held tightly to our core beliefs. The thread, or weft, which is woven in and out of a warp to form the cloth, represents the changing needs, values, and usability of quantitative skills in biology at community college. Without the weft, the tapestry would hang bare like the bones on a skeleton, lacking the substance. Leaving identifiable holes in the tapestry like gaps in our understanding of CCs. At the end of the chapter, a plan for a needs assessment using a mixed methods design is presented before transitioning to the methods chapter.

Figure 3: Weaving of needs assessment of math/quantitative skill in biology education at CCs
Students in Community College

The framework for understanding community college education must begin with the students it is intended to serve. What were once referred to as nontraditional students, independent students made up 51% of students in community college (IWPR, 2018). Independent students in CC meet at least one of the criteria for Free Application for Federal Student Aid (FASFA). These include

- Being at least 24 years old; married; a graduate or professional student; a veteran, an orphan, in foster care, or ward of the court; a member of the armed forces; an emancipated minor; someone who is homeless or at risk of becoming homeless; or having legal dependents other than a spouse. (IWPR, 2018, p. 1).

In January of 2018, the American Association of Community Colleges (AACC) reported a slightly higher number of independent students. The AACC reported that 58% of students received financial aid of some kind and that 36% were first-generation students, 17% were single parents, 12% reported disabilities, 7% were non-US citizens, and 4% were veterans (AACC, 2018). Understanding the composition of the undergraduate student population in the US provides insight into CC research by bridging the connection between effective principles for inclusion, curriculum design, and faculty support and development of instructional techniques.

Retention of independent students in CC is enhanced when students have a “clear roadmap of the courses they need to complete a credential” (Bailey, Jaggars, & Jenkins, 2015). Movement from a “cafeteria approach” where CC students select from a broad spectrum of electives and courses has been replaced by a “Guided Pathways” approach (Bailey et al., 2015; Schwartz, 2019). Guided Pathways offer students a clearly defined conduit combined with
support services to streamline time to graduation (Bailey et al., 2015). A recent study found that more than 250 CCs in the US have adopted a Guided Pathways approach (Schwartz, 2019).

Four-year institutions can actively support CC student transition and retention. A study conducted by the AACC in 2012 found that students transferring into 4-year institutions performed as well as “native” students when the receiving institution focused on student transfer success (Mullin, 2012). Transfer success is enhanced by 4-year institutions being more accepting of CC credit hours for classes and by having an open dialogue with CC institutions regarding articulation agreements (transfer policies between 2-year and 4-year institutions), assessments, and course design. While some critics argue that students are often penalized for taking classes at CCs by 4-year institutions that require students to “retake classes,” as more students enter community colleges the routine acceptance of previous hours is becoming more of the norm (McFarland & Pape-Lindstrom, 2016; Mullin, 2012; Park et al., 2018). In 2012, “28% of bachelor’s degree earners started at community colleges and 47% took at least one course at a community college” (Mullin, 2012, p. 4).

Streamlined and supportive pathways are not the only needs of CC students today. Colleges are “providing more wraparound services,” such as food pantries, laundry, car care, and financial services (Schwartz, 2019, p. 3). Additional enticements, such as flexible course schedules and financial assistance, are being offered to recruit students who had suspended their schooling. Other studies have examined the relationship between industry and CC certification. “Research-practice partnerships” give CC students the opportunity to engage with industries in their community and, in turn, give businesses a voice in institutions and access to well-trained students (Levesque, 2018).
Feelings of inclusivity and equity for students is an additional component for success addressed in CC literature. In 2018, the Community College Journal of Research published a photovoice study of student experiences in community college (Herbert et al., 2018). Students were given cameras to record photos representing their lives and experiences as a community college student. Researchers then categorized the photos and conducted interviews with students using a photo analysis method (Wang & Burris, 1997). Several findings emerged, the most prevalent being, “Relationships are everything—in the eyes of students, faculty are the most important people on campus” (Herbert et al., 2018, p. 7). These results are consistent with research into teaching immediacy, or “nonverbal behaviors that reduce physical or psychological distance between teachers and students” (Andersen, 1979, p. 543), which has been shown to increase student learning and engagement. A 2017 mixed methods exploratory study of 185 undergraduate biology students found that when students perceived that their instructor knew their name, they were more likely to feel a sense of community, belonging, and investment in the course material (Cooper, Haney, Krieg, & Brownell, 2017).

In addition to teaching immediacy, name recognition, and relationship building, recent “mindset” research has yielded some interesting results. A study published by Science Advances in February 2019 reported that a survey of 150 STEM professors and more than 15,000 students “revealed that radical achievement gaps in courses taught by fixed mindset faculty were twice as large as the achievement gaps in courses taught by a more growth minded faculty” (Canning, Muenks, Green, & Murphy, 2019, p. 1). This study had three comparison components: 1) a survey to faculty to identify fixed or growth mindset, 2) analysis of student grades, and 3) student end-of-course evaluations. While this study was conducted with STEM classes at large 4-year institutions, the results are applicable to CC institutions. Results of this research suggest that
faculty mindset contributes to course design, selection of materials, approaches to innovative teaching techniques, and interest in professional development. Understanding faculty mindset beliefs is important for making decisions about faculty support and professional development at all levels. The following subsection of this literature review examines CC faculty more closely.

**Faculty in Community College**

It cannot be overstated that the needs and expectations resting on all undergraduate faculty members’ shoulders are extensive (Grubb, 1999). Some would argue CC faculty are better positioned to make instructional and curricular changes because they typically don’t conduct research and may have smaller class sizes (Cohen & Brawer, 2008; Webb, 2007). Others would argue that community college faculty teach a greater diversity of students and therefore have more obstacles to overcome (Grubb, 1999). As previously described, biology is the primary science course taught at the postsecondary level. CC biology faculty teach an average of five courses a semester while balancing the infusion of new data science skills related to the discipline and staying abreast of changing vocational certifications and articulation agreements with 4-year institutions (Grubb, 1999; Harbour, 2015; Mellow & Heelan, 2008).

Research studies examining the needs of community college faculty are largely focused on two main areas: needs related to high numbers of adjunct faculty and needs related to student achievement. In 1996, the Community College Review published a qualitative research study that now stands in contrast to more recent research (Paths et al., 1996). The methods included interviews with 22 community college faculty in their first 6 years of teaching at a midwestern community college. The researcher themed three perceived faculty benefits to working at a CC: 1) freedom from the worry of publishing or conducting research, 2) an ability to focus entirely on teaching, and 3) the ability to work in higher education without the need for a terminal degree. In
just over two decades later, the expectations for CC faculty have changed significantly. Research, including securing funding and publishing products, particularly in the hard sciences, is now encouraged of permanent CC faculty members (Pope & Miller, 2000). Permanent faculty in CCs also share many of the same pressures to perform and serve on committees as land-grant institutions (Malcom et al., 2016; Olson & Labov, 2012; Pope & Miller, 2000). While instances of faculty with advanced degrees in CCs remain less than in 4-year intuitions overall, in the areas of math and science this occurrence is on the rise (Harbour, 2015). In 2008, 55% of CC faculty held master’s degrees as compared to 26% in 4-year public institutions (Provasnik & Planty, 2008, p. 9). And 12% percent of CC faculty had PhDs as compared to 58% in public 4-year institutions (Provasnik & Planty, 2008). While the differences between faculty expectations and education may be narrowing, the workforce appointments by institutions is expanding to include fewer full-time faculty.

Adjunct Faculty

As noted in the Introduction, adjunct faculty rates, particularly in science and math fields in community college, are at nearly 70% of faculty (Diegel, 2013; Malcom et al., 2016). Concern exists surrounding the uncertainty of CC faculty related to job security as well. The American Association of University Professors published a Data Snapshot in 2018, stating that 63% of faculty in CCs were on annual contracts, with “28% having multi-year or indefinite contracts and 8% having less than an annual contract (for example, by semester)” (AAUP, 2018,p. 3), representing a cause for concern (AAUP, 2018). In CC literature, the high rates of adjunct faculty working in temporary appointments are well documented: “The use of part-time instructors is a good idea gone wrong because of fiscal motives. Originally, such teachers were hired in order to bring certain kinds of expertise into the community college” (Grubb, 1999, p.
331). A 2006 regression analysis of graduate rates of CC students was designed “to test whether graduation rates at public community colleges vary as schools increase their reliance on part-time faculty” (Jacoby, 2006, p. 1089). While the results did show that increases in part-time faculty significantly decreases student graduation rates, the study is preliminary; other confounding variables, such as unemployment rate factors, were not included. Historically high unemployment rates increase student enrollment in CCs but also tend to decrease the completion rate (Beach, 2011; Cohen & Brawer, 2008; Harbour, 2015). Whether these trends were correlated was not fully explored. Still, “the principal finding of this study suggests that community college graduation rates decrease as the proportion of part-time faculty employed increases” (Jacoby, 2006, p. 1100).

A similar and more recent Community College Journal of Research and Practice study found some contradictory results. The author used one-way ANOVAS to examine the relationship between course retention and adjunct and permanent faculty by using class records of student grades in core courses (Hutto, 2017). The author employed Tinto’s theory of retention, which emphasizes the role of faculty-student relationships as an indicator for success (Tinto, 1993). Surprisingly, the adjunct faculty had statistically significant higher levels of student retention. There are several limitations to this study that should be considered, however. The study was conducted at only one institution with low diversity: 73% of the students were Caucasian, and all of the participants were enrolled in general education courses. A study that included multiple institutions, greater diversity of students, and biology or math courses could show different results (Hutto, 2017). Other CC studies examine faculty participation in curricular change and professional development. Adjunct faculty in CCs are usually not paid to participate in professional development, nor are they compensated for work with students outside of course
hours (Cohen et al., 2013; Diegel, 2013; Mellow & Heelan, 2008). This disengagement with institutional support has a long history in CC literature. For example, an evaluation of CC faculty in 1967 revealed findings consistent with what we have described in this research, although 52 years have passed. “They [faculty] speak of inadequate time to do their jobs properly; their need for professional refreshment; their roles in college government; professional affiliations; [and] teaching in the junior college as a permanent [position]” (Garrison, 1967, p. 54).

In a 2014 report from the Center for Community College Student Engagement addressing strategies for improving working conditions for CC adjunct faculty, the following strategy was offered: compensate adjunct faculty to attend orientations, retreats, professional development, and departmental meetings. In addition, offering incentives for adjuncts participating in evaluation and mentoring programs as well as providing information about subsequent course assignments before the end of term helps increase faculty retention and quality of instructional materials (CCCSE, https://files.eric.ed.gov/fulltext/ED561191.pdf 2014). Other adjunct incentives, such as dedicated office space and compensation for meeting with students during office hours, contribute to the sense of belonging and inclusion of adjunct faculty (Diegel, 2013). This research study aimed to not only uncover the needs of students and faculty as described in literature but to connect these pieces or threads in our loom metaphor to curriculum.

**Biology Curriculum in Community College**

CCs and their faculty can, and do, make a significant contribution to the certificate training and transition of biology students to 4-year institutions nationwide. Associate’s degree-granting institutions conferred more than 5,000 associate’s degrees for articulation in biological and biomedical sciences in 2015 (AACC, 2016); likewise, associate’s degrees in health professions and related programs continually report numbers reaching at or above 200,000
degrees per year (AACC, 2016). The National Center for Science and Engineering Statistics (NCSES) reported that 50% of recipients of bachelor’s degrees had attended CC at some point in their academic careers (Mooney & Foley, 2011). Students graduating with a bachelor’s degree from health and sciences fields attend CC at high rates, with 48.9% of undergraduates in biological/life sciences coming from CC, and 65.9% of all health undergraduates taking classes in CC at some point in their undergraduate careers (Mooney & Foley, 2011; Tsapogas, 2004). Despite these high rates of attendance in CC biology courses, relatively little biology education research has been conducted with CC populations to understand teaching and learning at these institutions (Schinske et al., 2017). As described, biology is a foundational course for associate of science degrees and many technical certifications particularly in medical areas at CC, yet the exact numbers of courses are difficult to measure due to the diversity of institutions and the deficient record-keeping practices (Durán & Marshall, 2018; McFarland & Pape-Lindstrom, 2016). In addition, as previously described, there are differences between the student and faculty population in CCs as compared to 4-year institutions. It is because of these unique differences and need for future information that reinforce the necessity of this research.

Developmental Education in CC

The practice of an open-door policy in CCs has sparked debate in the literature as it applies to the need for (and sometimes against) developmental education or additional supports to improve student skills (Beach, 2011; Cohen & Brawer, 2008; Cohen et al., 2013; Harbour, 2015). Terms like prerequisites, no-requisite, accelerated, and “cooling-out” periods are all words that have been used to describe developmental education, particularly regarding math or quantitative skills, in CC (Clark, 1980; Ford, Grantham, Ford, & Grantham, 2010; Hern et al., 2009; McCoy & Pierce, 2009; Shaffer et al., 2016). Whether or not weak student readiness in
mathematics skills interferes with the infusion of quantitative skills in undergraduate biology is one area in which CCs have received more attention in literature.

In the 1960s Burton Clark proposed that CC mentors and advisors encourage students who were unprepared to take a “cooling out” (Clark, 1960) period to either reexamine their career direction and courses or to step back and enter remedial courses to improve readiness. As one might imagine, this “cooling out” (Brint & Karbel, 1989; Clark, 1960, 1980) and other approaches to remedial or developmental education have been hotly debated over time. With the emergence of Bio2010 and Vision and Change reports (AAAS, 2009; National Research Council, 2003) in the last 10 years, the field of biology has weighed in with its own solutions to student readiness. CC educators typically fall into two postures regarding math prerequisites: 1) those who feel that math prerequisites or developmental math courses are essential to student success, and 2) those who find math prerequisites ineffective or harmful because they make no difference in student success and slow time to graduation (leading to student dropout) (Brint & Karbel, 1989; Hern, 2012; Hern et al., 2009).

Recent studies have offered alternative avenues to support students through developmental education. In an acceleration or no-requisite model, students complete modules or coursework to “catch up” to classmates without having to devote time to taking a prerequisite course. Examples such as MathBench (Nelson et al., 2009) and EdReady (NROC, https://nroc.org/) are programs designed to assist students in either a prerequisite, co-requisite, or accelerated model. MathBench is an open education resource (OER) consisting of 10 biology modules that highlight math/quantitative skills associated with biology using online education resources. MathBench modules are designed to be used as either a supplement or as an introductory route into the infusion of math in biology. EdReady is an online resource that offers
online instructional modules and resources for preparatory practice for entrance exams and/or developmental education on all core disciplines. Individual accounts are free, and institutions can participate in a fee model to collect assessment data to use for placement of students. In 2012 a no-requisite, experiential model for “shorter pathways in developmental English and Math” was published in *Change*, describing an initiative in all California schools to align curriculum toward a standards-based approach combined with real-world application of skills (Hern, 2012). If students perform well when learning outcomes are clear and connections to the real world are evident (Kovalik, 2012; Kovalik & Olsen, 2001), a closer look at the intersection of math and biology could support curriculum development.

**The Intersection of Math and Quantitative Skills in Biology**

Bio2010 (National Research Council, 2003) and Vision and Change (AAAS, 2009) are two policy documents most frequently mentioned in literature evidencing the importance of quantitative skills in introductory biology education at the 2-year and 4-year levels. Both contain recommendations for curriculum and learning outcomes that include ways in which introductory biology courses can infuse quantitative skills to mirror emerging needs of a STEM-ready, data science experienced workforce. These frameworks include references to experiential and active learning practices for faculty and highlight recommendations for administrative and institutional changes; however, they fall short of discussing how an educator or academic administrator might design and implement a quantitative biology curriculum with experiential teaching practices. Bio2010 is more comprehensive, with “recommendations” centered on eight “concepts and skills for the new curriculum” (p. 31) for biology education. There are two levels of recommended changes in Bio2010. The first recommends communication within science departments integrate biology-focused active learning curriculum modules into preexisting courses (p. 53), and in the
second level of change, “interdisciplinary courses could be developed” or “mathematics courses could be developed” (p. 53) to include increased quantitative skills in biology. While open communication is central to any institutional change operation, one has to consider some of the unique challenges CC biology faculty and administrators may face. With high rates of adjunct faculty and little time and resources for professional development, thinking about alternative supports for quantitative biology in CCs may be the best way to impact change. A return to foundation skills, such as the scientific method, combined with active teaching and learning is one way curriculum design in CCs can reach all students (Eaton & Highlander, 2017; Edwards et al., 2015; Mesa, 2012).

A Re-emphasis on the Scientific Method to Increase Understanding of Quantitative Skills

In support of research concluding that math prerequisites do not increase student success in introductory biology, a movement to purposely return to the scientific method (Hern et al., 2009; Karsai & Kampis, 2010; Karsai & Knisley, 2009), specifically the manipulation of data to increase engagement and understanding for real-world application, has occurred. A complement to Open Education Resources (OER) in biology education is accessibility of simulation software to increase interaction in data manipulation and analysis. A student needs to hypothesize and test their data (Karsai & Kampis, 2010). Cookie cutter labs where the hypothesis question is chosen for them does not translate to long-term learning (Basey, Mendelow, & Ramos, 2000; D’Avanzo, 2013). “Mathematics, inquiry-based learning, and the application of modern philosophy of science could produce pedagogy to better teach biology as a science” (Karsai & Kampis, 2010, p. 632). And, if it is not possible for students to collect the data themselves, simulation software can be used for students to formulate their own hypotheses and variables to run with the software. While this theme of active, inquiry-based teaching and learning is consistent in biology
education literature, what is missing are challenges or advantages CC biology educators experience in implementing these best practices in their own curriculum.

**Community Colleges Role in Society**

The goal of this needs assessment study related to CC biology education was to help define the value and utility of community college education as it applies to a field of interest such as biology and vocations and studies related to the field. The “real benefit of community college cannot be measured by the extent to which it contributes to the overthrow of the social class system in America” (Cohen & Brawer, 2008, p. 437). What we can do is help to describe the characteristics that “help individuals learn what they need to be effusive, responsible members of society” (Cohen & Brawer, 2008, p. 438).

As described in Chapter 1, at the turn of the 20th century community colleges grew out of the necessity to have a skilled, educated workforce to meet the needs of society. “In 1988, the Nationwide Commission on the Future of Community Colleges recommended that these colleges help build communities by creating partnerships with employers and making facilities available for workforce trainings” (Kasper, 2002, p. 16). As our needs for a STEM-ready workforce continue to expand, so do expectations of our society. “Reacting to technological and other changes, community colleges continue to test their flexibility as they strive to address changing educational and training needs” (Kasper, 2002, p. 21).

**Chapter Conclusions**

The structure of this chapter was laid against the backdrop of a loom to create a tapestry to describe and highlight openings in CC research for more exploration. These openings in the tapestry are where the weft, or thread, can add structure to elucidate truths about CC biology education. This chapter provides a framework for understanding CC students, faculty, and
biology curriculum through published works. Included in this chapter are baseline information about students and faculty presented through historical and cultural research as well as statistical reporting for associations and national organizations related to CCs. Spaces in the literature include information about how the curriculum is chosen for CC biology courses. While there are recommended guidelines for quantitative skills and a demonstrated need for a data science literate workforce, little attention has been paid to CCs and preparing their educators to infuse these skills into their coursework and teaching pedagogy. Much of the expectations for math/quantitative content in CC biology come from the requirements set by articulation agreements with 4-year institutions and/or with certification programs. Forging this gap between national, certification, and institutional expectations for biology students and the reality of CC students and faculty needs frame this research. This literature review helps to define the current position of CC biology students and faculty and to provide evidence for exploring the space between needs and desired outcomes through a needs assessment.
Chapter 3: Methodology

This chapter describes an exploratory mixed method design to assess faculty perceptions of mathematical instruction needs in community college biology education. A needs assessment considers the beliefs and values of people in organizations, or institutions, as they relate to an assessment of worth and usability for the people being served by the evaluation (Watkins, West Meiers, & Visser, 2012). In a needs assessment the people performing the service and those closest to the population being served inform the reality based on their experiences (Altschuld & Watkins, 2014; Patton, 2018). The approach in this research included a needs assessment of mathematic and quantitative skills in biology education using an exploratory sequential mixed methods design. This research was conducted in two phases of data collection. Phase 1 included interviews with CC biology faculty recruited at national biology conferences, and Phase 2 included data from a nationally disseminated survey to CC biology faculty. This chapter begins with a description of the mixed methods research design followed by Phase 1 and 2 information, including the sample populations, instrumentation, and data collection procedures, and concludes with an analysis plan and limitations.

Research Design

An exploratory sequential mixed methods design was used to assess the needs of undergraduate CC biology faculty regarding math/quantitative skills in biology (Creswell, 2009, 2013; Creswell & Plano Clark, 2007; Tashakkori & Teddlie, 2003). The mixed methods design contained two phases. Phase 1 included interviews with community college faculty who attended the National Association of Biology Teachers (NABT), BioQUEST Making Meaning through Modeling Summer Workshop, Society for the Advancement of Biology Education Research (SABER), and Undergraduate Biology Gordon Research conferences in 2017. These interviews
with engaged science educators were conducted to assist in the discovery of perceived benefits and challenges of mathematics or quantitative skills in introductory biology courses.

The second phase of research involved an expert panel of biology and mathematics faculty and disciplinary experts from both CC and 4-year institutions (see Appendix A). Members of the expert panel contributed to the validation of the Phase 1 interview analysis as well as participated in a modified Delphi Method to assist in the design of an inventory survey instrument for Phase 2 of the research (Colton & Covert, 2007; Landeta, 2006; Skulmoski, Hartman, & Krahn, 2006). In this particular research model, the Delphi Method occurred in each of the analysis and integration phases of the mixed methods design (see Figure 4). Four members of the expert panel met with the researcher biweekly over a 6-month period in the analysis and validation phase of the research, and all of the expert panel members met with the researcher monthly over an 8-month period and online during the spring and fall of 2018. The Delphi Method included shared coding of qualitative files and an online editing and validation of inventory survey, as well as formal presentations of Phase 1 data and draft surveys at in-person meetings.

Figure 4: Exploratory sequential mixed methods research design
Position Statement

The researcher has spent over 20 years in education as a teacher, curriculum designer, school principal, and education evaluator. Despite these experiences in education and curriculum design, the researcher attempted to set aside any preconceived expectations about quantitative and mathematics skills in biology education in order to discover the nature of CC biology faculty experiences. Self-reflection in the form of bracketing (M. Andrews, Day Sclater, Squire, & Tamboukou, 2004) interview transcriptions and analytic memos (Emerson, Fretz, & Shaw, 1995) assisted the researcher in recognizing biases. In addition, monthly check-ins with members of the expert panel served to focus the researcher.

Needs Assessment in Exploratory Research Design

Needs assessments that include qualitative and quantitative data in a mixed methods approach are more informative than those focusing on only one collection tool (Phillips, Wilkinson, & Buck, 2012; Witkin & Altschuld, 1995). Needs assessment researchers Wilkin and Altschuld (1995) described the use of an expert panel in a “modified or group Delphi.” They wrote, “We see all of the techniques as providing avenues for improving data gathering and analysis in Needs Assessments...” (Witkin & Altschuld, 1995, p. 208). The exploratory model described in this research included several data collection tools, such as interviews, an expert panel, and an inventory survey. In later works, Altschuld’s writing emphasized a “hybrid framework” (Altschuld, 2015; Altschuld, Hung, & Lee, 2012) where a “What Should Be” survey is included (Altschuld, 2015, p. 84). The goal of a “What Should Be” survey in a hybrid approach is to define the space between existing needs and “what might be important for this community” (Altschuld, 2015, p. 85). The research design for this dissertation study included
this hybrid, multifaceted approach for needs assessment in a two-phased mixed methods research design.

**Phase 1: Sample and Population**

Phase 1 study participants consisted of 20 CC faculty who attended the following conferences or workshops in 2017: The Society for the Advancement of Biology Education Research Annual Conference (SABER), the Gordon Research Conference on Undergraduate Biology Education Research, the National Association for Biology Teachers Annual Conference (NABT), and the BioQUEST Making Meaning through Modeling Summer Workshop. At the conferences the researcher and colleagues passed out flyers outside of presentation and breakout sessions asking for volunteers. By deliberately recruiting from these biology conferences, the researcher anticipated that participants would likely provide informed, thoughtful responses to questions about factors that support or hinder integration of quantitative/math skills into biology curriculum given their attendance in these workshops. The goal of specifically characterizing advantages and challenges encountered by CC biology faculty aligned with three recruitment assumptions. Faculty who were a) thoughtful about their own teaching, b) likely to have tried to integrate evidence-based pedagogies into their teaching, and c) likely to be aware of the importance of quantitative/math skills in biology necessarily limited the sample.

Phase 1 participants consisted of full-time CC faculty, both with more than 10 years of experience (14 participants) and less than 10 years of experience (six participants), as well as adjunct faculty (three participants). While this interview group over-represents full-time instructors (full-time instructors represent one third of all CC instructors nationally), nevertheless it helped the researcher define questions regarding the availability of as well as access to professional development for adjunct and early career faculty (in Phase 2 of the research). The
interview group was also largely female (75% in this group as compared to 50% of CC instructors nationally) and Caucasian individuals (95% of the interviews as compared to 85% of CC instructors nationally). While there were no specific hypotheses as to how gender or race might impact the reporting of the interview phase, it influenced the researcher’s decision to include a demographic section in the Phase 2 inventory survey to explore any possible differences. Geographically, the participants in Phase 1 were diverse and represented colleges in both the northern and southern regions of coastal western states, interior western states, midwestern states, and eastern states. In total, faculty from 15 US states were represented in Phase 1.

**Phase 1: Instrumentation**

In semi-structured interviews lasting 40-70 minutes, participants described their experiences teaching quantitative/math skills at CCs, their perceptions of the advantages and challenges in teaching quantitative skills at their institutions, and their thoughts on what would motivate CC instructors (including themselves) to attend professional development targeting quantitative biology instruction. Interview questions were designed in collaboration with members of an expert panel and the protocol can be found in Appendix B. IRB approval was completed in collaboration with four members of the expert panel. Interviews were audiotaped and transcribed.

**Phase 1: Analysis**

A qualitative approach was used in Phase 1, permitting the researcher to explore the essence of teaching introductory biology in CC (Flick, 2014; Laverty, McManus Holroyd, Sloan, & Bowe, 2014; Saldana, 2015). To demonstrate the needs of CC biology faculty, the language used by interviewees to describe the reality of teaching quantitative skills in undergraduate
biology reflected core beliefs and values. Immersing the researcher in the language and culture of CC biology faculty provided an exploratory framework to construct needs and values while designing the Phase 2 inventory (Creswell & Plano Clark, 2007; Creswell, Plano Clark, Gutmann, & Hanson, 2003; Leavy, 2017). The researcher and four members of an expert panel assisted in the categorization and coding of the interview data (see Table 1). These expert panel members were selected because of their participation in recruiting interviewees and for their interest and experience in qualitative research. Focused coding was used to determine categories and themes present within the data (Saldana, 2016; Strauss & Corbin, 1990). The first round of coding began with two focused categories: 1) Challenges to teaching quantitative/math skills in biology, and 2) Advantages to teaching quantitative/math skills in biology, including incentives to attend professional development activities. To establish themes within these categories, transcript data were read in their entirety by the researcher and four expert panel members to get an initial sense of participants’ experiences and thoughts. These members identified codes in three full transcripts each in order to establish a preliminary codebook and reach consensus on initial codes via online meetings using the Zoom virtual meeting platform. After jointly establishing a codebook, the researcher coded the 20 interviews while dividing the four expert panel member into two groups each to examine the alignment of codes in 10 interview transcripts each. The paired teams coded the 10 interview files in their groups using the preliminary codebook, then met with the researcher weekly during May through August 2018 to compare code consensus.

After each pair coded their set of interviews, Axial coding, or second-level coding, (Saldana, 2016) was used to narrow the codes into themes. Interview quotes were then themed by the other research group’s pair for inter-rater reliability. Because coding for the different
themes was conducted separately for each category, it was appropriate to calculate inter-rater reliability separately for both categories. Inter-rater reliability, calculated as Cohen’s kappa, was calculated at 0.886 for Challenges, 0.885 for Advantages, and incentives to participate in professional development (McAlister et al., 2018; Perreault & Leigh, 2006). Discrepancies between the two coding groups were resolved in online discussions via the Zoom virtual meeting platform over two weekly meetings. Representative quotes were chosen for each theme by the researcher. The quotes were lightly edited for confidentiality and clarity (to be pure with description or references to previous dialogue) by including brackets to replace names with pseudonyms or pronouns and then rechecked by the researcher and the expert panel interview group members to ensure that they retained their original meaning.

**Phase 1: Trustworthiness**

Several recommendations by Patton (2002, 2012, 2018), Creswell (2009), and Saldana (2016, 2014) to increase the credibility and trustworthiness of the interpretations were included in this study: deriving codes independently before cross-checking with other members of the expert panel during consensus sessions, checking transcripts against audio files when wording or meaning was unclear, taking notes during consensus sessions and adjusting code descriptions accordingly, providing examples in the codebook, and discussing the major themes among all review members to ensure interpretations were consistent across each group.

**Phase 1: Limitations**

Because they were recruited at national conferences for biology education, instructors in Phase 1 of the research may have greater access to funds for PD, may be enthusiastic about new teaching innovations, or may have experienced previous successes infusing math skills into biology education than those not included in this phase of the research. Thus, additional
incentives beyond those reported in this study were included in the Phase 2 inventory survey. The data in Phase 1 of the research were valuable because they uncovered what might be considered the entry-level incentives to attend quantitative biology professional development activities. Lastly, the interviewees’ perceptions are unique to their experiences, and it was important to consider that the data were viewed entirely through CC faculty’s “lens” of the world (Denzin & Lincoln, 2013); the data did not include other views such as those from administrators or students. Despite these limitations, the data collected can be meaningfully interpreted to inform investigations of affordances and constraints to teaching quantitative/math skills in CC contexts for the purpose of designing a larger inventory survey in Phase 2 of the research.

**Phase 2: Sample and Population**

Phase 2 included an inventory survey sent out broadly to biology faculty across the US. Over a 2-month period, the researcher conducted a national search of CC institutions to collect email addresses of biology faculty and departmental email addresses from institutional websites. Next the researcher asked the expert panel to share the inventory survey with colleagues, home institutions, and associations where they were members. Additionally, the survey was shared on two social media sites: the National Institute for STEM Evaluation & Research (NISER) and the Quantitative Biology Undergraduate Education & Synthesis (QUBES) hub. The inventory survey was also shared through associations and organizations where the researcher has participated in evaluations, research, workshops, or conferences that have a connection to undergraduate biology educators, such as BioQUEST, Bio INSITES, QUBES, NSTA, the Gordon Research Conference, and the National Institute for Mathematical and Biology Synthesis (NIMBioS). Included in the analysis of this research are 290 CC faculty survey respondents from 44 states.
Phase 2: Instrumentation

Participation in the design of the Phase 2 inventory of math/quantitative skills in biology education was completed with feedback employed within a modified Delphi Method with the larger expert panel. As described in the literature, a modified Delphi Method panel is expanded to include a larger group of experts (Hartman & Baldwin, 1995; Skulmoski et al., 2006). In this research, the original four panel members who assisted in the coding analyses of Phase 1 interview data are expanded to include 14 members of a larger panel of biology, mathematics, and disciplinary experts in the field.

Both in-person and virtual meetings facilitated the transition from the Phase 1 qualitative research to the Phase 2 survey inventory. Following the analysis of the qualitative interviews during the spring and summer of 2018, the researcher presented initial Phase 1 results at the National Institute for Mathematical and Biological Synthesis (NIMBioS) at the University of Tennessee and at the BioQUEST Curriculum Consortium summer meeting. NIMBioS supports “Working Groups” where faculty can propose to meet on a specific research topic. The researcher attended a NIMBioS CC Biology working group (April 26-28, 2018) and the BioQUEST Summer Workshop at Harvey Mudd College (June 18-24, 2018). Both meetings served as first-round feedback for presentation of the researcher’s Phase 1 results. At the April NIMBioS working group meeting, the researcher spent a half-day presenting the results and meeting members of the expert panel to begin the draft design of an inventory. At the BioQUEST summer workshop in June 2018, the researcher presented a poster of Phase 1 results, lived in dormitory space with biology faculty, and attended breakout sessions discussing curriculum measures and benchmarks for quantitative skills biology. Monthly virtual meetings and an in-person meeting at BioQUEST with the CC Biology NIMBioS working group
continued throughout the summer and early fall until the second in-person meeting held October 25-27, 2018 at NIMBioS. During this 3-day meeting, the researcher had the opportunity to spend another half-day meeting with expert panel members as a whole group to share a semifinal analysis of Phase 1 data as well as a draft of the inventory survey. During the meeting, the researcher made several revisions and shared the survey with the expert panel. In the weeks following the meeting, two rounds of the survey draft were sent to the expert panel. After each round, the inventory survey was sent out again for additional edits and suggestions via email. The research culminated in a final virtual meeting with the entire expert panel in November 2018, along with a request for IRB approval of Phase 2 of the research, the inventory instrument. Approval was granted in early December 2018. This IRB approval for the Phase 2 inventory survey was in addition to the Phase 1 IRB approval for interviews with CC biology faculty. Appendix C shows the online survey.

**Phase 2: Data Analysis**

Analysis procedures included maintaining data cleaning and analysis journals (Morrow & Skolits, 2017). The inventory survey received a total of 840 responses. Twenty-nine respondents declined to participate in the survey and were removed from the data set. An additional 152 responses were removed based on the following criteria: 1) they were not in the field of biology, 2) they were non-teaching staff, and 3) they were non-teaching undergraduate or graduate students. Remaining respondents were grouped into broad two categories: 1) 4-year institutions with 343 respondents, and 2) community college or 2-year institutions (including 14 high school AP biology respondents) with 290 respondents. The 290 community college respondents were the focus of this research and are described in the following survey inventory results.
Integration of Phase 1 and Phase 2 Elements

While curriculum indicators and benchmarks for science education in grades K-12 are normed through state and national guidelines, such as the Next Generation Science Standards (NGSS), undergraduate biology education guidelines, particularly with regard to CC education, are less defined. In Phase 1 of this research, interviewees communicated that the biology skills taught at their institutions are largely dictated by articulation agreements or course content agreements with local 4-year institutions and/or certificate programs. Course content is also influenced by the National Research Council’s Bio2010 (2003) and the American Association for the Advancement of Science’s (AAAS) Vision and Change (2009) document, which offer both curricular and instructional strategies for undergraduate biology education, as well as curriculum texts and open-sourced materials online that give some guidelines for quantitative skills in biology. In order to design a meaningful and reliable math in biology inventory instrument, the researcher included curriculum documents such as Bio2010 and Vision and Change in addition to recommendations for engaging in a Delphi method with the expert panel members.

After categorizing and coding the 20 interviews with CC biology faculty, the researcher collaborated in developing a listing of needed mathematics skills in biology from Phase 1 with the expert panel members, both in person, at two working group meetings, and through monthly virtual meetings using the Zoom video platform. In a similar way to working with a small group of the panel members to validate interview codes in Phase 1 of the research, a subgroup of five expert panel members and the researcher collaborated in a Google Sheet to track related resources, journal articles, and texts in introductory biology.
In particular, two online sources of curriculum models were used to assist in the collection of math skills in biology interview data, MathBench (https://mathbench.umd.edu/) and EdReady (https://edready.org). MathBench is an open-sourced set of curriculum models designed to assist faculty and students in integrating and understanding quantitative skills in biology. Community college expert panel members Christianne Neiuwsma, Stacey Kiser, Kristin Jenkins, and Vedham Karpakakunjarm all had a familiarity with MathBench materials through their home institutions. The MathBench curriculum is organized into 10 main mathematical areas with corresponding biological concepts. Students can work through the modules and related biological processes on their own or in connection with classroom work. A set of “Top Ten: MegaSkills and Concepts” are provided on the website, which helped to inform and validate Phase 1 themes. The EdReady website offers opened-sourced as well as tailored curriculum for entrance and placement examinations, remedial coursework, and standardized tests. Expert panel member Ahrash Bissell is president of the Monterey Institute of Technology & Education which encompasses the NROC Project that hosts and supports the EdReady website. Expert panel members Louis Gross and Suzanne Lenhart have collaborated on several joint projects related to quantitative skills in the biological sciences, one of which, a student text, Mathematics for the Life Sciences (2014), was employed by the researcher to design skills for the math inventory. In addition, Louis Gross is a collaborating author in Vision and Change (2009), the aforementioned publication containing conceptual curriculum benchmarks and recommended pedagogical practices for teaching quantitative and math skills in biology.

A consolidated matrix of math/quantitative skills from the aforementioned sources combined with topics and skills generated from Phase 1 interviews informed the design of the inventory in Phase 2 of the research. A working group meeting with the expert panel in October
2018 at NIMBioS afforded the researcher with an opportunity to present consolidated concepts in the format of ranking style matrices in a draft survey. Edits were made collaboratively with the expert panel during the in-person meeting as well as in two additional online iterations. Each time the researcher made changes and sent the survey out to the panel again for comments and edits. A semi-final version of the survey was piloted with four faculty members from CC and 4-year institutions in a video walkthrough before sending the inventory instrument to the Internal Review Board at the University of Tennessee for approval.

**Inventory Survey Instrument Design**

The mathematics in biology inventory survey was designed and distributed using the Qualtrics online survey platform. It was designed to have a less than 15-20-minute completion time frame and consisted of four main sections: mathematics inventory, professional practices, professional development, and background information. The survey inventory can be found in Appendix C. Ranking agreement scales arranged in a matrix were used for the mathematics inventories, professional practices, and professional development sections. Open-ended response questions followed each matrix, and multiple-choice selections were offered for background information.

**Phase 2: Limitations**

A limitation of the Phase 2 inventory was that a field test of the inventory survey beyond the 14 members of the expert panel was not conducted. While a Delphi Method contributes to the validity of the instrument, the reliability of constructs in the survey could be enhanced through a field test in future iterations.

After reviewing survey results, the researcher observed that an area in which the survey could be improved was in regard to the questions asking about student skills in the course of a
semester. The survey captured a faculty member’s perception of student skills at one point in time, say, at the beginning of the semester, and a student may change over time. In other words, while a student may struggle with basic division regarding computing averages at the start of the semester, near the end of the biology course, if quantitative skills are infused, they may perform better. One way to improve this survey inventory in future iterations will be to indicate the time during the semester when asking questions about student ability.
Chapter 4: Findings

This chapter contains the findings of a needs assessment of math skills in CC biology by employing an exploratory sequential mixed methods design. The research questions addressed in these findings are 1) What challenges and advantages do CC biology faculty experience when including quantitative/math skills in biology courses? 2) What quantitative/math skills do CC biology faculty value in their courses? 3) How do CC biology faculty perceive their efficacy in teaching quantitative/math skills to their student population? and 4) What are the needs of CC biology faculty in teaching quantitative skills in their courses? A qualitative research approach was taken in the analysis of the 20 Phase 1 interviews as well as with the open-ended survey responses in the Phase 2 inventory survey. Descriptive measures were used to analyze the quantitative measures in the Phase 2 inventory survey. The chapter concludes with demographic information from the Phase 2 survey inventory.

Results of Phase 1: Exploratory Interviews with CC Biology Faculty

The major themes generated from the interviews with CC biology faculty in Phase 1 were comprised of two major pre-established focus-coded categories: 1.) challenges to teaching quantitative/math skills in CC and 2.) advantages or affordances to teaching math/quantitative skills in biology at the community college level including incentives for participating in professional development. This result section introduces the challenges as faculty relate them to limiting the teaching of quantitative/math skills and follows with advantages to including quantitative/math skills in CC biology classes, including incentives to participate in professional development. Figure 5 displays the first focus-coded categories, challenges to teaching math skills in biology.
<table>
<thead>
<tr>
<th>Student background or ability, 92</th>
<th>Time in class, 32</th>
<th>Social support, 19</th>
<th>Time to develop materials, 21</th>
<th>Inherited curricula, 29</th>
<th>Curricular resources, 24</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedagogical Content Knowledge (PCK), 46</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 5: Themes and instances for challenges to teaching quantitative/math skills in CC biology courses**
Category 1: Challenges to Teaching Math Skills in CC Biology

Nine themes are included in the category of challenges to teaching quantitative/math skills in CC biology courses offered by respondents. Each theme is described below using quotes to illustrate and support the findings (see Figure 5). The words “instances” in Figure 5 refer to the number of times a coded response was given.

Challenges Related to Students’ Math Readiness (Student background or ability)

Within this category of challenges to teaching quantitative skills in biology, this theme addresses both cognitive and affective factors that influenced students’ math engagement. Included in this theme are statements related to weaknesses in student math background, low student math self-efficacy, student lack of math interest, and cognitive overload with math content and relate to how faculty perceived students’ readiness to engage with quantitative concepts in biology. When considering cognitive factors such as preparation and math knowledge and skills, instructors explained that students might not be “math ready,” expressing that they may not have adequate math skills since they often enter biology courses without prerequisites or up-to-date math training. This lack of preparation left students to struggle with the “simple skills” required for the course, such as conversions between units. Some instructors attributed this lack of preparation to the hiatus some CC students take before returning to obtain their degree.

There’s no math pre-req to get into my course, and [CCs] have a lot of non-traditional students that come back after many years of having formal education; they take a break, and then they come back to school. And so, they often have really hard challenges around remembering the math that they had, really thinking through what does an exponent mean, how to do fairly simple arithmetic without a calculator, or just kind of thinking
through those numbers. —Julie (female full-time instructor, >10 years of teaching experience)

Instructors felt that such students were improperly placed into their classes, expressing that students “have gotten overrides” for prerequisites and “were allowed into the class without the pre-requisites, sometimes, because it just fit their schedule.” This created a situation in which students of very “different levels” and “various abilities” were present in a single class.

Students’ fear of math and low math self-efficacy was a second challenge often expressed in conjunction with lack of math preparation. Instructors reported that this was an added barrier to incorporating quantitative/math skills into their biology classes.

...students are afraid of math. That in effect means that if I want to incorporate more math, more quantification, more working with numbers into my courses, I am always going to deal with that wall, that fear that students have anytime math things come up. Now, I've incorporated some things that I feel are absolutely essential. Too bad, I'm going to deal with that wall, but the number of times you have to keep hitting your face into that fear of math wall, the harder it is to want to incorporate more. —Curt (male part-time instructor, <5 years of teaching experience)

Encountering the “wall” of student fear could be discouraging for instructors. Likewise, instructors recognized that if students didn’t have a minimum level of math skills and/or feared math, they often lost interest in learning the biological concepts.

...if they don’t have, I won’t say a strong background, but I guess maybe a strong background, even a medium background, or an average background, in algebra. They may not be able to understand the calculations that were done, and thus I lose them, and
they are not as interested in learning the concepts. —Sunny (female part-time instructor, 5-10 years of teaching experience)

Other instructors reported that students simply were not interested in math, stating that their eyes would “gloss over” when math was introduced. Overall, wide variability in students’ math background and self-efficacy was reported as a frustration, especially when it led to increases in the time it took to walk students through quantitative concepts.

**Lack of Time to Teach Quantitative/Math Skills During Class (Time in class)**

A second theme, lack of time in class, was based on faculty statements indicating that an interviewee was hesitant to add more to a schedule already packed with required content, especially if that content was going to take a lot of time to cover.

*We have 15-week semesters and I just feel like I am just pressed for time a lot, to cover the information. Especially having gone through and teach them how to do some basic algebra.*

—Sunny (female full-time instructor, 5-10 years of teaching experience)

This was further complicated by the variable skill levels in the class since instructors could not anticipate how long something would take to teach. Instructors expressed concern that they would spend too much time instructing students with less developed quantitative skills while leaving more advanced students bored or disengaged.

*If I have to spend 10 minutes showing them how some quantitative skill applies to whatever we’re working on, then I gotta add another 30 minutes for those students that are really unprepared because you have to take them back to the real basic skills that they need in order to be able to understand it.* —Dave (male full-time instructor, >10 years of teaching experience)
Lack of Time to Develop Curricula (Time to develop materials)

Lack of faculty time to develop materials was a serious constraint for many instructors. Following an expression of how little time she had to develop material, Mikaela explained how her heavy teaching load imposed time limitations.

*I teach anywhere from 16 to 21, 24 hours. That’s 30 contact hours for me a week because labs are only half time...I pretty much just teach. That’s it. Cause we also have to do all of our lab prep, all of our own everything...We’re required five hours a week minimum, student consultation or office hours and sometimes that’s hard to get in. —Mikaela (female full-time instructor, >10 years of teaching experience)*

For part-time instructors, time limitations were exacerbated because they worked other jobs or filled adjunct positions at multiple institutions. Both full-time and part-time instructors recognized that the per-course salary part-time faculty received was insufficient to adequately compensate the time and effort needed to develop new material.

*I think that’s a big barrier [part-time instructors are] not really willing to put in more time to do something novel and out of their comfort zone for the amount of nominal money that they're getting paid. —Mary Beth (female full-time instructor, >10 years of teaching experience)*

Weakness with Inherited Curricula (Inherited curricula)

Because there was little external impetus or time to develop quantitative/math biology materials anew, instructors sometimes found that inertia impeded change. They often relied on previously developed curricular materials in their teaching. Several instructors discussed how difficult it was to take the initial step to develop new materials because of the extra effort involved.
Sometimes it can be difficult, honestly, from an inertia standpoint. I already have my lecture slides prepared. Why would I want to modify them and make my life hard adding these two things? Curt (male full-time instructor, <5 years of teaching experience)

Others felt pressure to use existing materials that other faculty used. However, this issue was alleviated when they were the only one teaching a course, as described by Ana:

For the majors’ course, there is another instructor who teaches it, and I follow the topics that he follows. However, this semester I am the only person teaching the class, so I have redesigned the labs to be more quantitative focused. Much more so than they were in the past. —Ana (female full-time instructor, <5 years of teaching experience)

Notably, the pressure to maintain an existing curriculum was enhanced when multiple sections of a course were taught by adjuncts or across multiple campuses. Sections are typically smaller at CCs (24-48 students), which increases the number of faculty to coordinate. Instructors described how this situation decreased the autonomy of individual instructors to contribute to course design and innovation. In explaining why quantitative topics were not included in a course he taught, Cam, a full-time instructor, highlighted these limitations.

The major’s biology is a lot more scripted. Way too cookbook for my liking but we did that because we have so many adjuncts...and because we are so spread out at different campuses and stuff, and we teach a lot of concurrent stuff in high schools, they made it very...we have a lab manual, we have a study guide that’s all the same. We still have variation in how we do things in class, but it’s all very scripted for the most part. —Cam (male full-time instructor, >10 years of teaching experience)
One adjunct expressed that they had less power to change curricula than full-time faculty, often because they taught in situations where full-time instructors were entrenched in existing practice.

*I disagree with some of the learning outcomes, but according to the guidelines they're supposed to be in my syllabus, which means if I put them in my syllabus, I have to teach them.* — Brianna (female part-time instructor, >10 years of teaching experience)

Brianna later expressed that in order to change the course she would have to wait out the older instructors, saying, “I will sit and wait. I am an adjunct.”

**Lack of Unified Learning Outcomes or Objectives** (Learning objectives)

The theme lack of unified learning outcomes or objectives focuses on the limitations imposed on what instructors must teach by the learning outcomes designated for the course at their institution, which may not align with the aforementioned national recommendations made by AAAS Vision and Change (AAAS, 2009; National Research Council, 2003) or Bio2010. Instructors expressed that since quantitative skills are not often emphasized in learning outcomes, they felt as though they were not valued by the broader faculty and administration.

*We don't have any learning objectives or anything like that in the biology or any of the science curriculum that are quantitative in nature. It's more knowledge, content based. They'll know this, they'll know this, they'll learn that. That's probably one barrier, because we just don't, as a group, say that it's important.* — Hugh (male full-time instructor, >10 years of teaching experience)

Having a set list of learning outcomes that they had to cover, often put in place to meet articulation requirements or accreditation, limited faculty because they could not fit other
objectives into their curricula. In essence, the presence of these learning outcomes exacerbated the in-class time constraints discussed above.

*I have a whole list of objectives that have to come across all these processes as well...A lot of my time in labs, I want them working on research and data. I don't want them looking under microscopes and that's a really big confinement I'm finding especially with assessment and accreditation coming through, where we’re bound by these learning outcomes. —Brianna (female full-time instructor, >10 years of teaching experience)*

**Lack of Curricular Resources for Quantitative/Math Skills Biology** (Curricular resources)

Within the theme lack of curricular resources, faculty cited a need for materials to teach quantitative/math skills as a serious hindrance.

*[Quantitative/math skills in biology] is not something that I feel like we see a lot of professional development opportunities on. You see the latest equipment, or the cool lab, or whatever, but you don't see how to incorporate t tests and Chi-squared into your curriculum. —Cindy (female full-time instructor, >10 years of teaching experience)*

Several instructors spoke to how quantitative examples and graphs were not often included in biology texts or were of low quality. They compared this issue to the incorporation of quantitative problems in other fields, recognizing that in biology, specifically, there is a paucity of quantitative problems and examples.

*...our textbooks, there’s no [math] problems in the back. There's maybe one in each chapter, there’s not 30 or 40 like there is in chemistry or calculus or physics, or any other STEM field, so it is an abomination. —Vicky (female full-time instructor, >10 years of teaching experience)*
This resulted in many instructors feeling like they needed to generate their own problems if they were to teach quantitative/math skills in biology. For instructors with low familiarity with math concepts, this was not feasible.

**Familiarity with Math Pedagogical Content Knowledge (PCK) (Math PCK)**

Familiarity and comfort with executing or teaching math skills and concepts or math pedagogical content knowledge (PCK) was included in statements faculty made regarding their knowledge of how to explain or represent particular concepts as well as their knowledge of students’ preconceptions and misconceptions of a particular concept (Shulman, 1986). Faculty stated that they had never learned certain skills that they wanted to teach, as expressed by Ana: “I definitely can’t teach it because I don’t know it myself,” or described that the time since they had engaged with specific math concepts limited recall.

*I, to be honest, if I was going to embark on this, it's been 15 years since I did stats and did my master's thesis, so I would have to, for at least that time, I'd have to refresh some things in order to teach that. —Cindy (female full-time instructor, >10 years of teaching experience)*

Even when faculty felt like they could perform a quantitative skill or knew a concept, they often expressed uncertainty about how to teach the skill; in other words, they felt they would need additional pedagogical content knowledge (PCK) to successfully teach (Schuchardt, Tekkumru-Kisa, Schunn, Stein, & Reynolds, 2017).

*So, I had a hard time explaining how when you ... This is kind of silly, but when you divide by a negative exponent, how it becomes positive. I had a hard time ... I'm like, "It just does!" —Julie (female full-time instructor, >10 years of teaching experience)*
Faculty emphasized that, although they wanted to teach these skills, their jobs did not afford them regular opportunities to practice or learn new skills. It was also often unclear whether these skills would be valued by their colleagues and departments as described in the next section.

**Lack of Peer Social Support** (Social support)

A lack of social support constituted its own theme and stemmed from both administrative and peer-to-peer interactions. Faculty mentioned lack of social support more as a barrier to others’ incorporation of quantitative/math skills instruction but not necessarily as a barrier to their own adoption. Below, when discussing her desire for more broad incorporation of quantitative/math skills into curricula, Brianna explains that her colleagues were reluctant to support and participate in these efforts.

...one of the problems also is resistance from other colleagues, but basically the resistance is just “I’m not going to do it.” My colleague is like, “I’m not changing anything. I’m retiring in a year and a half. I’m not teaching new labs. I’m not incorporating anything new. Don’t ask him he’s already gone to the dean and said, ‘Don’t ask me to do anything.’” —Brianna (female part-time instructor, >10 years of teaching experience)

Similar to colleagues, administrators were not reported as active adversaries to incorporating quantitative/math skills into curricula, but some instructors reported administrative apathy.

*I wish I could say that someone in my administration even cared.* —Kathy (female full-time instructor, >10 years of teaching experience)
While social support was not a direct barrier to incorporation of quantitative/math skills by the participants in our study, an indirect barrier may be the expressed lack of value for quantitative/math instruction at some campuses.

**Math-Averse Biology Culture** (Math-averse biology culture)

The final theme among constraints presented the broader concern that biology, as a discipline, fostered a math-averse culture. Some instructors explained that math phobia was common among biology students. After being asked at the end of his interview if there was anything he wanted to comment on regarding teaching quantitative/math skills in biology, Tom elaborated on this idea:

*The culture of math phobia in at least the students that I see, or maybe it’s this country, I don’t know. Maybe it’s the world, I don’t know. But this culture of math is to be avoided, is a huge problem, because it erodes confidence in math, and it postpones the math that they are willing to take. And so ultimately, that then, postpones all their other things that depend on that.* —Tom (male full-time instructor, >10 years of teaching experience)

Other instructors expressed concerns that math was not seen as a part of certain biology endeavors by their students. One instructor, Linda, described this as students viewing math as “its own world” apart from biology; she explained that students often did not view math as important to their studies. Another instructor put the onus for this on the broader biology community.

*I think that's a barrier that's peculiar to biology, and that's a structural barrier that our culture's generated... [Students] don't expect to do math in biology, it's like, "Well, it's more than just math. There's other quantitative stuff." We've signaled that [math is] not*
there, over and over again. So, I'm not shocked. I think that's one of the biggest problems.

—Vicky (female full-time instructor, >10 years of teaching experience)

These instructors argued that while there were smaller, more discrete constraints, a change in culture was needed to make progress in quantitative biology instruction.

**Category 2: Advantages and Affordances**

Nine themes are used to describe advantages to teaching quantitative or math skills in biology at CCs (Figure 6). Each theme is described in more detail below with supporting quotes.
Figure 6: Advantages/affordances to teaching quantitative/math skills in biology
Professional Development

Professional development was the most frequently reported advantage for incorporating quantitative/math skills into courses. When asked what types of professional development would be or had been helpful, several instructors discussed professional development related to refreshing their own quantitative/math skills.

Yeah, I think some professional development around, you know, sort of refreshing those skills back. It's been a long time since a lot of us have had calculus, and kind of really thinking through again, what do those equations do and how do they work. —Julie (female full-time instructor, >10 years of teaching experience)

Faculty specifically mentioned professional development as a way for them to learn quantitative skills such as “R... or other statistical programs like SPSS or Python [Ana]” or “bioinformatics tools [Kathy]” that they would then be able to teach to their students.

Instructors also expressed a desire to learn pedagogies that would enhance the teaching of quantitative skills. Several felt ill-equipped to teach mathematical concepts and thought professional development could be used to bolster their math PCK. Expanding upon the quote about dividing by negative exponents in the Constraints section, Julie expressed how professional development would help her to develop PCK.

And then, I think where I've run into some struggles is that explaining part. Like even though I'm pretty good at explaining lots of things, there were still a few things that I just couldn't explain for the mathematical education perspective, and sort of how to teach that. How can I do better at teaching that, how can I explain it where there's more than one way, in just saying, "Oh, it becomes positive." How could I do a better job of explaining it to the students from a mathematical perspective?... That would be good
Finally, instructors reported that professional development workshops that both provided quantitative activities and discussed how to integrate these activities into the biology content of their courses would be valuable. One instructor explained, “A lot of people don’t realize that there are a lot of things that they are teaching that have a quantitative component.” —Dave

Other faculty acknowledged the connection between quantitative skills and their course content but were looking for help in how to incorporate the quantitative skills into their curriculum. One respondent explained that having help integrating skills into the curriculum and leaving professional development with materials that could be used in his classes would be a great help in starting to incorporate more quantitative/math skills in biology.

*It would be a workshop. It would be, “Here is how you incorporate this quantitative technique into your class to teach cellular respiration instead of using these classic slides that such and such book provides you.” Or something like that. Certainly, I think that would be a professional development type activity that several people would be quite interested in attending. Particularly if those kinds of materials could be made available to you.* —Curt (male part-time instructor, <5 years of teaching experience)

**Curricular Resources**

As reflected in the prior quote by Curt, many faculty expressed that they would like more access to developed curricular materials or stated that developed curricula have helped them. Faculty emphasized their desire to have resources that were developed specifically for CC contexts and could be easily integrated into their courses. Instructors who had found such resources described how the resources allowed them to incorporate quantitative/math skills.
Some faculty found and modified resources on their own, either by using online search engines or relying on known websites that contain educational materials, such as HHMI Bio Interactive or the National Center for Case Study Teaching in Science.

*I'm creating these different quantitative bio activities in my courses, looking for resources online. By resources, I'm literally just typing...It's my protist lab this week, so I did "protist and math," and just looking at different activities that pop up and things that I can do that relate both to the content as well as incorporating statistics and math into it.*

—Ana (female full-time instructor, <5 years of teaching experience)

Other instructors obtained quantitative curricula through professional development opportunities or through national initiatives. For example, instructors who participated in a BioQUEST/QUBES workshop, an HHMI Bio Interactive Faculty Mentoring Network (sponsored by QUBES), or the Small World Initiative reported having access to quantitative curricula that they were then able to implement in their courses. Below, Debbie describes how attending professional development activities introduced her to new curricula that she then incorporated into her classes.

*I went to a session about quantitative analysis at [an education conference] this past year. I was part of [a professional development activity]. We went to [the conference] as part of that. Somebody came and talked to us about quantitative analysis, and statistical analysis. I thought a lot of it really made sense. So, I've incorporated some of that, which was statistical analysis.* —Debbie (female full-time instructor, 5-10 years of teaching experience)
Colleagues

When instructors needed help understanding math concepts or how to teach them, several found that math colleagues at their institution were particularly helpful (instances = 19, individuals = 10, Figure 6, Appendix D). Some CC instructors reported existing partnerships or relationships with their math department.

_So, we do have a good partnership with our math department...They also provide a lot of advice to faculty members that want to know, "How should I teach this topic?" So, our math department is really good at outreach and helping faculty._ —Cindy (female full-time instructor, >10 years of teaching experience)

Several instructors also expressed that these math colleagues would work with them to design biology-specific math examples. Kathy discussed how this would be mutually beneficial for math and biology instructors.

_...we’ve got some pretty forward-thinking math faculty that are always interested in real world examples of things. They like to use biological examples, so I’ve talked with some of them._ —Kathy (female full-time instructor, >10 years of teaching experience)

Other instructors discussed their desire to reach out to math colleagues when needed but had not yet engaged in partnerships or collaborations. Although no one expressed that they had experienced co-teaching with a math colleague, two instructor participants expressed interest in co-teaching. Dave explained how co-teaching interdisciplinary courses would allow additional supports for students to emerge.

_I think if we actually got to the point where we were teaching interdisciplinary courses that those support structures would have to be there. They would have to pop up. They could come from the math department itself or a combination of them and us. I think that_
would be something that would facilitate [students’ quantitative/math skills in biology learning]. —Dave (male full-time instructor, >10 years of teaching experience)

National Association Offerings

National associations also assisted in incorporating quantitative skills by providing both previously developed curricula and intellectual support in the form of professional development. Among the national initiatives and resources listed were the National Association for Biology Teachers (NABT), BioQUEST, the BioQUEST Curriculum Consortium, Quantitative Undergraduate Biology Education and Synthesis (QUBES), and American Association for the Advancement of Science (AAAS). Some of these, including BioQUEST and QUBES, also offered social support as described below.

Social Supports

The theme of social supports consisted of supports originating from others that were primarily psychosocial in nature, meaning that they were related to the social factors that encourage changes in individuals’ thoughts and behaviors. Peers and colleagues were important sources of social support, and instructors asserted that it was especially helpful to have peers at the same institution who could support one another in quantitative/math biology integration.

The instructors in biotech and genetics, we're all progressive and on the same page of feasible change and it's fluid. We want to make it as smooth as possible for the students. —Mary Beth (female full-time instructor, >10 years of teaching experience)

The quote above emphasizes that Mary Beth’s colleagues had a certain mindset that supported change. This was also mentioned in regard to math colleagues in particular. One participant referred specifically to her math colleagues having “growth mindsets” (Vicky), referencing Carol Dweck’s work (Dweck, 2006). She emphasized that being in agreement about
the idea that students could improve their knowledge through hard work helped develop camaraderie with her math colleagues. Along with this camaraderie, shared experiences and troubleshooting were important forms of support when incorporating new material. The quote below illustrates how quantitative/math skills professional development provided this kind of support.

The [quantitative skills in biology workshop] one was the one I did sign up for. The cool thing about those workshops is that you meet people who are trying to do the same thing, and you stay in touch with those same folks so that when you're trying to put stuff in your classroom you have that support structure that you can talk to them about it, which I still do. —Dave (male full-time instructor, >10 years of teaching experience)

Support from administration or, more specifically, lack of administrative barriers was frequently mentioned in the context of social support. Several instructors expressed that there “wouldn’t be any barriers” to implementing quantitative biology curricula if the administration was on board.

If we had a dean that thought, we should be sitting in there and teaching cookie cutter labs I wouldn’t be able to [teach quantitative biology]. —Brianna (female full-time instructor, >10 years of teaching experience)

**Autonomy and Active Learning**

Although there was often pressure to cover certain biological concepts, which sometimes served as a constraint (see above), many faculty experienced autonomy in making teaching decisions in their classrooms. This autonomy afforded them opportunities to include quantitative/math material in their course if they desired. Even instructors who reported the
necessity of teaching course-specific learning outcomes discussed flexibility to teach quantitative/math skills in biology.

_We are given an outline of what we are expected to cover and then we can go with it any direction we want, as long as we cover those concepts._ —Sunny (female full-time instructor, 5-10 years of teaching experience)

Notably, however, some instructors discussed that flexibility and autonomy arose only after they were no longer constrained by others’ curricula. Even if the expectation of cross-course curricular alignment was not an overt expectation, they still felt pressure to conform to curricular norms. This aligned with the constraint of inherited curricula described above.

Instructors who had a reasonable amount of autonomy often chose to incorporate evidence-based pedagogies into their teaching in addition to quantitative/math skills and concepts. Several of these instructors mentioned that data-driven labs allowed them to incorporate quantitative skills into their courses. Other instructors mentioned that active learning pedagogies, such as case studies or team-based learning, were vehicles for introducing quantitative skills into course content.

_Since they’re working in groups too, they’re dependent on each other to do the work, and that makes it easier to do that sort of thing, whether it’s a virtual lab in class or new calculations or to complete ... sometimes I’ll have them do something and I don’t necessarily need to see that work, but I want to see them answering thought questions about what they did._ —Ronnie (female full-time instructor, >10 years of teaching experience)

These instructors expressed that certain active learning techniques helped them alleviate some of the constraints associated with quantitative/math biology instruction. _Flipping the_
classroom afforded them more time to teach, and incorporating group work helped instructors manage struggling students by allowing more peer-to-peer instruction.

**Expected Curricular Outcomes**

When quantitative/math skills and concepts were included as part of learning outcomes, articulation agreements, or accreditation requirements, they sometimes acted as an incentive for instructors to include quantitative/math in their courses.

*I think that the incentives [to teach quantitative/math skills in biology] would have to be around articulation agreements. Like if the four-year schools in our state that our Board of Regents negotiates with started to demand those kinds of skills and competencies; I think that that would be probably the only incentive for faculty to go there. Because I think it is a challenging thing to do with students and if they don’t have to, they don’t.* — Julie

However, some instructors were dubious about the effect that this would have. Sandy expressed that even when quantitative biology skills were explicit components of articulation or accreditation agreements, their inclusion was unlikely to be sufficient to motivate actual curricular change.

*You know, for part of our accreditation you have to show that you include quantitative reasoning, so we know better than to remove it, at least from the course, but I don’t know how much everybody does of it.* — Sandy (female full-time instructor, >10 years of teaching experience)

**Student Supports**

A commonly desired advantage was student supports in quantitative/math skills, and instructors reported such supports were helpful when available. These affordances originated
from a variety of supports provided at different times during a student’s tenure at CC. Support for students to learn math prior to their enrollment was described as a benefit to their success at quantitative/math skills tasks. These supports took the form of either remedial math courses or specific course prerequisites.

*Our institution is very supportive around remedial math and math skills. If [students have] had exposure to that, there’s a lot of resources around that, so I think the climate is pretty good.* — Cam (male full-time instructor, 5-10 years of teaching experience)

However, despite recognizing the benefits of these experiences for students regarding quantitative skills, instructors also cited that remedial courses and prerequisites could extend time to degree completion, resulting in students becoming discouraged and leaving the program. After discussing benefits of students having remedial math prior to her course, Linda discussed the drawbacks.

*[Remedial math courses] can take forever. That’s one of the things at least our college has been looking really heavily at, trying to find quicker ways because students get so discouraged that they never come back. Our push has been for retention lately, so I’m hearing a lot about it lately.* — Linda (female full-time instructor, 5-10 years of teaching experience)

Other supports exist to help students during their time in biology classes. Study rooms and learning assistance centers were reported to be beneficial in providing students with extra help. In one case, instructor interactions in these locations resulted in increased camaraderie and a shared sense of purpose. Vicky discussed benefits to both students and instructors who interacted with a learning assistance center where instructors from multiple departments had meetings with students.
So much of the reason [students are] in the STEM study room is around quantitative stuff. There’s a whole whiteboard that’s just full of equations, just so that they have it there, it’s a standing whiteboard that’s always in there. It's a place where math is applied, because there’s engineering students in there, and physics students in there, and chemistry students and biology students. The interdisciplinary nature of student learning in that room has changed faculty's interdisciplinary teaching, which is kind of [neat]. —

Vicky (female full-time instructor, >10 years of teaching experience)

Tutors who were usually located within learning assistance centers also provided supports for students. However, tutors’ efficacy was variable from institution to institution. At some institutions, instructors viewed these tutors as highly efficacious.

We do have excellent math tutors for the students, so that’s a nice support system. —

Edith (female full-time instructor, >10 years of teaching experience)

At other institutions, instructors questioned whether tutors were useful for students.

[The students] have to go to a biology tutor and the biology tutor isn’t expecting a math question. They might not be able to answer that, so ... Sometimes [the tutors are] not even from our school, which is really bad. They may not even know what we teach... —Sandy (female full-time instructor, >10 years of teaching experience)

Having access to technology for students to use was frequently described as a help and support for students when teaching quantitative concepts.

I use Excel just because it’s an easy program to teach students, and most students have access to Excel. —Ana (female full-time instructor, < 5 years of teaching experience)
Institutional Funds

Funds to support development of new curricula or course release time was another advantage. Some CC faculty described how time to develop curricular materials could be afforded by funds to pay for course releases. On the other hand, several instructors described funding mechanisms that would allow them to be compensated for the significant amount of time needed to develop new course materials.

*If I get the grant money that I applied for from the college, I'm gonna try some course-embedded research experiences with my General Biology I this semester. One using bean beetles, one doing antibiotic resistant genes and soil, and then using the DNA barcoding, and actually approach it... A lab. I'm setting up a whole new website, and all kinds of things.* —Hugh (male full-time instructor, >10 years of teaching experience)

However, instructional grants or funds for course development are not always available to part-time instructors, which may make up around two thirds of instructors at a CC (National Center for Education Statistics, 2008).

*As far as what I would consider to be resources available for the purposes of new curriculum development [...]. As a part-time instructor, that's really not available to me.* —Curt (male full-time instructor, <5 years of teaching experience)

Results Phase 2: Inventory Survey Results

Ranking scale questions were presented as matrix tables to gauge the importance of math skills in three ways: introduction to biology courses, perceptions of student ability, and the respondents' confidence in teaching those same skills. Two additional ranking matrix table measures followed the inventory skills tables, asking respondents for their agreement with statements regarding autonomy in curriculum, curriculum, and accessibility and interest in
professional development. Stack bar charts are used to display agreement with each of the five ranking scales. Open-ended response boxes followed each ranking scale. Inductive coding (Saldana, 2016) was used to categorize and theme responses. Tree maps and themed quote tables display open-ended responses. The inventory survey included a demographic section that included institution size, courses taught, teaching experiences, gender identification, and racial and ethnic background. Questions about teaching roles branched out to include additional questions for adjunct faculty. As differences were exhibited in both cited literature and Phase 1 interviews, the inventory survey sought to learn more about what unique challenges and benefits adjunct faculty may experience in CC.

The first set of ranking inventory questions asked survey respondents to rate the importance of the listed quantitative and mathematics skills to the introductory biology courses they teach (see Figure 7). The top five skills that CC faculty rated as “essential” at over 50% each were 1) Creating graphs at 51%, 2) Converting units of measurement at 53%, 3) Determining that an answer is approximately accurate at 54%, 4) Interpreting tables at 66%, and 5) Interpreting graphs at 68%. The skills that were rated as “of little importance” or “not important” at combined highest rates were the “use of statistical tests” and “writing mathematical equations from a verbal description” at 39% and 23%, respectively. These results were contrary to some of the recommendations of Vision & Change and Bio2010 (AAAS, 2009; National Research Council, 2003) where the use of statistical tests, algebra, and writing equations are highlighted. Yet, when we compare these results, they are consistent with the experiences shared in the Phase 1 interviews.
Inventory questions asking faculty to rate the level of importance for the following math skills in their CC biology classes.

<table>
<thead>
<tr>
<th>Math Skill</th>
<th>Essential</th>
<th>Very Important</th>
<th>Of Average Importance</th>
<th>Of Little Importance</th>
<th>Not Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>write mathematical equations from a verbal description</td>
<td>8%</td>
<td>23%</td>
<td>36%</td>
<td>21%</td>
<td>12%</td>
</tr>
<tr>
<td>understand rates of change</td>
<td>18%</td>
<td>38%</td>
<td>30%</td>
<td>12%</td>
<td>3%</td>
</tr>
<tr>
<td>choose an appropriate model to describe a biological system or phenomenon (e.g. Hardy Weinberg, discrete vs. continuous, stochastic) explain descriptive statistics (e.g. mean, standard deviation)</td>
<td>13%</td>
<td>26%</td>
<td>34%</td>
<td>18%</td>
<td>9%</td>
</tr>
<tr>
<td>use statistical tests when appropriate (e.g. t-tests, chi-square)</td>
<td>26%</td>
<td>31%</td>
<td>29%</td>
<td>10%</td>
<td>3%</td>
</tr>
<tr>
<td>make simple probability calculations (e.g. Punnett square)</td>
<td>12%</td>
<td>24%</td>
<td>25%</td>
<td>24%</td>
<td>15%</td>
</tr>
<tr>
<td>convert units of measurement</td>
<td>39%</td>
<td>35%</td>
<td>16%</td>
<td>8%</td>
<td>3%</td>
</tr>
<tr>
<td>determine that an answer is approximately accurate (does my answer make sense) scale up or down using magnitude and significant digits (scientific notation)</td>
<td>53%</td>
<td>27%</td>
<td>15%</td>
<td>5%</td>
<td>1%</td>
</tr>
<tr>
<td>use elementary functions (linear &amp; non-linear, exponential, and logs)</td>
<td>54%</td>
<td>33%</td>
<td>22%</td>
<td>1%</td>
<td></td>
</tr>
<tr>
<td>create graphs (e.g. graph equations, interpret intercept &amp; assumptions)</td>
<td>20%</td>
<td>34%</td>
<td>25%</td>
<td>10%</td>
<td>4%</td>
</tr>
<tr>
<td>interpret graphs</td>
<td>13%</td>
<td>24%</td>
<td>34%</td>
<td>18%</td>
<td>11%</td>
</tr>
<tr>
<td>interpret tables</td>
<td>51%</td>
<td>28%</td>
<td>13%</td>
<td>6%</td>
<td>2%</td>
</tr>
<tr>
<td>manipulate equations (e.g. plug in values, solve for a value)</td>
<td>68%</td>
<td>21%</td>
<td>8%</td>
<td>2%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>66%</td>
<td>24%</td>
<td>8%</td>
<td>2%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>31%</td>
<td>28%</td>
<td>24%</td>
<td>10%</td>
<td>8%</td>
</tr>
</tbody>
</table>

Figure 7: It is [level of importance] for my students to be able to...
Following the ranking scale matrix was an open-ended response question asking for any additional comments about mathematical skills that would be of value to the courses. Sixty-two respondents added comments regarding additional math skills. Inline or in vivo coding (Saldana, 2016) was used to categorize and theme responses whereby the researcher analyzed each line of text in the comments to arrange responses into common groupings. Of note in the open-ended responses was a need for foundational math skills. Lesser importance is placed on higher level quantitative measures in areas such as statistics and algebra, which are recommended skills in undergraduate biology literature. Figure 8 displays a tree map of the themed open-ended responses. When asked what additional comments about math skills are of value to their classes, more than 50% of responses fell in two areas: 31%, 19 respondents, noted that fractions, decimals, percents, and ratios were very important, and 19%, 12 out of 62 respondents, commented that measurement conversions and units were very important. Table 1 shows sample quotes from the open-ended responses to the matrix.
Figure 8: Please add any additional mathematical skills that are of value to your courses
Table 1: Themed responses to open-ended question about additional math skills that would be of value to courses

<table>
<thead>
<tr>
<th>Themed responses</th>
<th>Corresponding quote from open response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fractions, decimals, percents,</td>
<td>“Understanding fractions, ratios, and percentages. Students still struggle with this and it is essential when understanding many</td>
</tr>
<tr>
<td>and ratios</td>
<td>biological concepts.”</td>
</tr>
<tr>
<td></td>
<td>“Use of ratios, understanding of decimals, and fractions (believe it or not many students at the intro level are very weak in</td>
</tr>
<tr>
<td></td>
<td>these basic skills).”</td>
</tr>
<tr>
<td></td>
<td>Understanding the relationship between fractions and percentages.</td>
</tr>
<tr>
<td></td>
<td>“Convert percentages to ratios very important.”</td>
</tr>
<tr>
<td>Metric units, conversions</td>
<td>“I'm not entirely sure this counts as a mathematical skill, but how to measure things appropriately (e.g. using a ruler</td>
</tr>
<tr>
<td></td>
<td>correctly). As elementary as this seems, I have encountered numerous students who cannot use a metric ruler correctly.”</td>
</tr>
<tr>
<td></td>
<td>“Understanding metric units and conversions between them.”</td>
</tr>
<tr>
<td></td>
<td>“Convert English units of measurement to metric units/values”</td>
</tr>
<tr>
<td>Real world applications</td>
<td>“I think it is critical for students to understand the connection between mathematics and understanding our natural world. To</td>
</tr>
<tr>
<td></td>
<td>many, math seems unrelated to biology, but it is critical to have a basic understanding about how we obtain, analyze and</td>
</tr>
<tr>
<td></td>
<td>interpret data. In addition, it is important to understand how models are used to help gain insight into complex phenomenon.”</td>
</tr>
<tr>
<td></td>
<td>“Having a grasp of very large and very small as biology covers both geologic time scales and the infinitesimally small like</td>
</tr>
<tr>
<td></td>
<td>viruses.”</td>
</tr>
<tr>
<td>Basics (+, -, *, &amp; /)</td>
<td>“Simple addition, subtraction, division and multiplication are essential.”</td>
</tr>
<tr>
<td></td>
<td>“Simple arithmetic (add, subtract, multiply, divide).”</td>
</tr>
<tr>
<td>Data analysis</td>
<td>“Understanding how to interpret results from models and how to model systems are essential skills.”</td>
</tr>
<tr>
<td>Algebraic equations</td>
<td>“Algebraic thinking, solving for the missing value. Mathematical reasoning, understand[ing] the story that the numbers are</td>
</tr>
<tr>
<td></td>
<td>telling.”</td>
</tr>
<tr>
<td>Statistics</td>
<td>“Hardy-Weinberg equation; population modeling equations; t-test; Chi-squared; p values.”</td>
</tr>
</tbody>
</table>
The second section set of ranking scale questions in the survey asked respondents to rank the likelihood of student ability regarding the same mathematical skills (see Figure 9). Here we see a difference in what faculty had marked as “essential” skills and what they feel students have “definitely” or “very probably” have the ability to do. For example, interpreting tables and graphs were ranked 66% and 68% “essential,” but student likelihood of “definitely” completing problems with those skills both ranked at 12%. Similarly, faculty rated skills such as determining if an answer is accurate at 54% and converting units of measure at 53% “essential” but rated the likelihood of students “definitely” being able to complete tasks associated with those skills at 7% and 8%, consecutively. Topics related to statistics, modeling, and algebraic equations ranked lowest in terms of likelihood of student ability. This finding demonstrates a gap between CC biology courses and recommendations for content in literature specifically with respect to modeling, statistics, and algebraic equations.
Faculty rate how well their students can perform the following math skills in their biology classes

- write mathematical equations from a verbal description
- understand rates of change
- choose an appropriate model to describe a biological system or phenomenon (e.g., Hardy Weinberg, discrete vs. continuous, stochastic)
- explain descriptive statistics (e.g., mean, standard deviation)
- use statistical tests when appropriate (e.g., t-tests, chi-square)
- make simple probability calculations (e.g., Punnett square)
- convert units of measurement
- determine that an answer is approximately accurate (does my answer make sense)
- scale up or down using magnitude and significant digits (scientific notation)
- use elementary functions (linear & non-linear, exponential, and logs)
- create graphs (e.g., graph equations, interpret intercept & assumptions)
- interpret graphs
- interpret tables
- manipulate equations (e.g., plug in values, solve for a value)

Figure 9: Students in introductory biology courses at my institution are [likelihood] able to…
An option to leave additional comments regarding student math skills was again offered following the second ranking scale matrix. Sixty-eight respondents added comments, and in-line coding of responses was conducted to categorize and theme the data. Figure 10 shows a tree map for themed responses and Table 2 displays sample quotes for the themes. When asked to share any additional comments about student abilities with respect to math skills in biology courses at your institution, again the reoccurring challenge of general math skills being needed at 28% (13 responses), as well as challenges surrounding the diversity of student skills at 23% (19 responses) emerged. Overcoming the challenges associated with a lack of prerequisites at 19% (15 responses) and math anxiety at 9% (7 respondents) were reported. What is of interest in these respondents is the additional connection to Real World Application of Skills at 6% (5 respondents), which was mentioned in the first ranking scale, and the addition of a category theme called Interdependence of Math & Science (15%, 12 responses), noting that the faculty have taken time to comment on the ways in which students struggle to see the connectedness of math and science. Table 2 displays corresponding sample quotes from the open-ended responses to the matrix.
Figure 10: Please share any additional comments about student abilities with regard to math skills in intro to biology courses at your institution.
Table 2: Themed responses to open-ended question about student abilities with regard to math skills in intro to biology courses at your institution

<table>
<thead>
<tr>
<th>Themed responses</th>
<th>Corresponding quote from open response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Math skills needed</td>
<td>“Simple addition, subtraction, multiplication and division are essential.”</td>
</tr>
<tr>
<td></td>
<td>“My students struggle with basic mathematical concepts, such as fractions.”</td>
</tr>
<tr>
<td>Diversity of student skills</td>
<td>“In a community college there is great diversity in the quantitative skills of students that varies from class to class.”</td>
</tr>
<tr>
<td></td>
<td>“At community college it is a very diverse group of students- varying ages, academic backgrounds, disabilities, etc. So, every class has a broad range of skill levels.”</td>
</tr>
<tr>
<td>Lack of prerequisite courses</td>
<td>“Intro to biology requires no math prerequisite to take the course. Students are typically weak in math.”</td>
</tr>
<tr>
<td>Interdependence of math and science</td>
<td>“Great variability from one student to the next; success in a math course is looked at as a single event rather than as a step on a path to learning and application of mathematical principles.”</td>
</tr>
<tr>
<td>Math anxiety</td>
<td>“Simple mathematical tasks throw students when encountered outside a math class. For example, most do know how to calculate an average, or do multiplication/division using multiples of 10. But when tasks with this in the context of a biology problem, they either can’t draw on the appropriate skill/knowledge, or they lack the confidence and must have me confirm how to do these things.”</td>
</tr>
<tr>
<td>Real-world application</td>
<td>“I teach mostly introductory biology and as stated before, most students have little or no understanding of the planet and its cyclical nature and even as biology majors cannot conceptually appreciate biological complexity.”</td>
</tr>
</tbody>
</table>
The third ranking scale matrix in the survey asked respondents to consider the same mathematical skills in terms of their confidence in teaching the listed skills (see Figure 11). The areas where faculty indicated the greatest teaching confidence were similar to the area ranked as highly important in the first matrix above and similar to the areas where faculty ranked lower levels of student ability in the second matrix. Interpreting graphs, interpreting tables, and convert[ing] units of measurement all rated at a 71% confidence level in teaching. Full confidence in teaching how to create graphs at 64%, make simple probability calculations at 62%, and determining if an answer is approximately accurate at 59% demonstrate consistency with faculty-rated levels of importance but are interesting contradictions to perceived student abilities. Of note once again are the areas of recommended curriculum where faculty feel less confident in teaching where national recommendations for undergraduate biology education place emphasis, such as teaching an understanding of rates of change at 28% full confidence, choosing an appropriate model to describe a biological system or using elementary functions at 26% full confidence, using statistical tests when appropriate at 22%, and teaching students to write mathematical equations from a verbal description at 20% full confidence.
Faculty rate how confident they feel teaching the following math skills in their CC biology classes.

<table>
<thead>
<tr>
<th>Skill</th>
<th>Full Confidence</th>
<th>Strong Confidence</th>
<th>Moderate Confidence</th>
<th>Slight Confidence</th>
<th>No Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Write mathematical equations from a verbal description</td>
<td>20%</td>
<td>31%</td>
<td>36%</td>
<td>10%</td>
<td>3%</td>
</tr>
<tr>
<td>Understand rates of change</td>
<td>28%</td>
<td>34%</td>
<td>30%</td>
<td>7%</td>
<td>1%</td>
</tr>
<tr>
<td>Choose an appropriate model to describe a biological system or phenomenon (e.g. Hardy-Weinberg, discrete vs. continuous, stochastic)</td>
<td>26%</td>
<td>34%</td>
<td>27%</td>
<td>9%</td>
<td>3%</td>
</tr>
<tr>
<td>Explain descriptive statistics (e.g. mean, standard deviation)</td>
<td>41%</td>
<td>33%</td>
<td>20%</td>
<td>4%</td>
<td>1%</td>
</tr>
<tr>
<td>Use statistical tests when appropriate (e.g. t-tests, chi-square)</td>
<td>22%</td>
<td>33%</td>
<td>27%</td>
<td>13%</td>
<td>6%</td>
</tr>
<tr>
<td>Make simple probability calculations (e.g. Punnett square)</td>
<td>62%</td>
<td>27%</td>
<td>9%</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Convert units of measurement</td>
<td>71%</td>
<td>19%</td>
<td>9%</td>
<td>1%</td>
<td></td>
</tr>
<tr>
<td>Determine that an answer is approximately accurate (does my answer make sense)</td>
<td>59%</td>
<td>28%</td>
<td>10%</td>
<td>2%</td>
<td>3%</td>
</tr>
<tr>
<td>Scale up or down using magnitude and significant digits (scientific notation)</td>
<td>48%</td>
<td>33%</td>
<td>14%</td>
<td>1%</td>
<td></td>
</tr>
<tr>
<td>Use elementary functions (linear &amp; non-linear, exponential, and logs)</td>
<td>26%</td>
<td>32%</td>
<td>27%</td>
<td>12%</td>
<td>3%</td>
</tr>
<tr>
<td>Create graphs (e.g. graph equations, interpret intercept &amp; assumptions)</td>
<td>64%</td>
<td>24%</td>
<td>10%</td>
<td>1%</td>
<td></td>
</tr>
<tr>
<td>Interpret graphs</td>
<td>71%</td>
<td>22%</td>
<td>6%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interpret tables</td>
<td>71%</td>
<td>23%</td>
<td>6%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manipulate equations (e.g. plug in values, solve for a value)</td>
<td>51%</td>
<td>29%</td>
<td>15%</td>
<td>3%</td>
<td>1%</td>
</tr>
</tbody>
</table>

Figure 11: I have [confidence level] teaching my students how to…
An open-ended response was offered asking respondents to add any additional comments about their confidence in teaching the preceding skills. In-line, focused coding was again used to categorize and theme all 39 responses. Figure 12 and Table 3 display theme names and sample quotes. The results were consistent with previously mentioned challenges in Phase 1 interviews and in the earlier matrices of the survey where lack of time and student prepareness are mentioned. Of note are new comments related to feelings of “confidence but need teaching resources” at 28% or 13 respondents, and feeling “confident because of previous teaching experience” at 11% or 5 respondents. Quotes in these areas, shown in Table 3, indicate a need for additional resources to meet student needs as well as instruction materials to address challenges.
Figure 12: Please add any comments about your confidence level teaching these skills
<table>
<thead>
<tr>
<th>Themed responses</th>
<th>Corresponding quote from open response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confidence but need teaching resources</td>
<td>“I am familiar with the above areas myself but would like to learn better ways of teaching strategies to my students to master them and have greater confidence in knowing when to apply these skills to different situations.”</td>
</tr>
<tr>
<td></td>
<td>“It would be nice to have reference material either as an appendix to the text or a website we could rely on.”</td>
</tr>
<tr>
<td>Students are just not prepared</td>
<td>“I would rate my personal confidence in each of these things one category higher than my confidence <em>teaching</em> them. The reason for the discrepancy is simply because it’s impossible to reach everyone all the time. There’s always at least one (usually more) student who I can’t seem to explain X in a way they understand.</td>
</tr>
<tr>
<td></td>
<td>“I have the requisite knowledge, however my confidence that students can learn these skills while in my biology course is low [because they are unprepared].”</td>
</tr>
<tr>
<td>Lack of time</td>
<td>“While I have confidence that I could teach these topics, I do NOT have time to do that AND cover what I need to in my biology class, especially when students come in not even being able to add.”</td>
</tr>
<tr>
<td></td>
<td>“I struggle with how much time I should spend on teaching these concepts, since I have BIO material to cover and students should come in with some math skills. Admittedly, I have not spent a great deal of time developing my math teaching skills, although I have re-re-re developed my material to teach these concepts to try to improve student learning.”</td>
</tr>
<tr>
<td>Confidence because of teaching experience</td>
<td>“I have had the great fortune to have been teaching biology, ecology and biostatistics for decades, so I have learned how to better communicate with my students. I taught a very diverse array of courses, but I always included a quantitative component.”</td>
</tr>
<tr>
<td>Resources for students</td>
<td>“I have strong math skills but have minimized the amount of math I include in my laboratory activities to very basic levels because of the time constraints of covering out course content and the wide range of abilities in each class. Anything that can help prepare students - e.g. materials they can work through on their own to pick up needed skills, or on-line assistance, etc. would help a lot.”</td>
</tr>
<tr>
<td>Not sure why students don’t understand</td>
<td>“I never had to take a stats class, and my field of biology was not stats-oriented, so anything in this area is challenging for me to explain. I have a good math sense and was good at math up to Calculus, but I have a hard time breaking down steps to help students solve a problem, especially when I feel time-pressure for all the other things that must be addressed in a lab or class.”</td>
</tr>
<tr>
<td>College support</td>
<td>“One of my best colleague/friends teaches math at the CC, she has helped me hone my math teaching skills.”</td>
</tr>
</tbody>
</table>
Following the first three ranking scale matrices, which address the same math skills in the perspective of importance to course, perceived student ability, and confidence in teaching, the remaining three ranking scales addressed curricular materials, autonomy in curricular development and in teaching, as well as professional development opportunities. Figure 13 displays respondents’ responses to questions about autonomy in teaching, including using active learning approaches as well as autonomy in making curricular changes. Of particular interest are responses to the statement, “Active learning is an effective way to embed quantitative skills in introductory biology education,” with 43% strongly agreeing, and 46% selecting “agree.” Active learning is a recommended teaching practice by national biology publications such as Vision and Change and Bio2010 (AAAS, 2009; National Research Council, 2003). Consistent with responses made in Phase 1 interviews are responses regarding compensation for the time it takes to refine curricular materials. Thirty-six percent disagreed and 31% strongly disagreed with the statement, “Compensation is available for faculty to make changes to the curriculum.” For the statement, “I have autonomy in how I teach introductory biology courses,” 34% marked “strongly agree,” and 50% marked “agree,” demonstrating freedom to make changes similar to Phase 1 interviews but displays a chasm between freedom and willingness based on lack of compensation. Other results in this ranking scale that mirror Phase 1 interviews are statements related to opportunities to collaborate with math colleagues and available supports for modifying and infusing previously developed course materials in classes. Forty-six percent of respondents “disagreed” or “strongly disagreed” with the statement, “There are sufficient opportunities for me to collaborate with math colleagues,” and 39% of respondents either “disagreed” or “strongly disagreed” with the statement, “There is support available to help me apply previously developed materials for my courses.”
Faculty rate their agreement to the following statements about the autonomy in developing CC biology curriculum.

I have the autonomy in how I teach introductory biology courses.

I am free to make changes to inherited curriculum at my institution.

Compensation is available for faculty to make changes to curriculum.

There are sufficient opportunities for me to collaborate with math colleagues.

My students are more engaged when quantitative skills are embedded in the curriculum.

Active learning is an effective way to embed quantitative skills in introductory biology education.

I am aware that previously developed curricula exist to support quantitative skills in introductory biology education.

I can access previously developed curricula to support the incorporation of quantitative skills in introductory biology education.

There is support available to help me apply previously developed materials for my courses.

Figure 13: Level of agreement with the following statements about introductory biology (autonomy/curriculum/active learning)
Following the ranking scale is an open-ended response question for any additional comments regarding curricular materials, feelings of autonomy, and supports. Twenty-eight responses were categorized and themed using in-line and focused coding (Saldana, 2016) as shown in Figure 14. Sample quotes are displayed in Table 4. Of note is the consistency in the responses and quotes related to being able to make changes in the curriculum, but additional challenges related to general awareness and access to materials.
Figure 14: Please add any comments regarding your level of agreement to the statements applying to faculty autonomy, curricular materials, and support.
Table 4: Themed responses to comments regarding level of agreement with the statements applying to faculty autonomy, curricular materials, and support

<table>
<thead>
<tr>
<th>Themed responses</th>
<th>Corresponding quote from open response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autonomy in curriculum</td>
<td>“I have some wiggle room in how I teach in my class but have to stick to the curriculum since students are given what notes they need to go by for the semester. I assume I have some say in what goes in the curriculum, but it has been around for a while I wouldn’t want to step on toes if I feel something needs to be changed. I wish we had an annual (or every two years) meeting of all the instructors that teach certain classes where we update curriculum.”</td>
</tr>
<tr>
<td></td>
<td>“I have the ability to determine how I teach but have required Learning Outcomes that are set at the state-level (so I have flexibility in how I teach but less about what content I teach, but quant skills fit in nicely).”</td>
</tr>
<tr>
<td>Not aware of quantitative biology materials</td>
<td>“I am not aware of any previously developed curricula to support incorporation of quantitative skills in introductory biology education. I am not sure if there is support available.”</td>
</tr>
<tr>
<td></td>
<td>“I am not aware of any places to access previously developed curricula is available to me for math skills outside of my institution.”</td>
</tr>
<tr>
<td>Uncertainty of impact</td>
<td>“We have difficulty just teaching them biology; adding math to the course would likely reduce completion rates given their utter lack of preparation.”</td>
</tr>
<tr>
<td></td>
<td>“It is difficult enough for students to master the language of biology let alone add more math.”</td>
</tr>
<tr>
<td>Lack of time to develop materials</td>
<td>“Time, or lack thereof, is my largest hurdle to surmount with respect to curriculum change.”</td>
</tr>
<tr>
<td></td>
<td>“I am vaguely aware of a plethora of materials out in cyberspace, but I have not had time to review them and determine what or how to incorporate them into my curriculum.”</td>
</tr>
<tr>
<td>Aware but where to find materials</td>
<td>“I know there are tons of materials out there, but the information is all over the place and I haven’t had the time to really dive into it.”</td>
</tr>
<tr>
<td>How to infuse quantitative biology materials</td>
<td>“I would like to learn more about math-related resources available to biology instructors.”</td>
</tr>
</tbody>
</table>
The next set of ranking scale questions asked respondents to rank their agreement with statements regarding curriculum, expectations for quantitative/math skills, and support at the institutions (Figure 15). More than half of the respondents either disagreed or strongly disagreed with four statements: “I am not free to make changes to inherited curriculum at my institution” at 64%; “Quantitative skills are not part of our introductory biology courses and learning objectives” at 54%; and “I sometimes lack the confidence to teach math skills in an introductory biology course” at 60%. These results are consistent with the previous rating scales associated with curricular autonomy and confidence in teaching, although of note is that the largest response of disagreement was with this statement, “I am not familiar with the math skills associated with introductory biology curriculum,” at 81%. This finding highlights the discrepancy between what faculty know to be truths about expectations for quantitative skills in their classes and what they are able to accomplish with students.

Additional responses in this set of ranking statements reinforce the challenges that were already shared in Phase 1 interviews and open-ended responses in previous questions on the survey. Notably, 67% of respondents agreed or strongly agreed that, “There is a lack of time to integrate quantitative skills into introductory biology classes.” Similarly, 72% of respondents agreed or strongly agreed that “There is a lack of time to develop materials to integrate quantitative skills into [an] introductory biology course.” To compound the challenge that faculty feel about time to integrate and time to develop materials to support the need for quantitative/math skills in biology education are the needs of the people being served by the courses—the students. A very large percentage of faculty (81%) agreed with the statement, “Most students in introductory biology courses have math anxiety.” And 74% of respondents agreed with the statement that “It is difficult to include quantitative skills into introductory
Faculty rate their agreement to the following statements related to time and support to make/infuse math in their classes.

There is a lack of developed curricular materials for including quantitative skills in introductory biology courses.

There are few people at my institution who support integration of quantitative skills in introductory biology courses.

There is a lack of time to integrate quantitative skills into introductory biology courses.

There is a lack of time to develop materials to integrate quantitative skills into introductory biology course.

I am not free to make changes to inherited curriculum at my institution.

Quantitative skills are not part of our introductory biology courses learning objectives.

Most students in introductory biology courses have math anxiety.

It is difficult to include quantitative skills into introductory biology courses because many students lack the necessary math skills.

I sometimes lack the confidence to teach math skills in an introductory biology course.

I am not familiar with the math skills associated with introductory biology curriculum.

There is pressure to teach certain topics that my students need to transfer to other institutions.

Figure 15: Level of agreement with the following statements (changes to curriculum, time, and support)
biology courses because many students lack the necessary math skills.” These challenges are further discussed in open-ended responses, which are themed in Figure 16 with accompanying sample quotes in Table 5.

Nineteen open-ended responses were themed using in-line, focused coding results in three categorized areas: 1) Balance: Curricular & Student needs at 44%, 8 responses, 2) Student math anxiety at 39%, 7 responses, and 3) Faculty feel lack of experience to change at 17%, 3 responses. This last category, faculty lacking experience to change, was an interesting response because it speaks to a possible correlation between what faculty know are expected quantitative skills for the course and the ability to enact those changes in curriculum or infusion of skills because of their perceived inexperience. This also is a consistent challenge addressed in CC literature with respect to the changes in adjunct faculty over time. Where historically a significant number of CC faculty were retired educators, a larger percentage of CC faculty are new graduates in the hard sciences who were unable to find full-time positions at 4-year institutions (Harbour, 2015).
Figure 16: Please add any comments regarding your level of agreement toward time, familiarity with skills, curricula and content knowledge
Table 5: Themed responses to comments regarding your level of agreement with time, familiarity with skills, curricula, and content knowledge

<table>
<thead>
<tr>
<th>Themed responses</th>
<th>Corresponding quote from open response</th>
</tr>
</thead>
</table>
| Balance: Curricular/Needs of students         | “It is a combination of not really needing substantial quantitative components of intro level biology for students to get the main biology concepts with a lack of student comfort and confidence with math that tends to hinder incorporation into many courses.”  
   “Our institution has rigorously-followed common course objectives that must be addressed for a favorable performance evaluation for our instructors. This leave little time for remedial work in math skills...”  
   “The lack of math skills that students come into my classes with is ridiculous. This semester I only had one student who could tell me what 4 minus 2 was. I regularly have students who cannot tell me if a variable is increasing or decreasing on a LINE graph. When I try to teach them, what is needed a lot of students don’t pay attention and don’t take notes, and most of them act like math does not matter to them, despite repeated examples of how important math is to any type of science career.” |
| Student math anxiety                          | “The main objection I have to integrating more quantitative skills would be that I don’t want students’ math phobia to prevent or distract them from learning the biology concepts that are required components of the course.”  
   “…the biological concepts already challenge our students, requiring much support and lecture/activities time. Bottom line, our courses are considered very demanding by our students. We are consequently losing students from the field of biology after their first college-level course in biology, so this is a serious issue.” |
| Faculty feel lacking experience to change    | “I’m sure I may be free to change curriculum, but I haven’t been here long enough to feel comfortable to take the initiative.”  
   “For some of these items I am not sure because I am a new teacher.”  
   “[Because I am new] For the first statement, I would be more likely to agree to the statement ‘I am unaware of developed curricular materials for including quantitative skills in introductory biology courses.” |
This last set of matrix questions were focused on questions related to professional development. Figure 17 displays the results from the survey. Interestingly, the responses to the first two statements were nearly equally divided between agreement and disagreement. The first statement, “Sufficient funds are available for professional development from my institution,” had a combined total of 35% expressing “agree” or “strongly agree,” and 41% expressed “disagree” or “strongly disagree.” The statement in the ranking scale, “I am responsible for most of the costs associated with professional development opportunities,” had 38% “agree” or “strongly agree” and 39% “disagree” or “strongly disagree.” These results echo what is suspected in literature about CC access to professional development—that availability is largely related to the funds available at the university, and inequities exist depending on state allocation of funds and the general financial well-being of the institution (Cohen, 2008; Harbour, 2015). Responses to all statements in Figure 17 show strong agreement with professional development opportunities, in particular the statement, “Attending professional development about quantitative skills in biology would enhance my ability to incorporate such skills in my classroom,” with 80% of respondents agreeing or strongly agreeing. Incentives to attend professional development are enhanced by the opportunity to acquire new teaching materials or build relationships with other educators. Seventy-nine percent agreed with the statement, “I am likely to attend professional development when it provides new teaching material,” and 83% agreed with the statement, “Meeting other educators at conferences and professional development workshops is important.”

Also displayed in this ranking scale figure are the challenges that CC faculty face with regard to missing class, location, or time. The last three statements in the matrix show high levels of agreement with statements directed at covering classes or protecting time with students. For example, 74% of respondents agreed or strongly agreed with the statement, “I am available and
Faculty rate their agreement to the following statements about access to professional development (PD)

Sufficient funds are available for professional development from my institution.

I am responsible for most of the costs associated with professional development opportunities.

Attending professional development about quantitative skills in biology would enhance my ability to incorporate such skills in my own courses.

I am likely to attend professional development when it provides new teaching materials.

Professional development is useful to my CV/resume.

Meeting other educators at conferences and professional development workshops is important.

My course load prevents me from participating in professional development.

I am available and willing to attend professional development online outside of traditional work hours.

When considering in-person professional development, location is important.

I am more likely to attend professional development when my classes are covered.

Figure 17: Level of agreement with the following statements (PD)
willing to attend professional development online outside of traditional work hours,” and 86% selected “agree” for the statement, “When considering in-person professional development, location is important.” Seventy-nine percent of respondents agreed with the last statement, “I am more likely to attend professional development when my classes are covered.”

The open-ended responses following the ranking scale reinforce the value and need CC biology faculty place on protecting class time with students. Thirty respondents offered open-ended responses, and Figure 18 and Table 6 display themed responses and sample quotes. Of note are the consistent themes of not missing class, costs and travel, and a willingness to attend PD online outside of class time.
Figure 18: Please add any comments about professional development opportunities
Table 6: Themed responses to comments regarding professional development opportunities

<table>
<thead>
<tr>
<th>Themed responses</th>
<th>Corresponding quote from open response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faculty cannot miss class</td>
<td>“When I have multiple preps and several content areas that I teach it is difficult to get to the amount of professional development I would like to attend. I don’t like to miss teaching days it puts me behind. I can only spread myself so thin.”</td>
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<td></td>
<td>“I am unlikely to attend a conference if I have to cancel or have a substitute for my classes - that is not fair to my students.”</td>
</tr>
<tr>
<td></td>
<td>“I don’t like subbing out classes for workshops... teaching, and having a consistent class, is my top priority.”</td>
</tr>
<tr>
<td></td>
<td>“I do not participate in professional development that takes me away from my classes.”</td>
</tr>
<tr>
<td>Finances</td>
<td>“We have adequate support for attending one meeting every two years. Going to a meeting every year requires me to spend my own money.”</td>
</tr>
<tr>
<td></td>
<td>“I am an adjunct, and often have additional work besides my teaching. This can make taking on professional development difficult. It’s easier when it’s on site, built into our flex time, and, as I am an adjunct, best if compensated, since I am underpaid compared to my peers.”</td>
</tr>
<tr>
<td></td>
<td>“The culture of our institution is that professional development should support the college as a whole rather than your discipline. For example, funding would be available to attend a conference about K12 to CC pipeline while funding to attend quantitative skills in biology would not.”</td>
</tr>
<tr>
<td>Location /travel</td>
<td>“I am not likely to attend professional development unless it is at an easily accessible location, does not detract from class time, and falls within reasonable hours, i.e. at night or in the afternoons, but not weekends.”</td>
</tr>
<tr>
<td></td>
<td>“I am more willing to attend professional development when I don’t have to travel.”</td>
</tr>
<tr>
<td></td>
<td>“The development programs I have attended have been at nearby campuses and on days I can attend.”</td>
</tr>
<tr>
<td>Self-directed PD/Online</td>
<td>“I do a lot online, so quick tutorial videos on certain topics like calculating average and standard deviation using biological data would be easily incorporated. Or, interpreting data from a graph etc...”</td>
</tr>
<tr>
<td></td>
<td>“Online PD is an excellent option. My institution does not provide funds to travel for PD workshops (only travel to conferences where presenting, and then only once every 3 years) so attending out-of-state opportunities is limited.”</td>
</tr>
</tbody>
</table>

Introductory Biology Courses Taught by Inventory Respondents in CC

Inventory respondents were asked to select from a list of CC introductory biology courses. Respondents could select more than one option, and additional text entry boxes were offered to capture other additional responses. Figure 19 displays responses with corresponding numbers for the number of times each course was selected, and additional demographic information can be found in Appendix E.
Figure 19: What CC biology courses do you teach?
Additional Information from Adjunct Faculty Teaching in CC

A branching question asking respondents to select their faculty status was asked to gain additional information from adjunct faculty members. Of the 290 respondents, 188 indicated that they were full-time/permanent faculty, 86 indicated they were part-time/adjunct faculty, and 16 respondents selected the “other” category, describing themselves as high school AP biology faculty or lecturer. The 86 respondents who selected part-time/adjunct faculty were branched to a section of the survey that asked seven additional questions. The first branching question asked part-time or adjunct faculty how many institutions they work at in a given academic year. Fifty-seven percent or 49 respondents stated that they work at one institution, 28 or 32.6% replied that they work at two intuitions, and 9 or 10.5% replied three. The next question asked whether they had office space at any of the institutions where they worked, and 58 or 67.4% replied yes and 28 or 32.6% replied no. The next two questions in the adjunct faculty section asked if their schedule allowed for time to meet with students and if they were compensated for that time. A large percentage of respondents, 68 or 79.1%, replied yes that their schedule afforded the opportunity to meet with students on campus, and 18 or 20.9% replied no, that their schedule did not allow them to meet with students on campus. The response to the question, “Are you compensated for office hours with students?” was “no” for 60 or 69.8% of respondents, and “yes” for 26 or 30.2% of respondents.

The next and final closed response in this section asked respondents if they would accept a permanent faculty position at the primary institution where they worked if available, and 59 respondents or 68.6% replied yes and 27 or 31.4% replied no. The last two sections of the adjunct faculty questions were open-ended. The first asked respondents, “What are the specific challenges you face as an adjunct professor?” Of the 68 adjunct faculty surveyed, 59 left open-
ended responses to this question, which were categorized and themed using in vivo or inline coding and focused coding (Saldana, 2016). The results are displayed in Figure 20 with sample quotes in Table 7. Of note are the areas related to low salary and feelings of having a lack of voice at the intuitions, both of which were included in 19% or 24 statements. Also of interest were the people who took the time to comment on the lack of pay and opportunity to work with students in 11% or 14 responses. Other areas of interest are those related to feelings of uncertainty about employment, in 12% or 15 responses. Consistent with ranking scale responses are feelings of having less curricular autonomy for adjuncts in 13% or 16 instances of statements addressing this challenge.
Figure 20: What are the specific challenges you face as an adjunct professor?
Table 7: Themed responses to "What specific challenges do you face as an adjunct professor?"

<table>
<thead>
<tr>
<th>Themed responses</th>
<th>Corresponding quote from open response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low salary</td>
<td>“Salary that is significantly less than what starting full-time faculty make.”</td>
</tr>
<tr>
<td></td>
<td>“Having to teach 60 contact hours over a year (full time at both schools is 30 contact hours, but over 2 semesters) in order to make $10,000 less (not counting benefits) than someone hired full-time...”</td>
</tr>
<tr>
<td>Lack of voice</td>
<td>“Lack of respect from administration. I feel many administrators treat adjuncts as expendable and of much lower quality.”</td>
</tr>
<tr>
<td>Curricular autonomy</td>
<td>“No control over curriculum.”</td>
</tr>
<tr>
<td></td>
<td>“Lot of material to teach for a semester, students and myself struggle with it sometimes.”</td>
</tr>
<tr>
<td>Uncertainty about employment</td>
<td>“Uncertain scheduling/course load. Less opportunity to participate in departmental discussions.”</td>
</tr>
<tr>
<td></td>
<td>“No guarantee of hours from one semester to another.”</td>
</tr>
<tr>
<td>No pay to work w/students</td>
<td>“Not having paid office hours is also a big challenge. I would really like to have dedicated office hours for students, but the lack a pay is a big detractor.”</td>
</tr>
<tr>
<td></td>
<td>“No paid compensation for extended grading periods and extra office hours.”</td>
</tr>
<tr>
<td>No office</td>
<td>Not having my own office space or a dedicated place to meet with students is a big challenge.”</td>
</tr>
<tr>
<td></td>
<td>“Office space: nowhere to meet with students. I make time to meet with students, but it significantly impacts family time.”</td>
</tr>
<tr>
<td>Multiple Institutions</td>
<td>“You can also get &quot;bumped&quot; from a course if a full-time person doesn't get enough students, the cost of driving, the running all over the place.”</td>
</tr>
<tr>
<td></td>
<td>“Scheduling to fit both schools [challenging].”</td>
</tr>
<tr>
<td></td>
<td>“Limited time, money spent on transport between different colleges, not a lot of control over my schedule, working 6 days a week at 3 schools to make ends meet, less time to focus on working on curricula or with students, no benefits”</td>
</tr>
<tr>
<td>Commute</td>
<td>“Time constraint for commuting in different institutes and not having time to participate in governance.”</td>
</tr>
<tr>
<td></td>
<td>“Long distance commute.”</td>
</tr>
<tr>
<td>Health Insurance</td>
<td>“Having to pay for all of my own benefits.”</td>
</tr>
<tr>
<td></td>
<td>“Uncertainty about health insurance ...”</td>
</tr>
</tbody>
</table>
The last question in the adjunct faculty section asked respondents, “What are the specific benefits you experience from being an adjunct professor?” Figure 21 displays the categorized themed responses with sample corresponding quotes in Table 8. As expected, 24 or 24% of statements reflected the advantages adjunct faculty feel toward having a flexible schedule. While some respondents in the previous question indicated that they did “have a voice” in decisions being made at their institutions, 13 or 18% of adjunct faculty felt that having little responsibility to institutions was beneficial. Sample quotes for this theme are centered on the benefit of not having extra responsibilities to participate in committees or take on administrative tasks. Of note are the statements in the theme, “Opportunity to hone teaching skills,” where 13 or 18% of respondents described the way in which teaching as an adjunct affords them the opportunity to improve their teaching methods and establish pedagogies.
Figure 21: What are the specific benefits you experience from being an adjunct professor?
Table 8: Themed responses to "What specific benefits do you have as an adjunct professor?"

<table>
<thead>
<tr>
<th>Themed responses</th>
<th>Corresponding quote from open response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexible schedule</td>
<td>“Flexible schedule! I can take a term off if I need to or teach at other institutions.”</td>
</tr>
<tr>
<td></td>
<td>“Working as an adjunct has been a great way to continue teaching while also spending some days as a stay-at-home parent of a young child.”</td>
</tr>
<tr>
<td>Opportunity to hone teaching skills</td>
<td>“Teaching experience in pursuit of career goals and personal fulfillment.”</td>
</tr>
<tr>
<td></td>
<td>“This provides the opportunity to find about the pedagogies and assessments that may need to change for higher learning outcomes for diverse student population.”</td>
</tr>
<tr>
<td></td>
<td>“Helps to hone my teaching skills, keeps me updated with my course material and may help me preparing for full time teaching positions.”</td>
</tr>
<tr>
<td>Little responsibility to institution</td>
<td>“No administrative tasks, meeting more professors from different institutions which allows for learning about other ideas.”</td>
</tr>
<tr>
<td></td>
<td>“There is a significant reduction in the workload with no need to be on departmental or institutional committees.”</td>
</tr>
<tr>
<td>Ability to focus on students</td>
<td>“I love teaching students of all abilities. I love the larger cross-section and different preparation levels of the students at community college. It is a challenge to help students better prepare the study habits and skills.”</td>
</tr>
<tr>
<td>Diversity of students &amp; colleagues</td>
<td>“Opportunity to teach students in multiple college settings with students coming from diverse backgrounds.”</td>
</tr>
<tr>
<td></td>
<td>“Getting opportunity to work with diverse faculty population to share to make things better for self and students.”</td>
</tr>
<tr>
<td>Great retirement or second job</td>
<td>“It is the best part-time job as a semi-retired teacher. Only 2 days per week and still stay in contact with both students and peers.”</td>
</tr>
</tbody>
</table>
Chapter Conclusion

Study conclusions are detailed in Chapter 5. As a preview, the findings reflected consistency between the Phase 1 interviews with CC faculty and the Phase 2 inventory survey. The first research question, addressing the challenges and advantages to including quantitative skills in biology courses, was themed in a manner consistent with the researcher’s needs assessment. Faculty valued their students’ needs, while regarding the guidelines and expectations of technical degrees and/or transition to 4-year institutions. Balancing student, curricular, and institutional expectations while keeping abreast of best teaching practices was both a challenge and an opportunity for growth in teaching pedagogy. Adjunct faculty who wish to earn a full-time salary experience challenges in balancing multiple institutions to gather enough income and challenges with being disconnected to and expendable by their institutions at times.

Answers to the second research question, “What specific math skills are valued?” were concentrated in basic math skills such as ratios, fractions, decimals, and measurement conversions. Open-ended responses emphasized the need for basic math support at a level lower than what is expected in the Bio2010 or AAAS Vision and Change Guidelines. The third research question sought insight into what faculty perceive as their efficacy in teaching quantitative skills in biology. Both the Phase 1 interviews and Phase 2 inventory survey demonstrated a gap between quantitative skills they know and what the faculty feel comfortable teaching (PCK). The final research question, “What are the needs of CC biology faculty to teach quantitative skills in their course?” in the Phase 2 survey mirrored the Phase 1 interviews, once again highlighting the need for supports for students and educators as well as access to open education resources, autonomy in course outcome and materials, as well as greater access and
funding support for PD. In the following chapter, specific study conclusions and recommendations are discussed.
Chapter 5: Conclusions and Implications

Conclusions

Quantitative/math skills are increasingly important for biology students, yet there are numerous challenges to incorporating quantitative skills into biology courses. The purpose of this study is to determine what quantitative/math skills CC biology faculty need and value in their curriculum. In Phase 1 of the research, the goal was to determine the advantages/affordances and challenges/constraints that CC instructors, in particular, face when incorporating quantitative/math skills into biology courses. As discussed, this needs assessment of CC biology instructors was important because 1) they teach a substantial percentage of undergraduate biology majors (McFarland & Pape-Lindstrom, 2016) and 2) few studies have focused on understanding the landscape of biology teaching and learning at CCs, which is likely different in key aspects than that of 4-year institutions (Schinske et al., 2017). In the first phase of the research, interviews with 20 CC biology faculty, nine themes emerged as challenges/constraints hindering CC faculty’s ability to integrate quantitative/math skills into their biology courses and nine themes that represented advantages for incorporating quantitative/math skills into CC biology classes. In Phase 2 of the research, responses to a nationwide inventory survey of biology faculty revealed that the previous themes were consistently present alongside inventory descriptors for quantitative/math skills in introductory biology courses. These advantages as they are described in the Phase 1 interviews and reinforced in the Phase 2 inventory survey can be used to address many of the challenges related to teaching quantitative skills that CC instructors identified and apply them to PD and curriculum design. Figure 22 displays the five main conclusions drawn from the research study followed by a
CC students have highly variable math backgrounds, necessitating added supports to help students learn quantitative/math topics.

Required learning outcomes and inherited curricula played a dual role in supporting or impeding quantitative/math skill in CC biology instruction.

Increased autonomy in CC teaching allowed some instructors to overcome limitations due to learning outcomes and inherited curricula.

Support from colleagues and professional development can help CC instructors learn new math skills and pedagogical content knowledge, alleviating constraints due to lack of instructors’ familiarity with math concepts.

Improving the accessibility of quantitative/math skills curriculum materials could alleviate challenges associated with lack of time to develop quantitative CC biology materials.

Figure 22: Study conclusions
description of each in subsequent paragraphs. Implications for the design of professional
development and suggestions for future research conclude the chapter.

**Study Conclusion #1: CC students have highly variable math backgrounds, necessitating added supports to help students learn quantitative/math topics.**

Every CC instructor that the researcher interviewed reported that there was considerable variation in math background or confidence in math abilities among students in their biology courses. This finding, combined with a lack of math prerequisites for biology courses, was reported as a challenge to incorporating quantitative skills into their courses. There is reason to believe that this variation may be more pronounced at CCs than at 4-year institutions. First, CC students are more likely to take developmental math courses than 4-year students (Chen, 2009), suggesting they are less academically prepared in mathematics. Previous mathematics experience influences students’ attitudes, self-efficacy, and anxiety toward math (Andrews, Runyon, & Aikens, 2017; Speth et al., 2017). A study of first-year students found those in developmental math had lower math self-efficacy and higher math anxiety than those in calculus (Speth et al., 2011). Second, CCs have a larger percentage of nontraditional students (McFarland & Pape-Lindstrom, 2016), who report lower math self-efficacy and higher math anxiety than traditional students (Durham et al., 2018; Woodin, Carter, & Fletcher, 2010). Despite the increased variation in student background that exists at CCs, instructors identified ways in which students were able to obtain out-of-class support that helped them succeed in classes that incorporate quantitative/math skills in biology.

Learning assistance centers or math resource centers that provide tutors or other types of remedial math support were helpful in addressing the wide variation in students’ math backgrounds. A learning assistance center is “a designated physical location on campus that
provides an organized, multifaceted approach to offering comprehensive academic enhancement activities outside of the traditional classroom setting to the entire college community” (Speth et al., 2011). Learning assistance center utilization, which often involves individual tutoring and remedial math support, has been shown to have a positive effect on student academic success in math courses (Manalo & Leader, 2007). Studies of CC students have shown that learning assistance centers and tutoring both contribute to students’ overall academic success (Wurtz, 2015), particularly for traditionally underserved groups (Schwehm, 2017; Wilson, Pickett, Wilson, & Pickett, 2017). CC students also reported that they valued learning assistance centers, especially when they work with individual tutors or coaches (Bruck & Bruck, 2018; Hendriksen, Yang, Love, & Hall, 2005; Perin, 2004). Importantly, tutoring support is not restricted to learning assistance centers. For example, online math tutoring has been shown to increase both CC and underserved students’ academic achievement as long as certain best practices are followed (Beal, Walles, Arroyo, & Woolf, 2011; Turrentine & MacDonald, 2006). Overall, this literature and results suggest that learning assistance centers and tutoring, when providing specific math skills and relating them to students’ courses, may help academically underprepared students master quantitative skills in their biology courses.

Instructors also expressed a desire to have students enter their courses having completed math prerequisites, which included remedial math courses, since they perceived students who had taken prerequisites to be better prepared to engage in quantitative/math tasks. Past research has shown that CC students who complete and pass remedial math sequences prior to engagement in other STEM courses tend to have greater success than those who do not (Chen, 2016; Ganga, Mazzariello, & Edgecombe, 2018). Yet, even though having math as a prerequisite for biology courses would help alleviate issues related to variable math preparation, it would
potentially introduce other problems related to retention. Developmental math sequences can increase time-to-degree, and in some cases, reduce retention since students in remedial courses are more likely to leave their program. In addition, positive outcomes are not always achieved for individuals who complete only part of their recommended developmental sequences (Chen, 2016). Thus, although exposing students to math prerequisites and/or developmental courses may help them grasp quantitative/math concepts when enrolled in biology classes, it may also have broader reaching negative effects on their persistence in STEM.

**Study Conclusion #2: Required learning outcomes and inherited curricula played a dual role in supporting or impeding quantitative/math skills in CC biology instruction.**

Established learning outcomes and inherited curricula constituted both a challenge as well as an advantage for including quantitative skill instruction in biology courses. Mandatory program learning outcomes are becoming more common at all institution types due to accreditation (Beno, 2004). Accreditors expect that institutions document student learning for each outcome; therefore, it becomes important for higher education institutions to continue to teach and assess these outcomes so that they can retain accreditation. Changing agreed-upon learning outcomes often involves a formal process including meetings and voting across an institutional district. At CCs, these outcomes are often linked to articulation agreements with 4-year colleges or workforce certificate programs in addition to accreditation (Beno, 2004), making them more challenging to change. Interviewees and survey respondents referenced biology course learning outcomes that were common across all sections of specific biology courses at their institution, or even across their CC system. In addition, as described by Vicky and Cam in Phase 1 interviews, there is pressure to keep learning outcomes constant over a large number of
sections taught by part-time instructors, many of whom are new to the positions each year and benefit from the added structure.

In some cases, these learning outcomes may benefit inclusion of quantitative/math skills instruction. Participants explained that since instructors are expected to teach content related to official learning outcomes, inclusion of specific quantitative learning outcomes facilitates inclusion of quantitative/math skills instruction in the course. In fact, in Phase 1 of the research, eight interview participants reported that including quantitative skills in learning outcomes or articulation agreements would incentivize more instructors to teach these skills. However, when course learning outcomes do not include quantitative skills, quantitative/math skills instruction can be hindered because there is not enough time to cover the required learning outcomes in addition to quantitative skills. This is especially true in classes where a larger proportion of the students are underprepared mathematically.

Like learning outcomes, inheriting curricula from other instructors could play a dual role in facilitating or hindering quantitative/math skills instruction, specifically situations in which existing curricula were handed down or imposed as “inherited curricula.” Though inherited curricula often did not include formal requirements such as learning outcomes, they may have imposed tacit social expectations on how to teach. This pressure was greater when more established instructors were teaching the course in a certain way and newer instructors felt that they could not deviate from the status quo. Other instructors felt that the inherited curricula was an easy way to approach teaching their classes because they lacked the time or activation energy that would be required to change the curriculum.

Study Conclusion #3: Increased autonomy in CC teaching allowed some instructors to overcome limitations due to learning outcomes and inherited curricula.
Despite common learning outcomes or inherited curricula that lacked quantitative components, several instructors felt that they had enough autonomy in their courses to incorporate these skills. Although they may have had to cover particular content to meet common learning outcomes, instructors were given freedom in how to teach the content, which afforded them opportunities to introduce quantitative skills related to the content. For example, one instructor from the Phase 1 interviews (Brianna) explained how she showed data and graphs whenever possible. Another instructor from Phase 1 (Ronnie) reported that she was able to incorporate HHMI activities related to course content to teach quantitative skills, although one might imagine that complete autonomy could have an opposite effect in some cases. For instructors who wish to avoid quantitative subjects, autonomy might allow them to easily leave quantitative skills out of the curriculum.

Part-time instructors may experience less autonomy than full-time instructors, making constraints due to learning outcomes and inherited curricula particularly salient for adjunct faculty. Statements by full-time instructors indicated that part-time instructors are more often asked to teach standardized curricula. Also, expressions from part-time instructors revealed that they may have to “wait” to change the curricula until they get a full-time position or older instructors move on. These statements are corroborated by studies of adjunct instructor job satisfaction, which have found that 2-year part-time faculty are less satisfied with their teaching autonomy than full-time CC faculty (Kinchen, 2010; Schmidt, 2008) or 4-year part-time faculty (Valadez & Anthony, 2001). However, some evidence indicates that gaps in satisfaction due to autonomy have lessened over the years (Eagan, 2008), and studies indicate that teaching support (e.g., resources, funds, and encouragement to improve teaching) from institutions and administrators can increase instructors’ sense of autonomy and satisfaction regardless of full- or
part-time status (Kinchen, 2010; Twombly & Townsend, 2008). Providing such supports, therefore, might also assist part-time faculty in incorporating quantitative/math skills or other innovations into their courses.

**Study Conclusion #4: Support from colleagues and professional development can help CC instructors learn new math skills and pedagogical content knowledge, alleviating constraints due to lack of instructors’ familiarity with math concepts.**

Participants acknowledged that they did not have expertise in particular quantitative skills, such as statistics, which would make it difficult for them to teach these skills. In some cases, this issue was due to the fact that a long time period had elapsed since they had used these skills in their own coursework or research. Yet, although knowledge of quantitative skills was necessary for instructors to teach quantitative/math skills, it was not sufficient. Many acknowledged that even if they were confident in their own quantitative skills, they were not confident in their math pedagogical content knowledge, which is known to be an important determinant of instructors’ teaching self-efficacy (Park & Oliver, 2008), ability, and likelihood of teaching the concept in question (Gess-Newsome & Lederman, 2001).

Social and intellectual support in the form of help from colleagues was identified as an important avenue by which biology instructors could learn quantitative skills and pedagogical methods for teaching mathematical concepts. Collegial interactions among instructors can be an important component of social support, leading to pedagogical change (T. C. Andrews, Conaway, Zhao, & Dolan, 2016; Tessa C. Andrews & Lemons, 2015; Penuel, Sun, Frank, & Gallagher, 2012). The study participants identified other biology instructors as well as math instructors as sources of support. Collaborations between math and biology instructors are particularly important for advancing quantitative/math skills instruction (Bergevin, 2010; Feser,
Vasaly, & Herrera, 2013). Although formal collaborations between math and biology instructors have resulted in extraordinary interdisciplinary curricula at the math-biology interface e.g., (Hern et al., 2009; Katkin & Reznik, 2005), the interviews demonstrated that simply having a collegial math faculty member consult for questions about teaching quantitative concepts could provide the support needed to teach quantitative skills for many CC instructors.

Professional development (PD) was also identified by participants as a way to provide intellectual support to either refresh math skills (e.g., statistics) or to learn new quantitative skills (e.g., bioinformatics, R), as well as to learn how to integrate these skills into their courses. A recent study examining quantitative PD for high-school instructors emphasized that PD should be long enough to provide both instruction in skills and engagement with exemplar curriculum materials (Schuchardt, Tekkumru-Kisa, Schunn, Stein, & Reynolds, 2017). This assertion echoes what this study’s participants desired from PD and what they found most valuable when participating in PD. Participants highlighted that they benefited most from PD when they could practice skills and adapt exemplar materials for their own course. A review of the faculty change literature emphasized that effective PD needs to go beyond simply supplying curricular materials to working with instructors over an extended period of time to help them implement curricular changes and provide feedback on the implementation (Henderson, Beach, & Finkelstein, 2011). Thus, social support is also an important component of effective PD. Studies of PD for CC instructors describe that “mentorship” models, in-person meetings, and open communication were all critical components in achieving PD goals, especially for part-time instructors and new CC instructors (Ching & Hursh, 2014; Diegel, 2013; Edwards et al., 2015). The same sentiment was expressed by several participants who mentioned the value of interacting with other PD participants as they worked to integrate new quantitative material into their courses.
Study Conclusion #5: Improving the accessibility of quantitative/math skills curriculum materials could alleviate challenges associated with lack of time to develop quantitative CC biology materials and lack of available quantitative/math skills materials.

This research uncovered several interesting findings regarding the accessibility of curricular materials developed to teach quantitative/math skills concepts. Although many participants reported using previously developed curriculum materials, often encountered through PD experiences, some participants reported that a lack of quantitative/math skills curriculum materials hindered their ability to incorporate quantitative skills into their biology courses. Many resources can be found online Table 1 in Aikens & Dolan, 2014, and Table 2 in Marsteller et al., 2010 (Aikens & Dolan, 2014; Marsteller et al., 2010). The results indicate that a lack of dissemination of quantitative/math skills materials, identified as a barrier by Marsteller and colleagues in 2010, still exists as a barrier today. CC instructors have limited access to resources and events where curriculum materials might be promoted (Schinske et al., 2017). For example, they often lack sufficient funds to pursue professional development, attend conferences, or pay for journal subscriptions. This suggests that more targeted efforts to advertise or distribute quantitative/math skills instructional resources to CC biology instructors may serve as an affordance to biology instruction.

In the same vein, a few participants discussed the paucity of quantitative/math examples in the texts used for their classes. This was highlighted specifically when referring to introductory biology texts, which generally lack features related to the scientific process, such as interpreting results and drawing conclusions (Duncan, Lubman, & Hoskins, 2011). One exception is the Integrating Concepts in Biology textbook (Campbell, Heyer, & Paradise, 2018), in which the authors explicitly included data analysis and interpretation questions, as well as a
feature called “BioMath Explorations” where students use math to explore biological concepts (Barsoum, Sellers, Malcolm Campbell, Heyer, & Paradise, 2013). However, it is unclear the extent to which such quantitative resources are used by CC instructors, and findings suggested that several of this study’s CC instructors use textbooks in which quantitative/math skills concepts are not readily addressed. This is concerning as it may exacerbate naïve expectations among students that biology does not involve math (Hall, Watkins, Coffey, Cooke, & Redish, 2011). It is also concerning as the absence of such materials would prove to be an additional barrier to finding and incorporating quantitative skills into CC biology classes.

**Implications for Professional Development**

This research has several implications for professional development of CC instructors and for administrators at CC institutions. The interviews and survey revealed that CC instructors desired professional development that would help them improve or develop their quantitative skills, provide quantitative curricula that is relevant and ready to embed in their courses, and facilitate their development of the Pedagogical Content Knowledge (PCK) necessary to teach the quantitative content. To accomplish this, professional development could be composed of workshops that focus on skill development followed by mentored teaching opportunities that focus on local adaptation of quantitative biology open-educational resources, which are freely accessible to all instructors. PCK is best developed through implementation of new curricula and subsequent reflection on the experience (Van Driel & Berry, 2012). Thus, a sustained professional development experience that encompasses implementation and reflection would facilitate the development of PCK. Indeed, reflection and feedback have been identified as critical to effecting change in teaching (Henderson et al., 2011). Moreover, a sustained professional development community and deliberate mentorship throughout the curriculum
change process has the potential to provide social support for QB instruction. This was identified as an affordance/advantage to teaching quantitative/math skills in biology by the participants and has been cited as an important component of success in CC PD e.g., (Edwards et al., 2015).

Additionally, professional development opportunities for CC faculty interested in quantitative biology instruction should include training on how to cater to classes that include students of highly variable math abilities and self-beliefs. CCs may have students who have not engaged in math for years and students who are experts in math in the same class. Therefore, professional development on differentiated instruction, a common practice in K-12 classrooms in which instruction is adapted to meet the individual needs of all learners in the classroom (Tomlinson, 1999; Tomlinson & McTighe, 2006), or quantitative biology professional development that includes specific curricular differentiated instruction strategies, may be particularly valuable to CC instructors. Training should also address how to help students with low math self-efficacy and high math anxiety. For example, cognitive reappraisal strategies, in which students are encouraged to reappraise their anxiety as beneficial for academic performance, has been shown to improve math test performance (Jamieson, Mendes, Blackstock, & Schmander, 2010). Likewise, expressive writing, in which students write about their worries, has been shown to improve performance of students with high math anxiety (Park, Ramirez, & Beilock, 2014).

**Future Research**

This study examined the needs of biology faculty to include quantitative skills in their courses, but community college mathematics faculty outside of the members of our expert panel were not consulted for their perspectives. This study could be expanded to include a coalition of math and science teachers in community college that includes an interdisciplinary approach to
professional development and curriculum design. The research began with a needs assessment for mathematical skills in the content of biology education by working with four large national organizations, BioQUEST, SABER, NABT, and QUBES, but future measures could be expanded to include mathematics organizations such as the National Council for the Teachers of Mathematics (NCTM). While the goal of this needs assessment was to develop a survey measure for assessing quantitative biology skills in CC courses, additional incorporation of mathematics faculty in the future would make for a strong interdisciplinary study.
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Appendices
## Appendix A: Expert Panel

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
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<tbody>
<tr>
<td>Melissa Aikens</td>
<td>Biology, University of New Hampshire</td>
</tr>
<tr>
<td>Ahrash Bissell</td>
<td>The NROC Project, Monterey Institute for Technology and Education, CA</td>
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<tr>
<td>Lisa Corwin</td>
<td>Ecology and Evolutionary Biology, Colorado University, Boulder</td>
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<tr>
<td>Linda Grisham</td>
<td>Director, Center for Teaching and Learning, Massachusetts Bay Community College</td>
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<tr>
<td>Louis Gross</td>
<td>Ecology and Evolutionary Biology and Mathematics, University of Tennessee, NIMBioS</td>
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<td>Kristin Jenkins</td>
<td>Director, BioQUEST, Montgomery Community College, MD</td>
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<td>Vedham Karpakakunjaram</td>
<td>Biology, Montgomery Community College, MD</td>
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<td>Stacey Kiser</td>
<td>Biology, Lane Community College, OR</td>
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<tr>
<td>Suzanne Lenhart</td>
<td>Mathematics, University of Tennessee, NIMBioS Education and Outreach</td>
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<td>Jillian Miller</td>
<td>Mathematics, Roane State Community College, TN</td>
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<tr>
<td>Claudia Neuhauser</td>
<td>Associate Vice President for Research, Director of Research and Computing, University of Minnesota</td>
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<tr>
<td>Christianne Nieuwsma</td>
<td>Mathematics, South Mountain Community College, AZ</td>
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<td>Anton Weisstein</td>
<td>Biology, Truman State University, MO</td>
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<td>Greg Wiggins</td>
<td>NIMBioS Education and Outreach</td>
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</table>
Appendix B: Interview Protocol

Welcome. Thank you for participating in this interview. The information you provide will be valuable for us to determine next-steps in CC faculty professional development in Quantitative Biology. My name is Sondra LoRe and I a research studying quantitative & math skills biology in Community College.

I appreciate your participation today and willingness to discuss your experiences teaching biology, and specifically your experiences and thoughts about teaching math and quantitative skills in biology. I want to learn about your experiences and thoughts. Your honest comments on these topics will help us learn about the landscape of quantitative biology instruction at CCs and better design professional development to meet CC instructors’ needs.

Before we begin, here are some tips that will help make our discussion today run smoothly. First, there are no right or wrong answers. I hope that you will feel free to share your thoughts and opinions, and that all of your thoughts and opinions are valuable. A little bit about privacy… your name will not be used in any reports about this project. You are welcome to use a nickname or to make up a name, if you don’t want to use your real name during this conversation.

I will be taking notes, but I will also be audio-recording today’s discussion. This helps me make sure I don’t miss anything that you say. The notes and recordings will not be shared with anyone outside of the research team. At any time if you do not want the recording of the discussion to continue, we can turn the tape recorder off. **You will not be personally identified or named in any reports from the research.**

Finally, I want to remind you that this is a research project and to make sure you understand your rights as a participant in this discussion. Most important for you to know is that
you can choose whether or not to answer any of the questions I ask. Participation is voluntary. Responses in no way impact your receipt of services from [conference organization or organization through which the participant was identified] and will not affect your participation in [conference/organization through which they were identified].

When you completed the online survey prior to this interview, you were asked to read a form saying what you are agreeing to do by taking part in the research study. By staying and participating, you are showing that you understand why you are here and that you agree to participate.

Before we start, do you have any questions about any part of the research study? Is there anything that’s not clear?

**Interview questions:**

1. Please tell me about the topics you teach that involve quantitative or math skills in biology.
   a. Do you typically teach these topics during a lecture section? A lab section?
   b. Which quantitative or math skills do you teach in your classes?
2. Please explain why you teach these topics in particular, what prompted you to teach these topics?
   a. Was your curricula for these classes inherited from a prior instructor or designed by you?
3. Please describe any barriers you perceive to teaching quantitative or math skills biology in your course.
   a. Barriers imposed by the institution?
   b. Barriers imposed by class structure?
   c. Barriers imposed by existing curricula or learning objectives?
   d. Barriers imposed by student background?
   e. Barriers imposed by personal capacity?
   f. Is there anything else that discourages you or makes it harder to incorporate these
skills into your classes?

4. Please describe any incentives or supports that exist to support faculty in teaching quantitative or math skills in biology at your institution.
   a. Are these incentives sufficient to support your instruction?
   b. Please describe other incentives or supports that would motivate you to incorporate more quantitative or math skills in your courses.

5. Please describe your use of quantitative or math skills in biology activities other than teaching.
   a. How often do you use these skills?
   b. Describe the context and purpose for their use.

We think of self-efficacy as one’s confidence in their ability to succeed at or accomplish a given task. I’ll first ask you about your personal quantitative or math skills and then how confident you are teaching these skills to your students.

6. Please describe the quantitative biology skills in which you are confident.
   a. Describe experiences that helped you develop confidence in performing quantitative/math biology skills.
   b. What training or experiences do you feel would help you or your colleagues to increase your confidence in performing quantitative/math biology skills?

7. Please describe the quantitative/math biology skills in which you are least confident.

8. Please describe the quantitative/math biology skills which you are confident in teaching.
   a. Describe experiences or actions you took to help you develop confidence in your quantitative/math biology teaching.
   b. What kinds of training do you feel would help you or your colleagues to increase your confidence in teaching quantitative/math biology?

9. Please describe the quantitative/math biology skills in which you are least confident in teaching.

10. Have you participated in any quantitative/math biology teaching trainings? If so, please describe your experience
   a. Did this training improve your confidence in your ability to teach quantitative/math biology skills?
   b. Describe how this training influenced your teaching of quantitative/math skills in
your biology courses.

11. If quantitative/math in biology training were available to you, describe what incentives would motivate you to participate?

12. Is there anything you would like to add or any thoughts you have on teaching quantitative or math skills in biology?
Appendix C: Quantitative/Skills in Biology Survey

INFORMED CONSENT STATEMENT:
Quantitative/Math Skills in Introductory Biology Inventory Survey

A. INTRODUCTION You are invited to take part in a research study designed to understand the needs of biology educators at the Community College and undergraduate level with regard to quantitative or math skills in their introductory biology courses.

B. INFORMATION ABOUT PARTICIPANTS' INVOLVEMENT IN THE STUDY
Your involvement in the study would include participating in an online survey for about 15-20 minutes.

C. RISKS There are no known risks associated with your participation in the project greater than those encountered in everyday life.

D. BENEFITS This research will help to understand the needs of faculty who teach introductory biology courses at the community college and undergraduate level to inform the design of future curriculum and professional development. There is no direct benefit to you for participating in the research study.

E. CONFIDENTIALITY of participant comments will be maintained. Participant comments noted will not be attributed to specific individuals. Data will be stored securely and only made available to the research and evaluation team at the University of Tennessee. Selected comments made may be included in reports and publications, but not attributed to individuals.

F. CONTACT INFORMATION If you have questions at any time about the study or the procedures, (or you experience adverse effects as a result of participating in this study,) you may contact the researchers, Sondra LoRe at slore@utk.edu or Gary Skolits, PhD at gskolits@utk.edu. If you have questions about your rights as a participant, you may contact the University of Tennessee IRB Compliance Officer at utkirb@utk.edu or (865) 974-7697.

G. PARTICIPATION Your participation in this study is voluntary; you may decline to participate without penalty. If you decide to participate, you may withdraw from the study at any time.

H. CONSENT I have read the above information. By clicking OK, I agree to participate in this study and will be directed to the survey

- OK, I agree to participate in this study.
- No, I do not agree to participate in this study
1. Please mark the level of importance of the following math skills in intro to biology courses. Make your choices based on your perceived importance to your course(s) and not on student ability.

It is (level of importance) for my students to be able to...

<table>
<thead>
<tr>
<th>Statement</th>
<th>Not Important</th>
<th>Of little importance</th>
<th>Of Average Importance</th>
<th>Very Important</th>
<th>Essential</th>
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<tr>
<td>write mathematical equations from a verbal description.</td>
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<td>understand rates of change.</td>
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<td>choose an appropriate model to describe a biological system or phenomenon (e.g. Hardy Weinberg, discrete vs. continuous, stochastic).</td>
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<td>explain descriptive statistics (e.g. mean, standard deviation).</td>
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<td>use statistical tests when appropriate (e.g. t-tests, chi-square).</td>
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<td>make simple probability calculations (e.g. Punnett square).</td>
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<td>convert units of measurement.</td>
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<td>determine that an answer is approximately accurate (does my answer make sense).</td>
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<td>scale up or down using magnitude and significant digits (scientific notation).</td>
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<td>use elementary functions (linear &amp; non-linear, exponential, and logs).</td>
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<td>create graphs (e.g. graph equations, interpret intercept &amp; assumptions).</td>
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<td>interpret graphs.</td>
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<td>interpret tables.</td>
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<td>manipulate equations (e.g. plug in values, solve for a value).</td>
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</tbody>
</table>

2.) Please add any additional mathematical skills that are of value to your courses and their level of importance.
3.) Please make the likelihood of students in your introductory biology courses being able to complete the following skills.

**Students in introductory biology courses at my institution are (likelihood) able to....**

<table>
<thead>
<tr>
<th>Statement</th>
<th>Definitely Not</th>
<th>Probably Not</th>
<th>Possibly</th>
<th>Very Probably</th>
<th>Definitely</th>
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</thead>
<tbody>
<tr>
<td>write mathematical equations from a verbal description.</td>
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<tr>
<td>understand rates of change.</td>
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<tr>
<td>choose an appropriate model to describe a biological system or phenomenon (e.g. Hardy Weinberg, discrete vs. continuous, stochastic).</td>
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<tr>
<td>explain descriptive statistics when appropriate (e.g. mean, standard deviation).</td>
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<tr>
<td>use statistical tests when appropriate (e.g. t-tests, chi-square).</td>
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<td>make simple probability calculations (e.g. Punnett square).</td>
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<tr>
<td>convert units of measurement.</td>
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<tr>
<td>determine that an answer is approximately accurate (does my answer make sense).</td>
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<td>scale up or down using magnitude and significant digits (scientific notation).</td>
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<tr>
<td>use elementary functions (linear &amp; non-linear, exponential, and logs).</td>
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<tr>
<td>create graphs (e.g. graph equations, interpret intercept &amp; assumptions).</td>
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<tr>
<td>interpret graphs.</td>
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<tr>
<td>interpret tables.</td>
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</tbody>
</table>

4.) Please share any additional comments about student abilities with regard to math skills in intro to biology courses at your institution.
5.) Using the same statements of math skills rate your confidence in teaching these math skills to students.

I have [confidence level] teaching my students how to …

<table>
<thead>
<tr>
<th>Statement</th>
<th>No Confidence</th>
<th>Slight Confidence</th>
<th>Moderate Confidence</th>
<th>Strong Confidence</th>
<th>Full Confidence</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

6.) Please add any comments:
### 7.) Please rate your level of agreement to the following statements about introductory biology

<table>
<thead>
<tr>
<th><strong>Statement</strong></th>
<th>Strongly disagree</th>
<th>Disagree</th>
<th>Indifferent</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I have the autonomy in how I teach introductory biology courses.</td>
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<tr>
<td>I am free to make changes to inherited curriculum at my institution.</td>
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<tr>
<td>Compensation is available for faculty to make changes to curriculum.</td>
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<tr>
<td>There are sufficient opportunities for me to collaborate with math colleagues.</td>
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<tr>
<td>My students are more engaged when quantitative skills are embedded in the curriculum.</td>
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<tr>
<td>Active learning is an effective way to embed quantitative skills in introductory biology education.</td>
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<tr>
<td>I am aware that previously developed curricula exist to support quantitative skills in introductory biology education.</td>
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<tr>
<td>I can access previously developed curricula to support the incorporation of quantitative skills in introductory biology education.</td>
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<td>There is support available to help me apply previously developed materials for my courses.</td>
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</tbody>
</table>

### 8.) Please add any comments:

---
9.) Please rate your level of agreement to the following statements

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly disagree</th>
<th>Disagree</th>
<th>Indifferent</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>There is a lack of developed curricular materials for including quantitative skills in introductory biology courses.</td>
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<tr>
<td>There are few people at my institution who support integration of quantitative skills in introductory biology courses.</td>
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<tr>
<td>There is a lack of time to integrate quantitative skills into introductory biology courses.</td>
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<tr>
<td>There is a lack of time to develop materials to integrate quantitative skills into introductory biology course.</td>
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<tr>
<td>I am not free to make changes to inherited curriculum at my institution.</td>
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<tr>
<td>Quantitative skills are not part of our introductory biology courses learning objectives.</td>
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<tr>
<td>Most students in introductory biology courses have math anxiety.</td>
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<tr>
<td>It is difficult to include quantitative skills into introductory biology courses because many students lack the necessary math skills.</td>
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<tr>
<td>I sometimes lack the confidence to teach math skills in an introductory biology course.</td>
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<tr>
<td>I am not familiar with the math skills associated with introductory biology curriculum.</td>
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<tr>
<td>There is pressure to teach certain topics that my students need to transfer to other institutions.</td>
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</tbody>
</table>

10.) Please add any comments:
11.) Please rate your level of agreement to the following statements regarding professional development opportunities.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly disagree</th>
<th>Disagree</th>
<th>Indifferent</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sufficient funds are available for professional development from my institution.</td>
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<tr>
<td>I am responsible for most of the costs associated with professional development opportunities.</td>
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<tr>
<td>Attending professional development about quantitative skills in biology would enhance my ability to incorporate such skills in my own courses.</td>
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<tr>
<td>I am likely to attend professional development when it provides new teaching materials.</td>
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<tr>
<td>Professional development is useful to my CV/resume.</td>
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<tr>
<td>Meeting other educators at conferences and professional development workshops is important.</td>
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<tr>
<td>My course load prevents me from participating in professional development.</td>
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<tr>
<td>I am available and willing to attend professional development online outside of traditional work hours.</td>
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<tr>
<td>When considering in-person professional development, location is important.</td>
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<tr>
<td>I am more likely to attend professional development when my classes are covered.</td>
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</tbody>
</table>

12.) Please add any comments about professional development opportunities:
13.) Please select your institution type (please check all that apply)
   - Community College
   - 4-year institution
   - High School
   - Minority Serving Institution
   - Tribal College
   - Public
   - Private
   - Parochial

14.) What is the size of your institution?
   - Less than 5,000 students
   - Between 5,000 and 10,000 students
   - More than 10,000 students

15.) Please select the state where you are teaching
   - [Dropdown w/state abbreviation]

16.) How many years have you been teaching?
   - 0-6 years
   - 7-12 years
   - 13-20 years
   - 21-30 years
   - More than 30 years

17.) What Biology Courses do you teach? (please check all that apply)
   - Intro to Biology
   - General Biology 1
   - General Biology 2
   - Anatomy & Physiology
   - Anatomy
   - Physiology
   - Ecology
   - Cellular biology
   - Evolution
   - Marine Biology
   - Human biology
   - Microbiology
   - Molecular Biology
   - Genetics
   - Other: __________
   - Other: __________

18.) What is your faculty status at your institution?
   - Full-time/permanent, tenure track
   - Full-time/permanent, non-tenure track
Part-time/Adjunct [Branching: If Part-time/Adjunct is selected]
  ○ Other:_____

18a. [Branching: If Part-time/Adjunct is selected]
How many institutions do you work as an adjunct professor?
  ○ 1
  ○ 2
  ○ 3
  ○ More than three

18b. Do you have office space at any of the institutions where you work as an adjunct?
  ○ Yes
  ○ No

18c. Does your schedule afford the opportunity to meet with students on campus?
  ○ Yes
  ○ No

18d. Are you compensated for office hours with students?
  ○ Yes
  ○ No

18e. Would you accept a permanent faculty position at your primary community college if it were available?
  ○ Yes
  ○ No

18f. What are the specific challenges you face as an adjunct professor?

18g. What are the specific benefits you experience from being an adjunct professor?

19.) What is your gender?
  ○ Female
  ○ Male
  ○ Non-binary/third gender
  ○ Prefer to self-describe: _____
  ○ Prefer not to say

20.) What is your race or ethnicity? [Check all that apply]
  □ White
  □ Hispanic, Latino, or Spanish
Black or African American
Asian or Asian Indian
American Indian or Alaska Native
Middle Eastern or North African
Native Hawaiian or other Pacific Islander
Other race or ethnicity (please specify): ___

21.) What is your highest level of education?
   o Associate degree (e.g. AA, AS)
   o Bachelor’s degree (e.g. BA, BS)
   o Master’s degree (e.g. MA, MS, Med)
   o Professional degree (e.g. EdS, MD, DDS)
   o Doctorate (e.g. PhD, EdD)

22.) Of which of the following organizations have you attended a regional or national conference? [Check all that apply]:
   o AACC (American Association of Community Colleges)
   o AMATYC (American Association of Two-Year Colleges)
   o NABT (National Association of Biology Teachers)
   o NSTA (National Science Teachers Association)
   o QUBES (Quantitative Biology Education & Synthesis)
   o BioQUEST Curriculum Consortium
   o ASE (Association for Science Education)
   o HAPS (Human Anatomy & Physiological Society)
   o AAAS (American Association for the Advancement of Science)
   o NAS (National Academy of Sciences)
   o AAB (Association of Applied Biologists)
   o ESA (Ecological Society of America)
   o ASCB (American Society for Cell Biology)
   o ASBMB (American Society for Biochemistry & Molecular Biology)
   o AIBS (American Institute for Biological Sciences)
   o None of the above
   o Other: _____
## Appendix D: Phase 1 Interview Codebook

### Challenges to Teaching Quantitative/Math Skills in CC Biology

<table>
<thead>
<tr>
<th>Code</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student background or ability</td>
<td>Student math backgrounds are often limited or out-of-date, making it more challenging to teach quantitative/math skills in biology.</td>
<td>[The students] have the ability to look at stuff, and we can work with them to figure out how to interpret. That's a skillset they have to work on, but in terms of their math backgrounds, a lot of our students come in with eighth grade or lower math levels. Trying to get them to understand and do the math behind any sort of statistical analysis, or even trying to get a nicer, maybe more complex or more in-depth kind of graphical representation can be difficult. - Cindy</td>
</tr>
<tr>
<td>Time in class</td>
<td>The lack of time available during class for math topics constrains quantitative/math instruction.</td>
<td>I guess another barrier would just be time. We have 15 week semesters and I just feel like I am just pressed for time a lot, to cover the information. Especially having going through and teach them how to do some basic algebra. - Sunny</td>
</tr>
<tr>
<td>Students self-efficacy or fear of math</td>
<td>Students’ confidence in their ability to do math or their fear of math make it more challenging to teach quantitative/math.</td>
<td>[the students] have a lot of math anxiety. I think that’s true, pretty much across the board with my students. I have a few students who come in and are reasonably comfortable with math, but even the students who are in higher math classes, will typically say that they’re not very comfortable doing it. - Debbie</td>
</tr>
<tr>
<td>Time to develop materials</td>
<td>The time it takes to develop new materials is substantial, constraining quantitative/math instruction.</td>
<td>...because of our teaching load, I did kind of just stick with that order because that’s what I inherited when I got here, and I hadn’t had time to fix it. I had that room this summer and this fall. - Mikaela</td>
</tr>
<tr>
<td>Familiarity with math</td>
<td>Instructors’ lack of familiarity or experience with certain math concepts, tools, or skills makes it more challenging to teach quantitative/math.</td>
<td>I would really like to teach R, and know R, but I don't know it at all. So I definitely can't teach it because I don't know it myself. - Ana</td>
</tr>
<tr>
<td>Math PCK</td>
<td>Instructors’ lack of math pedagogical content knowledge (how best to teach math topics) makes it more challenging to teach quantitative/math.</td>
<td>Respondent: As far as modeling goes, I feel comfortable talking about the theory behind the modeling but actually teaching the equations and the derivatives and the step by step, how we get there through the modeling,</td>
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<tr>
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<tr>
<td>Curricular resources</td>
<td>The lack of previously developed curricular resources available for CC quantitative/math instruction makes it more challenging to teach biology.</td>
<td>You see the latest equipment, or the cool lab, or whatever, but you don't see how to incorporate t tests and chi squared into your curriculum. - Cindy</td>
</tr>
<tr>
<td>Inherited curricula</td>
<td>Teaching materials that have been handed down from previous teachers or are the standard in what is used may constrain incorporation of quantitative/math into curricula if they do not already include quantitative/math skills.</td>
<td>[the curricula] was inherited. We have freedom with how we present it but as far as the curriculum map of the objectives and that sort of stuff, that was all laid out... The major's biology is [very] scripted. Way too cookbook for my liking but we did that because we have so many adjuncts, they figure it out that a lot of them weren’t even doing labs, they were skipping a bunch of stuff they were ... and so they .... and because we are so spread out at different campuses and stuff, and we teach a lot of concurrent stuff in high schools, they made it very ... we have a lab manual, we have a study guide that’s all the same. We still have variation in how we do things in class, but it’s all very scripted for the most part. - Cam</td>
</tr>
<tr>
<td>Social support</td>
<td>The lack of social support from departmental higher-ups or peers makes it more challenging to teach quantitative/math skills.</td>
<td>The intro is more of a barrier because there's so many faculty teaching and they're resistant to change. They know that it needs to be changed. They just are not convinced that this is the way to [successfully change] - Mary Beth</td>
</tr>
<tr>
<td>Cognitive overload with content</td>
<td>Adding quantitative skills to curricula results in cognitive overload (students being unable to cognitively process more information) which makes it more challenging to teach biology.</td>
<td>For the actual science majors, the ones that are in there, I think the class is just a lot, so they will do it, but I think at the time, there's just so much information coming out, and it's all new, all the cell stuff is new, that they have a bit of a harder time with the quantitative</td>
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<td>Definition</td>
<td>Example</td>
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<tr>
<td>Math-averse biology culture</td>
<td>The culture of biology and the expectations of biology are such that math is not viewed or presented as an important part of biology, making it more challenging to teach quantitative/math skill in biology.</td>
<td>There is an underlying cause. We've taught them that. Our biology education in the community has taught them to not expect [math], and to select against [math]. For the gen-ed classes they're taking it ’cause it's not chemistry and it's not physics. Part of that too is that we've done this to ourselves. - Vicky</td>
</tr>
<tr>
<td>Student interest</td>
<td>Students are not interested in and/or will not engage with quantitative/math content, making it more challenging to teach biology.</td>
<td>And then personally, I just think most students, like I said earlier, when you get to anything math, their eyes gloss over and roll back in their head and they zone out, and you can sit there for an hour, giving a great talk or whatever it is, and they'll still have no clue what you did an hour later, because they just zoned out because they heard the word 'math' or saw a summation sign. - Hugh</td>
</tr>
<tr>
<td>Learning outcomes</td>
<td>Institution-wide learning outcomes for biology courses often do not contain quantitative skills, making it more difficult to justify inclusion of quantitative/math skills in a class curriculum.</td>
<td>We don’t have any learning objectives or anything like that in the biology or any of the science curriculum that are quantitative in nature. It's more knowledge, content based. They'll know this, they'll know this, they'll learn that. That's probably one barrier, because we just don't, as a group, say that it's important. - Hugh</td>
</tr>
<tr>
<td>Inertia</td>
<td>The lack of an impetus / momentum / inertia constrains becoming engaged in quantitative skills instruction (i.e., there is no &quot;activation energy&quot; to initiate a change).</td>
<td>Sometimes it can be difficult, honestly, from an inertia standpoint. I already have my lecture slides prepared. Why would I want to modify them and make my life hard adding these two things? - Curt</td>
</tr>
<tr>
<td>Code</td>
<td>Definition</td>
<td>Example</td>
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<tr>
<td>Part-time instructor limitations</td>
<td>Part-time instructors experience unique challenges associated with resources or time available to dedicate to teaching, making it more challenging to teach biology.</td>
<td><em>I have to say that I think many instructors don't focus on [incorporating math]. I do not blame the adjunct faculty. They get paid less than full-time faculty and so I would say they're de-incentivized to do anything really extra.</em> - Mary Beth</td>
</tr>
<tr>
<td>Math support for students</td>
<td>The lack of support originating from outside of the classroom for students to learn and practice math skills makes it more challenging to teach biology.</td>
<td><em>I would guess no. If I can think of [no supports for students] other than ... I mean we have math tutors, but they don’t know Hardy-Weinberg is the example. They don’t know what that is. They’ll know the math if they look at it, but they don’t know it either.</em> - Linda</td>
</tr>
<tr>
<td>Difficulty in developing quantitative biology materials</td>
<td>It is difficult to develop quantitative biology lectures making it more challenging to teach quantitative biology.</td>
<td><em>As far as developing resources, yeah, it’s harder. It would be way easier to develop a lecture about something, than to find actual, real quantitative data on a lot of topics.</em> - Debbie</td>
</tr>
<tr>
<td>Classroom physical structure</td>
<td>Specific classroom physical structures make it more challenging to teach quantitative biology.</td>
<td><em>The class is typically taught in a standard lecture room, which makes it difficult sometimes in terms of technology with quantitative skills, so it tends to be limited to worksheet based, with calculators on their table.</em> - Ronnie</td>
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</tbody>
</table>
### Advantages to Teaching Quantitative/Math Skills in CC Biology

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professional development</td>
<td>Professional development in quantitative biology instruction can support incorporation of quantitative/math skills into instruction.</td>
<td>I think one of the things I actually got out of [professional development in QB] that I'm using right now is I'm doing figure of the day with my classes, which is working amazingly well. I do it in my lab courses, and my labs meet once a week. - Ana</td>
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<tr>
<td>Autonomy in teaching</td>
<td>Being able to decide on one's own topics and determine the direction of one’s own teaching allows incorporation of quantitative skills into instruction.</td>
<td>However, this semester I am the only person teaching the class, so I have redesigned the labs to be more quantitative focused. Much more so than they were in the past. - Ana</td>
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<tr>
<td>Curricular resources</td>
<td>Having access to previously developed and implemented quantitative/math instructional materials supports incorporation of quantitative skills into instruction.</td>
<td>[The national network] has lots of various activities that work in incorporating quantitative biology into courses. That has, at least for me, really improved the students' education. Instead of me coming up with something, using these well-developed materials that have been used over and over again and have been modified as problems have arisen and developed by other faculty. - Ana</td>
</tr>
<tr>
<td>Social support</td>
<td>When colleagues, chairs, or deans are supportive of and enthusiastic about quantitative biology teaching, this supports incorporation of quantitative/math skills into instruction.</td>
<td>Understanding that colleagues are [incorporating new curricula too], doing the same thing, colleagues are helping to kind of break this path through and we talk about it at meetings, we talk about it at undergraduate research meetings, department meetings, at conferences, seeing new ideas and basically stopping and thinking and going, &quot;Okay, well, you know, maybe I don’t have to keep doing it that way,&quot; I can toss it out and do something new. - Brianna</td>
</tr>
<tr>
<td>Prerequisites</td>
<td>Having a math prerequisite or corequisite for taking a course may support incorporation of quantitative/math skills into instruction.</td>
<td>Again, when we have a prerequisite on this class, which is something they keep fighting a little bit to try to get rid of because it does prolong a lot of students’ time at the college, but thus far we’re still winning. We are still winning that they have to take the math before they take our course. Then they still have to take this general class before they take anatomy</td>
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<td>Code</td>
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<tr>
<td>Math colleagues or</td>
<td>Coordination or collaboration with a math department or colleagues supports</td>
<td>And so, I reached out to a math colleague and they had some really better ways of explaining [the math concept], and helping the student understand, &quot;Oh, okay, I get it. Now it's gonna inverse.&quot; - Julie</td>
</tr>
<tr>
<td>departments</td>
<td>incorporation of quantitative/math skills into instruction.</td>
<td>We discuss things. This past semester I put the genetics lectures on Canvas and then we did a lot of the Punnett squares, monohybrid crosses, and dihybrid crosses in class. I think that worked out. Possibly that might be a route to go in the future to incorporate more quantitative elements into the classes, just put the lectures online and just cross your fingers and hope they watch them before they come to class. - Sunny</td>
</tr>
<tr>
<td>Active Learning</td>
<td>Teaching using active learning styles supports incorporation of quantitative/math skills into instruction.</td>
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<tr>
<td>Instructional grants or</td>
<td>Obtaining or receiving instructional grants supports incorporation of</td>
<td>...if I get the grant money that I applied for the college, I'm gonna try some [quantitative/math curricula] with my [Biology class] this semester. - Hugh</td>
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<tr>
<td>funds</td>
<td>quantitative/math skills into instruction via added time to develop curricula or incentives to try new things.</td>
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<tr>
<td>Access to technology</td>
<td>Having access to computer programs, such as Excel, can provide a resource that supports quantitative/math instruction.</td>
<td>I use Excel just because it's an easy program to teach students, and most students have access to Excel. - Hugh</td>
</tr>
<tr>
<td>National Initiatives</td>
<td>National initiatives and programs (e.g., Vision and Change) support</td>
<td>I think for us, the importance of incorporating and growing quantitative skills in our program, is based on our focus on Vision and Change, and quantification is one of the important competencies that is a part of that. And so, I think that any change that we have in our department, is gonna be motivated by that philosophical desire to improve our biology teaching based on that framework. - Tom</td>
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<tr>
<td></td>
<td>incorporation of quantitative/math skills into instruction.</td>
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<td>Code</td>
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<tr>
<td>Remedial math support</td>
<td>Support for students to gain remedial math skills before or outside of class supports incorporation of quantitative/math skills into instruction.</td>
<td>[The institution] has counselors and tutors available in a math resource center that we can contact and help put in touch with those students if they need some extra help, or remediation in certain skills...I've been able to send a student somewhere to help, and they've gotten that help if they sought it. - Julie</td>
</tr>
<tr>
<td>Learning outcomes</td>
<td>When quantitative skills are a part of the explicit learning outcomes for a class, it supports incorporation of quantitative/math skills into biology instruction.</td>
<td>We do some common questions for course-level outcomes. And some of those involve some quantitative reasoning. If you can give faculty these answers, say, &quot;This is an example of an exam. We look at it every year, and we drop questions.&quot; If you introduce that at the beginning of the quarter, then that helps scaffold what [new faculty members'] expectations are. - Vicky</td>
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<tr>
<td>Articulation with 4-year Biology curricula</td>
<td>Articulation with four-year school curricula can provide an incentive to teach QB if the four-year curricula include QB skills.</td>
<td>Like if the four-year schools in our state that our Board of Regents negotiates with started to demand those kinds of skills and competencies; I think that that would be probably the only incentive for faculty to go there. Because I think it is a challenging thing to do with students and if they don't have to, they don't. - Julie</td>
</tr>
<tr>
<td>Learning centers</td>
<td>Learning or Instructional Support Centers on campus can offer out of class support to students learning QB or support instructors' learning of QB and QB PCK.</td>
<td>Incentives and support...We do have a large ... It's called a STEM learning center, so science, technology, engineering and math, that has tutors. They were usually part-time work; full-time faculty members how are paid through a tutoring budget to assist students. - Curt</td>
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<tr>
<td>Small class size</td>
<td>Small class size allows more interaction with students and knowledge of what is happening in the class, supporting incorporation of quantitative/math skills into instruction.</td>
<td>I'm in a very small class size numbers; I get to know every single one of my students. I can usually, I mean as long as they're self-reported, I can pick up on any challenges that they're having, and I can work with them one-on-one - Julie</td>
</tr>
<tr>
<td>Required for accreditation</td>
<td>When quantitative/math is required for accreditation, it supports incorporation of quantitative skills into instruction.</td>
<td>...you know, for part of our accreditation you have to show that you include quantitative reasoning, so we know better than to remove it, at least from the course... - Sandy</td>
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<tr>
<td>Code</td>
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<tr>
<td>Classroom physical structure</td>
<td>Specific classroom physical structures may make it easier to teach quantitative/math skills in biology.</td>
<td>Sometimes we can get into a computer lab and do a little bit of heavier stuff in the lab. We can use laptops, which is great, but in lecture, we tend to be a little limited because our classes are bigger. - Ronnie</td>
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</table>
Incentives to Participate in Professional Development (PD)

<table>
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<tr>
<th>Code</th>
<th>Definition</th>
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<tbody>
<tr>
<td><strong>Attainment value</strong></td>
<td>Motivation to participate in PD that originates from viewing the PD activity as an activity of value to the communities the individual identifies with. This is often manifested by representations of value, such as awards.</td>
<td>Certainly, teaching awards can be nice... I don't know, recognition, small award from the department level or something or incorporating novel techniques and quantitative aspects into your microbiology course. Some nice sounding blurb. - Curt</td>
</tr>
<tr>
<td>Award or recognition</td>
<td>An award given or recognition from a meaningful community incentivizes participation.</td>
<td>[Attending] be very intrinsic. I'd be like, &quot;This is something I want to do.&quot; I would move forward. Again, I'm lucky that I'm at an institution where there's typically support for any sort of interest that you show in learning a new skill or bringing a skillset into the classroom. - Cindy</td>
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<tr>
<td><strong>Intrinsic value</strong></td>
<td>Motivation to participate in PD that originates from being interested in the topic or PD or a closely connected topic.</td>
<td>The biggest incentive just be improving my teaching and to help improve student's knowledge. - Sunny</td>
</tr>
<tr>
<td>Interest/value in quantitative skills for biology</td>
<td>Interest in quantitative skills as a topic incentivizes participation.</td>
<td>And, you know, the incentive of, at the end of the workshop, not only would I have new skills, but I would have things I could take directly into the classroom. I think that would be a big incentive. - Julie</td>
</tr>
<tr>
<td>Interest/value in student success</td>
<td>Interest in students’ success and recognition of quantitative/math skills as a component contributing to success.</td>
<td>[The professional development team] came out for a day and did professional development to a group of faculty at our community college and one other community college, they had faculty send to this workshop, and I brought them in</td>
</tr>
<tr>
<td><strong>Utility value</strong></td>
<td>Motivation to participate in PD that originates from viewing the PD as providing the necessary skills, experiences, or credentials to achieve a desired goal beyond simply attending the PD.</td>
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</tr>
<tr>
<td>New teaching materials</td>
<td>New teaching materials that can be used in one's classes to incorporate quantitative/math skills.</td>
<td></td>
</tr>
<tr>
<td>Gains in new math skills</td>
<td>New math skills that can be employed when teaching quantitative biology topics.</td>
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<tr>
<td>Code</td>
<td>Definition</td>
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<tr>
<td>Math PCK</td>
<td>New skills and knowledge regarding how to teach quantitative/math skills that can be employed when teaching quantitative biology topics.</td>
<td>Then I would love a work-through session where you could bring in some labs or some stuff and start to actually dig into the how would I adapt this; how would I incorporate those pieces into this material. - Cindy</td>
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<tr>
<td>Payment</td>
<td>Monetary payment as compensation for time spent.</td>
<td>Interviewer: ... if quant bio training were available to you, describe what incentives would motivate you to participate. Respondent: Probably money...Because it's hard to get ... we do so much without getting paid. To do something extra and not get paid is very challenging because we're always asked to do something extra - Sandy</td>
</tr>
<tr>
<td>Credential or CV</td>
<td>A credential or potential for a note to be included on a CV or in a future letter of recommendation, enabling access to future professional opportunities.</td>
<td>For me, personally, it would basically be about putting the recognition, the awards on future job applications, my CV saying, &quot;My colleagues have recognized me for this kind of expertise, this kind of ...&quot; - Curt</td>
</tr>
<tr>
<td>Networking</td>
<td>Introductions to and interactions with a new network of people that can offer various supports that assist with teaching QB skills.</td>
<td>So, having that incentive that there are going to be people in the region that [those who attend PD] can also interact with later when [the curriculum change] gets hard, and they have problems that they need to solve. - Vicky</td>
</tr>
<tr>
<td>Lower costs</td>
<td>Alleviation of barriers to participation that are associated with added difficulties including financial, time, and access difficulties.</td>
<td>So, travel costs paid would be a benefit. We don't have a lot of travel money at our institution and so, sort of help with those costs would be really important. - Julie</td>
</tr>
<tr>
<td>Alleviating financial costs</td>
<td>Paying for expenses associated with attending PD.</td>
<td>Time, like if it was during the week, to have substitutes to teach my class for example, so I could participate. - Kathy</td>
</tr>
<tr>
<td>Code</td>
<td>Definition</td>
<td>Example</td>
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<tr>
<td>Considering timing</td>
<td>Timing the PD so as to not conflict with important other obligations, such as finals, the first and last week of classes, etc.</td>
<td>And also, just a lot of people don't know how ... It's like this is a Friday Saturday, or a Thursday Friday, my answer's, &quot;No I can't do it cause I teach.&quot; If you have something that says, &quot;If you're teaching on these days here's how to do it.&quot; That would be a big help, because our teaching load is really high. - Vicky</td>
</tr>
<tr>
<td>Considering location (nearby)</td>
<td>Locating PD nearby or offering PD at locations that are easy to physically access.</td>
<td>The biggest one is, for those kinds of trainings ... If they're local, if they're at my school, I wouldn't really need incentives because it's something I really do want to improve. - Ana</td>
</tr>
</tbody>
</table>
Appendix E: Demographic Information from Phase 2 Inventory Survey

A demographic section followed the ranking sections of the survey to obtain background information about respondents. As previously discussed, 290 CC respondents are included in Phase 2 survey results, with 124 responses from institutions with more than 10,000 students, 94 from institutions between 5,000 and 10,000 students, and 72 respondents representing institutions with less than 5,000 students (see Figure 23). Five options were given for respondents to select a range of teaching experiences: 61 of respondents had 0-6 years of teaching experience, 60 respondents had 7-12 years, 79 had 13-20 years, 63 had 21-30 years, and 27 had more than 30 years of experience (see Figure 24).

The 290 responses to the survey came from faculty representing all US states except for Alaska, Maine, North Dakota, South Dakota, Vermont, and New Hampshire. Figure 25 displays a graphic picture of the responses via state. Circle size is representative of the number of responses per state; the larger the circle the greater the number of responses. For example, the state of Oregon had seven responses and Washington State had 13 responses.
Figure 23: What is the size of your institution?
Figure 24: How many years have you been teaching?
Figure 25: Please select the state where you are teaching
Respondents were asked to share their level of education, gender, race and ethnicity as displayed in Figures 26, 27, and 28. When asked to select their highest level of education, 146 or 50% indicated that they had a doctorate, 15 or 5% selected professional degree (i.e., EdS, MD, or MDDS), 123 or 43% of respondents selected master’s degree, and six or 2% selected bachelor’s. Four gender options were displayed on the survey including male, female, non-binary/third gender, prefer to self describe, and prefer not to say. The responses were as follows: 183 responses or 63.1% identified as female, 103 or 35.5% identified as male, two responses identified as non-binary/third gender, one or 0.3% or respondents selected prefer not to say, and the same number, one and 0.3% selected prefer to self describe and wrote female, gender non-conforming. The race and ethnicity of respondents are self-described in the following ways. Two respondents or 1% selected “other” and were asked to please describe, indicating they were “humans,” and two respondents or 1% described themselves as Native Hawaiian or other Pacific Islander. Twenty-four or 8% described themselves as Hispanic, 15 or 5% as Black or African American, 25 or 9% as Asian or Asian Indian, and 222 or 76% as white.
Figure 26: Highest degree
Figure 27: Gender
Figure 28: Race/Ethnicity
In the last section of the survey respondents to select all of the organizations where they have participated in a regional or national conference and 373 selections were made as displayed in Figure 29. Of note are that the two organizations with the highest participation are specifically geared toward biology and science teaching; the National Association of Biology Teachers (NABT) had 76 respondents and the National Science Teachers Association (NSTA) had 58 respondents report that they had participated in these organizations. Other high rates of membership were the American Association for the Advancement of Science (AAAS) at 46, and the Human Anatomy & Physiology Society (HAPS) at 44. Interestingly, the two listed organizations that are specifically geared toward CC education had a small representation, with only one respondent indicating participation in the American Association of Two-Year Colleges (AMATYC) and nine indicating the American Association of Community Colleges (AACC).
**Figure 29: Professional organizations**

<table>
<thead>
<tr>
<th>Organization</th>
<th>Percentage</th>
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</thead>
<tbody>
<tr>
<td>AMATYC (American Association of Two-Year Colleges)</td>
<td>1</td>
</tr>
<tr>
<td>AAB (Association of Applied Biologists)</td>
<td>2</td>
</tr>
<tr>
<td>NAS (National Academy of Sciences)</td>
<td>9</td>
</tr>
<tr>
<td>ASBMB (American Society for Biochemistry &amp; Molecular Biology)</td>
<td>9</td>
</tr>
<tr>
<td>AACC (American Association of Community Colleges)</td>
<td>9</td>
</tr>
<tr>
<td>AIBS (American Institute for Biological Sciences)</td>
<td>11</td>
</tr>
<tr>
<td>ASCB (American Society for Cell Biology)</td>
<td>20</td>
</tr>
<tr>
<td>QUBES (Quantitative Biology Education &amp; Synthesis)</td>
<td>27</td>
</tr>
<tr>
<td>ESA (Ecological Society of America)</td>
<td>30</td>
</tr>
<tr>
<td>BioQUEST Curriculum Consortium</td>
<td>31</td>
</tr>
<tr>
<td>HAPS (Human Anatomy &amp; Physiological Society)</td>
<td>44</td>
</tr>
<tr>
<td>AAAS (American Association for the Advancement of Science)</td>
<td>46</td>
</tr>
<tr>
<td>NSTA (National Science Teachers Association)</td>
<td>58</td>
</tr>
<tr>
<td>NABT (National Association of Biology Teachers)</td>
<td>76</td>
</tr>
</tbody>
</table>
Vita

Sondra LoRe grew up in Franklin Square, New York with plans to pursue teaching in mathematics and economics. She attended the University of Massachusetts, where she earned a bachelor of arts degree in economics. After working for two years as a corporate trainer in the Boston area she moved to East Tennessee with her husband to pursue her master’s degree in education. Upon completing her masters of science degree in curriculum and instruction from the University of Tennessee, she began teaching in grades K-6 in Knoxville area schools. While teaching and welcoming two children into her family, she completed her educational specialist degree in educational leadership, administration, and supervision from Lincoln Memorial University and spent the last 5 years of her 18-year service in K-12 as a school principal. In August of 2014, she began working as an evaluator of education programs at the University of Tennessee while earning her Ph.D. in Educational Psychology, in the evaluation, statistics, and measurement program.