5-2016

Evaluating College Biology Laboratory Accommodations For Students With Blindness And Visual Impairments

Barbara Rae Heard
University of New England

EVALUATING COLLEGE BIOLOGY LABORATORY ACCOMMODATIONS FOR STUDENTS WITH BLINDNESS AND VISUAL IMPAIRMENTS

By

Barbara Rae Heard

B.S. in Medical Technology (The Pennsylvania State University) 1973
M.S. in Biological Sciences (Western Michigan University) 2003

A DISSERTATION

Presented to the Affiliated Faculty of

The College of Graduate and Professional Studies at the University of New England

In Partial Fulfillment of Requirements

For the degree of Doctor of Education

Portland & Biddeford, Maine

May, 2016

Barbara Rae Heard
May, 2016
Educational Leadership

EVALUATING COLLEGE BIOLOGY LABORATORY ACCOMMODATIONS FOR STUDENTS WITH BLINDNESS AND VISUAL IMPAIRMENTS

Abstract

Studies show that active participation in science laboratory activities promotes student learning. However, students with blindness and visual impairments (BVI) often confront obstacles to active participation in the required activities of the college biology laboratory. Legislation requires institutions of higher education to provide accommodations for students with disabilities, yet the institutions must also maintain the academic integrity of their courses and programs. While college biology instructors provide specific accommodations, such as tactile models and audible devices, to enable active participation by students with BVI, they do so without research-supported guidelines for best practices. This mixed methods study sought to evaluate the effectiveness of the specific accommodations provided by gathering the perceptions of students with BVI who had successfully completed a college biology course, and college biology instructors who had taught a student with BVI. Data was collected entirely through researcher-developed, anonymous Internet surveys containing both closed- and open-ended questions. Effectiveness was evaluated by determining whether each student was able to meet seven criteria noted in the literature to be associated with active participation and student learning. Five students and 15 instructors participated. Specific accommodations were not provided for three students. Of the students provided specific accommodations, two met all seven criteria, 15 did not. Results of the study provided insight into methods for continued research evaluating the effectiveness of the specific accommodations provided for students with BVI in the college biology laboratory, and in the laboratories of other STEM disciplines. Study outcomes supported the importance of active participation by students with BVI in biology laboratory exercises, and were consistent with the need for advance planning, instructor professional development, and continued research. As more students with BVI realize success in the college biology laboratory, more may choose to pursue degrees in biology or other STEM disciplines, increasing the representation of students with BVI in the STEM professions.

Key words: *Accommodations, Biology, Students with blindness and visual impairments*

University of New England
Doctor of Education
Educational Leadership

This dissertation was presented
by

Barbara Rae Heard

It was presented on
March 21, 2016

and approved by:

Brianna Parsons, Committee Member
University of New England

Michael Patrick, Committee Member
University of New England

Mitchell Levy, Committee Member
Atlantic Cape Community College

DEDICATION

This book is dedicated to my parents, Murl E. and Harold R. Heard, and to my brother, H. Roderic Heard. Your remarkable lives of scholarship and vigilant community service were inspirational; your unconditional love and support sustaining. You are sorely missed.

ACKNOWLEDGEMENTS

I want to acknowledge SurveyMonkey® for providing information about accessibility, and thank the individuals in customer support for their prompt assistance as I developed and implemented the surveys. Word Press® deserves my appreciation for helping me create an accessible blog with customized headings and colors, and for rapidly responding to my inquiries. My thanks to Google™, which enabled me to locate and search through countless resources and solve the many frustrating formatting problems I encountered while composing this manuscript.

Rachel Kasperek in UNE's IRB department and Bethany Kenyon, access services librarian, deserve my appreciation for quickly and patiently answering all of my questions. UNE is fortunate to have you.

To Dr. Irene Duranczyk of the University of Minnesota I send my heartfelt thanks for generously donating ideas, support and encouragement at a time I needed them most.

I also send my deep appreciation to Sister Kenny. You were a woman of wisdom, perseverance, and courage who helped so many, including me. Thank you.

To my fellow biology instructors, Dennis, June, and Jolie, I extend my thanks for your generous suggestions, opinions, time, and support. I also want to thank Chris for his assistance in ensuring the student survey could be read by JAWS for Windows®.

I want to thank my informal study group: Andrea, Cassandra, Christina, Cristina, Henry, Jenn, Pam, Shelley, and Stefanie, and my dissertation group: Mary, Stefanie, Terri-Lynn, and Victoria, for your critiques, suggestions, moral support, humor, and encouragement. Each of you had a profound effect on my ability to cross this finish line. You helped to dispel the loneliness that pervades an online program, and spurred my determination to finish.

I want to acknowledge my dissertation chair, Dr. Brianna Parsons, for donating suggestions, advice, and prompt replies to my many queries. Dr. Michael Patrick provided important comments that enabled me to improve the content of this manuscript. Dr. Mitchell Levy offered valuable advice and critique of the content, in addition to insight into considerations for this study. Dr. Michelle Collay contributed numerous helpful suggestions during this project's formative stages. To each of those individuals I extend my sincere appreciation. Their gifts of time and continued support enabled me to navigate my way through the many challenges associated with this study.

Dr. Godfrey Barlatt deserves acknowledgment for supporting my decision to pursue this goal. Your continual interest, support, wisdom, and encouragement were sustaining. Thank you.

My astounding learning partner, Shelley McClure, earned my admiration, respect, and hearty thanks for being my rock and my champion. You are the epitome of an ethical scholar and are a true professional. Your honesty, generosity, insight, patience, and wisdom were invaluable; you both challenged and inspired me. I am so proud to call you my friend. Thank you for being you, and for always being there for me.

To the anonymous individuals who participated in this study I extend my sincere thanks for generously donating your precious time and for sharing your insightful stories.

To my brother, I send my thanks for being the best big brother any little sister could have had. My brother modeled integrity, wisdom, professionalism, and generosity, and his gifted quick wittedness is sincerely missed. I wish I could hear you say it one more time, Rod: "Be good to yourself!" I try.

My mother would have steadfastly supported my efforts to achieve this dream, for it was her dream as well. She returned to school later in life, paving the way for me. She taught me the

importance of kindness, and instilled in me a love for teaching. By helping to build schools and medical clinics, starting a preschool for disadvantaged children, and counseling hurricane victims, my mother provided the incentive for me to find my own way to give. Thanks for everything, mom.

My father had a story or quip for every occasion. He challenged me to think outside the box with his countless riddles and puzzles, encouraged me to examine issues from every perspective, and challenged me to always ask why. It was his personal struggle with macular degeneration that spurred my interest to find ways to support students with blindness and visual impairments. My father's integrity, humor, wisdom, strength, and devotion to God made him one of the finest individuals to have ever graced the face of this Earth. I was so fortunate to be his daughter. Words fail me. Thanks, daddy.

My dear sister, Carol, provided love and support during each step of this long path. Your confidence in my ability to complete this journey was steadfast. Thank you for always believing in me.

To my grandson, Liam, and my granddaughter, Melanie, I send my thanks for making me smile on even the darkest of days.

And finally, to my three lovely daughters, Jessie, Mandy, and Emma, I extend my sincerest appreciation for putting up with my absences, forgetfulness, endless queries about ways to increase the number of participants for this study, and your patient instruction in helping me solve the many problems with websites and social media. You are all remarkable individuals of whom I am so proud. Each of you is a precious gift that brings me incredible joy. You give my life meaning and make my life complete. I am truly blessed.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE: INTRODUCTION

The terms *science* and *laboratory* are inextricably bound. Course content comes "alive" in the science laboratory ("Neuroscience," 2010, para. 1), making it vital for all students taking a college biology course, including those with blindness and visual impairments (BVI), to actively participate in the laboratory exercises. According to the National Science Teachers Association (NSTA), the laboratory experience is an essential component of science courses ("The Integral Role," 2007). Laboratory exercises enable students to reinforce and apply concepts, explore the scientific method of research, use the techniques and tools of the field, interpret data, and formulate conclusions ("Scientific Inquiry," 2004). Active participation in the science laboratory improves student learning (Supalo, 2010), because "students learn when they construct their own understanding as a result of active engagement" (Goubeaud, 2010, p. 237).

In many states, such as Maryland, New Jersey, and Oklahoma, institutions require their degree-seeking students to take one general education laboratory science course ("A General Education," 2007; "Policy," 2016; "Student Guide," n.d.). The courses students can take to satisfy that requirement fall within the realm of "science, technology, engineering, and mathematics," or STEM ("Profile of Undergraduate Students," 2014, p. 44). Science courses within STEM include disciplines such as chemistry, physics, astronomy, earth science, and biology. Because more students with BVI are attending college (Callahan, 2011; Scott, 2009), it would follow that increased numbers of students with BVI are enrolling in laboratory science courses to meet general education requirements. Despite that potential increase, students with BVI do not routinely enroll in college biology courses. When they do, they may be expected to view specimens under a microscope (Fitch, 2007) or record field observations (Moon, Todd, Morton, & Ivey, 2012). Those tasks can present obstacles for students with BVI.

Visual impairments range from mild visual impairment to total blindness ("Blindness and Vision," 2011, para. 1). Blindness is a "severe vision impairment, not correctable by standard glasses, contact lenses, medicine, or surgery" (para. 1). Contrary to what many people believe, individuals classified as legally blind may have some degree of visual ability ("How Blind," 2016). However, according to the Centers for Disease Control and Prevention, the lives of individuals with blindness are profoundly affected by the disability ("Blindness and Vision," 2011). Those difficulties can translate into obstacles for students with BVI in higher education.

Legislation and organizational policies are reducing barriers to success for students with disabilities. The provisions of the Americans with Disabilities Act (ADA) pertain to post-secondary institutions, and apply to state-funded as well as "private colleges and vocational schools" (Leuchovius, 2003, p. 1). The ADA "prohibits discrimination and ensures equal opportunity" for all individuals ("The Americans," n.d., para. 1).

Also contributing to reducing barriers are statements from the National Science Board, which affirmed in its 2010 report that "every student in America deserves the opportunity to achieve his or her full potential" ("National Science Board," 2010, p. v), and the National Science Teachers Association, which advocates for the safe inclusion of students with "physical needs" in laboratory experimentation ("The Integral Role," 2007, para. 2). Perhaps as a result, the number of students with disabilities seeking higher education degrees is now on par with that of non-disabled students ("Briefing Paper," 2015). Statistics reveal, however, that only 4% of students with disabilities study in the natural or physical sciences (NCES as cited in Moon et al., 2012).

Approximately 26 million students were enrolled as undergraduates in the 2011-12 school year (Radwin, Wine, Siegel, & Bryan, 2013). Just over 11% of those undergraduate students declared a disability ("Profile of Undergraduate Students" 2014). Of the 26 million undergraduate students, 6.5% declared a major in a natural or physical science. Of those approximately 1.7 million students, only 5.3%, or fewer than 90,000 students, also disclosed a disability. The number of students with BVI enrolling in STEM courses, declaring STEM majors, and/or pursuing graduate STEM degrees was not located, but 3.6% of the undergraduate students disclosing a disability in the 2011-2012 school year disclosed a visual disability ("Profile of Undergraduate Students," 2014). That number was an increase from the 2007-08 value of 2.7% ("Profile of Undergraduate Students," 2010).

The U.S. Bureau of Labor statistics indicated in 2014 that of individuals over 25 with a disability, approximately 16% earned a bachelor's degree. That figure is more than double for individuals without a disability ("People With A Disability," 2015). For students pursuing graduate STEM degrees, 5% reported disabilities. Only 1% succeeded in earning a doctoral degree in a STEM field (Moon et al., 2012). Employment statistics do not paint a better picture. Just over 26% of individuals over 25 with disabilities who have earned a bachelor's degree are employed, whereas almost 76% of individuals over 25 with a bachelor's degree who do not have a disability are employed ("People With A Disability," 2015).

The paucity of students with disabilities in the STEM disciplines has several causes. Children with disabilities may not be exposed to scientific experiences during their early education that tend to spark an interest in science, possibly arising from the lack of adequate teacher preparation in supporting students with disabilities (Moon et al., 2012). Some students with disabilities have been persuaded against seeking a degree in a STEM discipline by the time they enter college, and some individuals with disabilities were "excluded from post-secondary STEM education" (p. 10). Pertaining specifically to students with BVI, Fraser and Maguvhe (2008) noted that many instructors "are not aware of what should be done to accommodate blind and visually-impaired learners . . . . [so] they discourage blind learners to take or consider science-related subjects as curriculum choices (p. 85). Further, many teachers in pre- and post secondary education have historically believed that the content in science was too visually based for those with blindness or visual impairments (Scadden as cited in Supalo, 2013).

To support students with BVI in higher education, general accommodations are provided. Those can include additional time to complete assignments, note takers, and tape recorders ("Accommodations," 2015; Sharpe, Johnson, Izzo, & Murray, 2005). Students with BVI need support beyond general accommodations in the science laboratory to enable them to complete specific tasks such as accurately measuring liquids and recording temperature and pH measurements. When students with BVI enter the biology classroom, accommodations specific to the biology laboratory must be provided for them, such as tactile models (Caldwell & Teagarden, 2007; Derra, 2015; Hutson, 2009; Miecznikowski, Guberman-Pfeffer, Butrick, Colangelo, & Donaruma, 2015; Rule, 2011; Wedler et al., 2012; Winograd & Rankel, 2007) and audible devices (Supalo, Wohlers, & McEnnis, 2009). Yet college biology instructors have little experience supporting students with BVI in their classes (Womble & Walker, 2001). Caldwell and Teagarden (2007) remarked that their students with BVI were, as far as they could determine, the first students with BVI to take general biology at West Virginia University. Regarding that inexperience, Moon et al. (2012) commented that "professors are frequently unable, unprepared, or otherwise ill-equipped to recognize and address the needs of students with disabilities" (p. 12). Additionally, instructors may be unfamiliar with available accommodations or they may lack "resources to make accessible pedagogy a reality" (p. 12). The problem is compounded because there are no standards regarding the specific accommodations provided for students with disabilities in science laboratories (Moon et al., 2012). Despite those facts, college biology instructors are providing specific accommodations for students with BVI in their laboratories (Caldwell & Teagarden, 2007; Derra, 2015; D. Huey, personal communication, November, 2014; Vollmer, 2012; Womble & Walker, 2001; J. Xu, personal communication, July, 2014).

Individuals with disabilities are underrepresented in the STEM disciplines both as students and as employees (Moon et al., 2012) in spite of the number of students with disabilities attending higher education. Enabling successful completion of college biology courses is one avenue that could improve the representation of individuals with disabilities in the STEM fields. To increase the number of students with BVI who successfully complete college biology courses, it is necessary determine whether the specific accommodations provided for them are effectively meeting the needs of both the students and the instructors. The lack of standards, coupled with instructor inexperience, begs the question of whether the specific accommodations are meeting those needs.

Study Problem, Purpose, and Research Questions

Students with disabilities confront the same anxieties transitioning to college as students who are not disabled, such as the influence of "attachment to parents and to peers" on a student's ability to adapt to college life (Lapsley, Rice, & Fitzgerald, 1990, p. 564). In addition, students with disabilities must surmount the difficulties presented by their disability (Adams & Proctor, 2010). As a result, students with disabilities "were more likely to report feeling that they do not fit in well as part of the college environment and may [have] thoughts of dropping out" (p. 175).

Despite the potential challenges, increased numbers of students with BVI are enrolling in college (Callahan, 2011; Scott, 2009), and students with BVI are taking college biology courses (Caldwell & Teagarden, 2007; D. Huey, personal communication, November, 2014; Hutson, 2009; J. Xu, personal communication, July, 2014; Vollmer, 2012; Womble & Walker, 2001). To support students with BVI in the science laboratory, many types of specific accommodations exist. However, there are no regulations regarding which specific accommodations must be provided for students with BVI. No studies have identified "a standard design for an accessible lab in any major STEM field" (Moon et al., 2012, p. 31). Models and technological devices are available from manufacturers; many adaptations can be modified or created on site. Thus, the specific college biology laboratory accommodations provided for students with BVI to enable them to participate in and learn from the laboratory exercises could vary by institution and among different instructors. Additionally, Pence, Workman and Riecke (2003) remarked, "unfortunately, most individual faculty encounter specific disabilities so rarely that they have little opportunity to build an experience base" (p. 295).

The "equal opportunity" required by the ADA ("A Guide," 2009, para. 9; "The Americans," n.d., para. 1) does not include lowering academic standards ("Reasonable," 2016). In fact, according to a consultant who specializes in providing legal guidance to colleges regarding ADA lawsuit compliance, it is the responsibility of colleges to give "equal weight to the academic integrity of institutional programs and the student's right of access to those programs" (S. Heywood, personal communication, September, 2015). Therefore, the provided accommodations specific to the college biology laboratory must enable "equal opportunity" ("A Guide," 2009, para. 9; "The Americans," n.d., para. 1) while maintaining the academic standards of the course ("Reasonable," 2016).

The availability of specific accommodations for students with BVI does not ensure their effectiveness, however. Several criteria were noted in the literature as important to student learning. Application of those criteria would require the specific accommodations to enable the opportunity for a student with BVI to (a) safely and actively participate in the laboratory activities (Duerstock et al., 2014; "The Integral Role," 2007), (b) be engaged in the class (Gormally, Brickman, Hallar, & Armstrong, 2011; Sinatra, Heddy, & Lombardi, 2015), (c) be accepted by classmates (Scruggs and Mastropieri, 2007; Supalo, 2010), (d) contribute to group activities (Barbosa, Jófili, & Watts, 2004; Gaudet, Ramer, Nakonechny, Cragg, & Ramer, 2010; Gormally et al., 2011), (e) demonstrate required skills (Di Trapani & Clarke, 2012; Fitch, 2007; Hunt, Koenders, & Gynnild, 2012), (f) meet all academic requirements ("Reasonable," 2016), and (g) acquire knowledge commensurate with that of their sighted classmates (Duerstock, 2015). Those standards are hereafter referred to as the *seven criteria,* as indicated in Figure 1.

Specific accommodations are provided for students with BVI in the college biology laboratory to enable successful completion of the course under the assumption that they are effective. Research was required to validate that assumption. One study was located that solicited student input to evaluate the effectiveness of tactile accommodations in the biology laboratory (de Souza et al., 2012). No studies were located that utilized the perspectives of both students with BVI and the instructors of students with BVI to determine whether the specific accommodations provided in the college biology laboratory were effective.

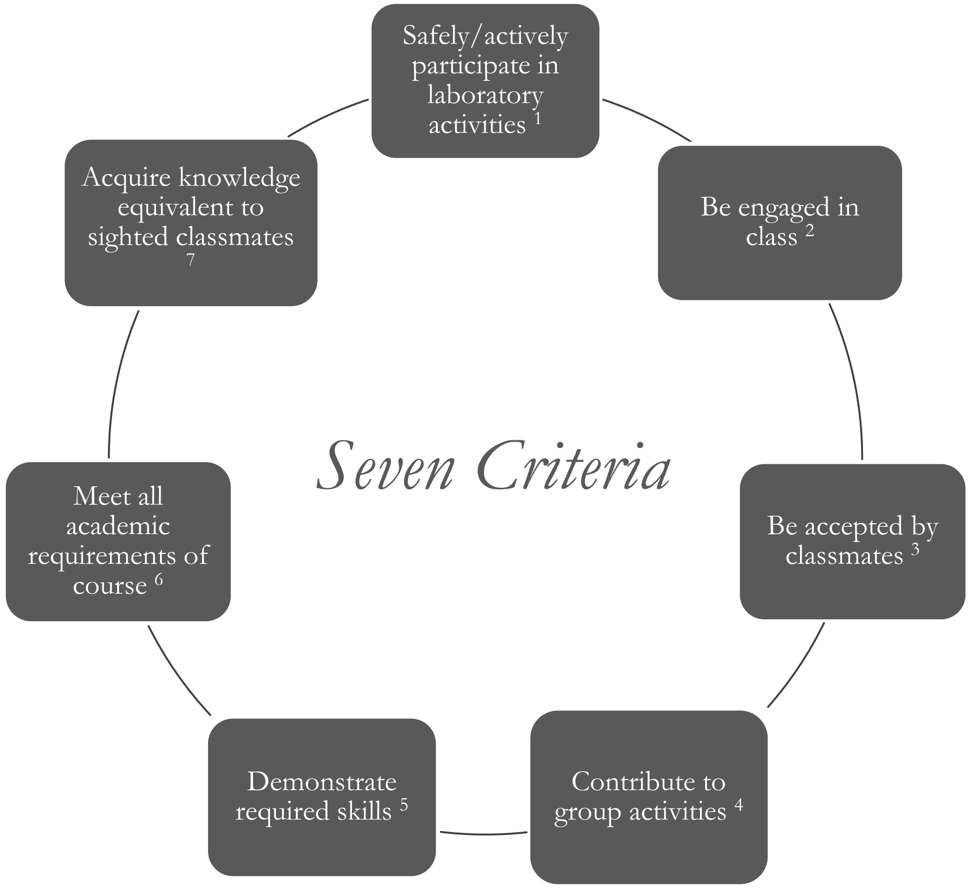

Figure 1. The *seven criteria*. 1 = Duerstock et al., 2014; "The Integral Role," 2007; 2 = Gormally et al.; Sinatra et al., 2015; 3 = Scruggs & Mastropieri, 2007; Supalo, 2010; 4 = Barbosa et al., 2004; Gaudet et al., 2010; Gormally et al., 2011; 5 = Di Trapani & Clarke, 2012; Fitch, 2007; Hunt et al., 2012; 6 = "Reasonable," 2016; 7 = Duerstock, 2015.

Specific accommodations in the college biology laboratory for students with BVI must be effective. To be effective, the specific accommodations must have met student and instructor needs. This mixed methods research study aimed to determine the effectiveness of specific college biology laboratory accommodations provided for students with BVI by examining the perspectives of both students with BVI who had successfully completed a college biology course, and those of college biology instructors of students with BVI. Accommodations must have permitted "equal opportunity" ("A Guide," 2009, para. 9; "The Americans," n.d., para. 1) to the student with BVI and enabled the academic standards of the course to be maintained

("Reasonable," 2016). Therefore, to be considered effective in this study, the specific accommodations must have enabled the student with BVI to meet the *seven criteria*.

An integral component in evaluating the effectiveness of the specific biology laboratory accommodations was the ability of the students with BVI to successfully complete the routine assessments of the laboratory portion of the biology course. Although researchers have noted that grades can be an invalid assessment of student learning (Allen, 2005), assessment in higher education enables institutions to demonstrate that their programs and courses meet high standards and graduate knowledgeable students (Goubeaud, 2010). Using the routine assessments of the course alone to evaluate the effectiveness of the specific accommodations would not have been appropriate, however. Grades do not normally reflect an evaluation of a student's safety, engagement, or acceptance by classmates, and skills and group contributions are not assessed in all college biology courses. Additionally, because laboratory exercises are often adapted for students with BVI, the assessments may have been altered as well, making equivalent assessment of learning difficult. Therefore, while this study focused on students who had successfully completed the course with a C or better, an indicator of successful completion of a course often used by institutions of higher education ("Prerequisites," n.d.; "Understanding," 2015), grades alone could not be used to determine whether the accommodations provided for students with BVI in the college biology laboratory were effective. Student and instructor perceptions of all *seven criteria* were necessary to ascertain the effectiveness of the specific accommodations.

To evaluate effectiveness, this study gathered college biology instructor's perceptions of whether the student with BVI was able to safely and actively participate in the laboratory exercises, remain engaged in the class, be accepted by classmates, make contributions to the group, master required laboratory skills, meet the academic requirements of the course, and learn as much as sighted classmates. Those perceptions were gathered to indicate the confidence of the instructors as to whether the student with BVI received "equal opportunity" ("A Guide," 2009, para. 9; "The Americans," n.d., para. 1), and learned the course content and required skills at a level comparable to the sighted students in the class who earned the same grade. In addition to the importance of instructor perceptions, Reinschmiedt, Sprong, Dallas, Buono, and Upton (2013) noted that the perceptions of the individuals with disabilities must be considered to determine whether accommodations met their needs. Student perspectives were gathered to indicate whether the students felt safe while participating in the laboratory exercises, believed they were engaged in the class, felt accepted by classmates, contributed to group activities, demonstrated required skills, met the academic requirements of the course, and felt he or she learned as much as sighted classmates receiving the same grade. Consequently, in addition to the grade achieved through college biology laboratory assessments, the perceptions of the students with BVI and instructors regarding many aspects of the laboratory experience were used to determine the effectiveness of the specific accommodations provided. Those perceptions were gathered through anonymous online surveys that included both closed- and open-ended questions.

This research enabled students with BVI to express their opinions about the specific accommodations provided for them in the college biology laboratory relative to their academic success. The study also enabled instructors of students with BVI to articulate their perceptions regarding the specific accommodations and the academic success of the students with BVI. It was believed that the perceptions conveyed by those combined voices would enable determination of whether the students with BVI met the *seven criteria*, and by extension would indicate whether the specific accommodations provided for students with BVI in the college biology laboratory were effective.

The central question guiding this research was whether the specific accommodations provided for students with BVI in the college biology laboratory were effective in meeting the needs of both the students with BVI and the instructors. This research study, therefore, was guided by two primary research questions:

> What are the perceptions of students with BVI regarding their experience in the laboratory portion of a college biology course?
>
> What are the perceptions of college biology instructors regarding their experience teaching a student with BVI in the laboratory portion of a college biology course?

Three sub-questions extended the inquiry and provided pertinent data for this study:

> To what extent do students with BVI believe that specific accommodations provided for them in the college biology laboratory enabled them to meet the *seven criteria*?
>
> To what extent do instructors believe that specific accommodations provided for students with BVI in the college biology laboratory enabled them to meet the *seven criteria*?
>
> What course and assessment modifications do college biology instructors believe should be made for students with BVI in the college biology laboratory?

Study results could be used to inform best practices in supporting students with BVI in the college biology laboratory, thus outcomes would be of interest to students with BVI and their parents, science educators, administrators, and individuals in disability support services. Additionally, this study collected data on the types of specific accommodations provided for students with BVI in the college biology laboratory, and which specific accommodations both instructors and the students believed were most beneficial. Each student has different needs depending on his or her particular visual challenge, necessitating that some accommodations be unique to the student, so that knowledge could inform future practice. Instructor perceptions regarding curriculum and assessment alterations that may be necessary to evaluate the learning and skills of students with BVI were also collected. Those opinions should prove informative as well.

Conceptual Framework

College biology instructors have limited experience teaching students with BVI (Womble & Walker, 2001), so it follows that few students with BVI have completed college biology courses. Despite that inexperience, instructors are providing specific accommodations for students with BVI in the college biology laboratory to enable successful course completion (Caldwell & Teagarden, 2007; Derra, 2015; Vollmer, 2012; Womble & Walker, 2001), and must do so in the absence of regulations or guidelines specifying what specific accommodations must be provided (Moon et al., 2012).

This study intended to evaluate the effectiveness of the specific laboratory accommodations provided for students with BVI in college biology courses. Perceptions of students with BVI who had successfully completed a college biology course, and of the instructors who taught students with BVI in a college biology course, provided insight regarding the effectiveness of those accommodations in providing the students with the "equal opportunity" to which the law entitled them ("A Guide," 2009, para. 9; "The Americans," n.d., para. 1), and whether the academic standards of the course were maintained ("Reasonable," 2016). Student perspectives were necessary because the students with BVI who had successfully completed college biology courses needed a voice regarding the specific accommodations provided for them. It is important to include the opinions of the students with disabilities in evaluating accommodations (Reinschmiedt et al., 2013). Further, Dill and Beerkens (2013) stated that "academic programs designed by and whose standards are assured through the collective actions of knowledgeable faculty members" provide maximum advantage to students (p. 354). Therefore, student and instructor perspectives were necessary to determine whether the specific accommodations met both student and instructor needs. *Seven criteria* identified as important to student learning in the college biology laboratory were used to evaluate the specific accommodations. In this study, if the specific accommodations enabled students with BVI to meet the *seven criteria*, it was concluded that they met student and instructor needs, and were therefore considered effective.

This study applied a "transformative mixed methods" approach because of its focus on issues affecting "marginalized" individuals (Creswell, 2012, p. 546), such as students with BVI. Instructors of students with BVI in the college biology laboratory and students with BVI who had successfully completed a college biology course that included a laboratory component were surveyed relative to their perceptions of the *seven criteria.* Answers to questions on the online questionnaires were examined with the intent of evaluating whether the specific accommodations for the students enabled a laboratory experience similar to that of sighted students receiving the same grade, and that students and instructors were confident that course rigor was maintained. Results were examined through the melded lenses of transformative learning theory, social justice education theory, and critical theory to determine whether the students were able to realize the "equal opportunity" required by law ("A Guide," 2009, para. 9; "The Americans," n.d., para. 1) and by social justice (Mertens, 2007; Torres, 2008). Additionally, the results evaluated whether the students and instructors felt that the academic standards of the course were maintained.

Assumptions and Limitations

This study assumed that the perceptions of instructors and students with BVI collected after course completion accurately reflected their actual experiences. Collecting data through anonymous online surveys precluded verification that participants met the specific criteria required for the study. It was assumed that only students with BVI meeting all study criteria, and only college biology instructors who had taught a student with BVI meeting study criteria, would complete the online questionnaires. Further, it was assumed that each institution had similar academic and skills requirements in comparable biology courses.

To participate in the study, individuals needed computer and Internet access. Unless participants learned of the study from the study website, or through social media, an email address was also required for study notification. Students with BVI also may have required a screen reader in order to complete the online survey. Prior to release, the student survey was checked for compatibility with JAWS® screen reading software, but students may not have had access to that software. The study also pre-selected for students who had completed the biology course with a C or better, limiting the respondents to those students able to successfully pass the class.

Another assumption dealt with the specific accommodations. Instructors may have determined that specific accommodations were not required for the student with BVI, when in fact the student would have benefitted from specific accommodations. Additionally, instructors may have indicated that tactile models were provided, but not all tactile models are equal. Some could have been created on site from special paints or other materials; other institutions may have purchased tactile models from companies specializing in their manufacture. This study assumed that all tactile models offered equivalent learning, and did not address any differences in the effectiveness of various tactile models. Other types of accommodations specific to the biology laboratory, such as audible thermometers, were also assumed to have equal efficacy regardless of different features or manufacturers. Further, no conclusions would be possible relative to which type of specific accommodation is best for different levels of visual challenge. Results of this study could not be used to determine whether audible or tactile modifications are best for students with blindness, for instance. Nor can study results aid in determining which type of accommodation works best for particular biology exercises. The latter considerations would need to be addressed in subsequent studies.

Some instructors may have already taught a student with BVI in the college biology laboratory, affording the instructor previous experience working with students with BVI. Likely, the available accommodations specific to the college biology laboratory at that institution would have been improved based on that prior knowledge. The student with BVI at that institution could have benefitted from the knowledge and techniques gained from that prior experience, suggesting a better experience for that student compared to the experience of a student with an instructor with no previous experience. Thus, the disparity in prior experience teaching students with BVI could have affected study results. To address that potential limitation, instructors were asked to indicate whether they had prior experience teaching a student with BVI.

Limitations also included the potential for instructors to bias the results because of their personal beliefs as to whether students with BVI should take college biology classes. Harshman, Bretz, and Yezierski (2013) remarked on the importance of positive instructor attitude toward students with BVI, and that they must "be willing to accommodate instruction and assessment" (p. 714). Students with BVI could have influenced the results based on their experiences with classmates, the instructor, or their grade, rather than basing their responses on the specific accommodations provided for them. Also, a portion of the instructors may have devoted extra time to the students with BVI.

Data was not located that enabled estimation of the number of potential participants in this study, but sample size was another limitation of this study. Because of limited instructor experience (Womble & Walker, 2001, p. 396), it follows that the number of instructors and students with BVI meeting participant criteria for this study was limited. Some individuals may have declined to participate for fear of being identified.

Scope and Significance

Student participants in this study had to be at least 18 years of age, and to have a visual impairment disclosed to the disability support services office (or equivalent) of their institution at the time they completed the college biology course. The course must have included a laboratory component that met in a face-to-face format. Further, the student must have taken the course at a two- or four-year institution sometime between 2010 and 2015. Those specific years were chosen because of the increase in technological innovations that have assisted students with BVI during that time span, and to increase the potential pool of participants. Since a grade of C can be used as an indication of successful course completion ("Prerequisites," n.d.; "Understanding," 2015), students were asked whether they earned a C or better in the course. Students who participated in the study were required to have Internet access, and if necessary, screen reader software in order to complete the online surveys. Instructors who participated in this study were required to have taught a student with BVI who met the study criteria. The questionnaires in the study were written in English. Therefore, fluency in English was a requirement for study participation.

Each student with BVI has specific visual challenges. Some students with BVI have partial vision; others have total blindness. It is possible for students with BVI to face additional physical, intellectual, or emotional challenges that affect their learning and their perceptions of the provided accommodations. Further, required laboratory activities in different courses in the biological sciences vary significantly, some courses presenting greater challenges to students with BVI than others. Therefore, generalization of study results should be made in light of those considerations. Additionally, though grades are used across the globe as a representation of student learning, some instructors include non achievement-based criteria in grades and some artificially inflate grades (Sadler, 2009). Interpretation of instructor responses should include the possibility that some instructors may have awarded a passing grade to a student with BVI that does not accurately reflect actual student learning.

In his dissertation, Supalo (2010) noted that few researchers have investigated the effectiveness of accommodations for students with BVI, a situation that has restricted efforts to support students with BVI in the science laboratory. This research addressed the question of whether the specific laboratory accommodations provided for students with BVI in the college biology laboratory were effective. The study documented student and instructor perceptions regarding the specific accommodations, and evaluated whether they enabled the "equal opportunity" required by the ADA ("A Guide," 2009, para. 9; "The Americans," n.d., para. 1) while maintaining the academic standards of the course ("Reasonable," 2016).

The perceptions of students with BVI who had completed a college biology course with a laboratory component, and of instructors who had taught students with BVI in the college biology laboratory, enabled an evaluation of the effectiveness of the accommodations provided for the students with BVI in the college biology laboratory. This study also examined the perceptions of whether the accommodations enabled the student with BVI to learn at a level equivalent to that of sighted students in the class who earned the same grade. Additionally, study participants were asked to describe specific accommodations that were beneficial so that particular types of accommodations could be evaluated. Instructors were queried as to the types of alterations made to laboratory content and assessments for the student with BVI, and whether they felt that learning and skills were still assessed, despite assessment alterations, at a level equivalent to that for sighted students. This research laid the groundwork for establishing best practices in providing specific accommodations for students with BVI in the college biology laboratory, and offered insight into methods for continued research.

Definition of Terms

The terms defined in this section are used throughout this dissertation. They are defined to provide the clarity necessary to ensure the intended interpretation (Roberts, 2010). Terms defined include *accessible*, *accommodations*, *accommodations specific to the biology laboratory, assistive technology device, blind, color blindness, effectiveness of accommodations, individual disability, seven criteria, student and instructor needs, universal design, universal instructional design, visual impairment*, and *web accessibility*.

Accessible. According to the Oxford Advanced Learner's Dictionary, accessible means that all necessary materials "can be reached, entered, used, seen, etc." ("Accessible," 2016, para. 1). That definition will apply in this study.

Accommodations. Accommodations are "modifications or adjustments to the tasks, environment or to the way things are usually done that enables individuals with disabilities to have an equal opportunity to participate in an academic program" ("Reasonable," 2016, para. 1).

Accommodations Specific to the Biology Laboratory. Accommodations specific to the biology laboratory are those provided to enable the student with BVI to safely and actively participate in and learn from the laboratory exercises. They do not include the accommodations that are generally provided for all college students with disabilities.

Assistive Technology Device. An "assistive technology device means any item, piece of equipment, or product system, whether acquired commercially off the shelf, modified, or customized, that is used to increase, maintain, or improve the functional capabilities [of individuals with disabilities]. . . . The term does not include a medical device that is surgically implanted, or the replacement of such device" ("AT in Education," 2008, para. 4).

Blind. A student with blindness has "visual acuity of not greater than 20/200 in the better eye with correction or a field not subtending an angle greater than 20 degrees" (Jernigan, 2005, para. 2). According to The American Heritage® dictionary of the English Language, blindness is "having a maximal visual acuity of the better eye, after correction by refractive lenses, of one-tenth normal vision or less (20/200 or less on the Snellen test)" ("blind," 2016). "Totally Blind individuals need Braille, raised-line drawings, audio recordings, and/or other non-visual media as an accommodation for accessing the content of visually presented materials" ("How Are the Terms," 2015, para. 5).

Color blindness. Individuals with color blindness have "trouble seeing colors and the brightness of colors in the usual way [and the] inability to tell the difference between shades of the same or similar colors" ("Color blindness," 2015, para. 7).

Effectiveness of Accommodations. Accommodations are effective if they meet student and instructor needs. See the definition of *Student and Instructor Needs*.

Individual with a Disability. An individual with a disability has "a physical or mental impairment that substantially limits one or more major life activities, a person who has a history or record of such an impairment, or a person who is perceived by others as having such an impairment" ("A Guide," 2009, para. 3).

Seven Criteria. Seven criteria are used in this study to determine whether the specific accommodations provided for students with BVI in the college biology laboratory are effective, meaning that they meet the needs of the instructors and the students with BVI. To meet the needs of the instructors and the students with BVI, specific accommodations in the college biology laboratory must enable the opportunity for a student with BVI to (a) safely and actively participate in the laboratory activities (Duerstock et al., 2014; "The Integral Role," 2007), (b) be engaged in the class (Gormally et al., 2011; Sinatra et al., 2015), (c) be accepted by classmates (Scruggs and Mastropieri, 2007; Supalo, 2010), (d) contribute to group activities (Barbosa et al., 2004; Gaudet et al., 2010; Gormally et al., 2011), (e) demonstrate required skills (Di Trapani & Clarke, 2012; Fitch, 2007; Hunt et al., 2012), (f) meet all academic requirements ("Reasonable," 2016), and (g) acquire knowledge commensurate with that of their sighted classmates (Duerstock, 2015).

Student and Instructor Needs. In this research study, if the student with BVI is able to meet the *seven criteria* necessary for student learning, then student and instructor needs will have been met.

Universal Design. Universal design "promotes the consideration of the needs of all potential users in the planning and development of a space, product, or program" (Goff & Higbee, 2008, p. 1)

Universal Instructional Design. Universal Instructional Design incorporates the tenets of Universal Design into education. The theory requires "considering the potential needs of all learners when designing and delivering instruction" (Palmer & Caputo, 2006, p. 1).

Visual Impairment. A visual impairment is "an impairment in vision that, even with correction, adversely affects . . . educational performance" ("Section 300.8," n.d., para. 31).

Web Accessibility. "Web accessibility means that people with disabilities can perceive, understand, navigate, and interact with the Web, and that they can contribute to the Web" (Henry, 2005, para. 1).

Conclusion

This research study sought to ascertain the effectiveness of specific accommodations provided for students with BVI in the college biology laboratory. Student and instructor perceptions regarding the specific accommodations provided in the college biology laboratory were gathered to determine whether those accommodations met both student and instructor needs according to the *seven criteria*. Determination of effectiveness was accomplished by evaluating whether the specific accommodations enabled "equal opportunity" ("A Guide," 2009, para. 9; "The Americans," n.d., para. 1) for the students with BVI while maintaining the academic integrity of the course ("Reasonable," 2016). It was posited that the results would reveal whether the specific accommodations provided for students with BVI in the college biology laboratory met the needs of the students with BVI and instructors of students with BVI according to the *seven criteria,* and were thus effective.

Referring to students with disabilities, Moon et al. (2012) noted that, "this population remains underrepresented and frequently experiences outright exclusion" (p. 13). This study enabled students with BVI to voice their opinions regarding their experience in the college biology laboratory. Further, the lenses of transformative learning, social justice education, and critical theories were used to evaluate whether the accommodations provided for the students enabled the "equal opportunity" that the law ("A Guide," 2009, para. 9; "The Americans," n.d., para. 1) and social justice (Mertens, 2007; Torres, 2008) require.

The subsequent portions of this study are presented in four chapters. A review of the literature comprises chapter 2, which explores enrollment of students with BVI in higher education, accommodations for students with BVI, and discusses the importance of evaluating the effectiveness of those accommodations. Chapter 3 introduces the methodology applied in the study, the research instruments, how data were collected, and how the data were analyzed. In Chapter 4, the results of the study are presented. Chapter 5 includes a summary and discussion of the results of this study, and recommendations for action and continued research. The references section and appendices complete this work.

CHAPTER TWO: REVIEW OF THE LITERATURE

Increasing numbers of students with blindness and visual impairments (BVI) are enrolling in college (Callahan, 2011; Scott, 2009). In part because some states and institutions require their degree-seeking students to complete one laboratory science course, students with BVI are taking college biology courses (Caldwell & Teagarden, 2007; D. Huey, personal communication, November, 2014; Hutson, 2009; J. Xu, personal communication, July, 2014; Vollmer, 2012; Womble & Walker, 2001), which generally include laboratory components. General accommodations, or modifications to the "learning environment to provide equal opportunity for academic or physical accessibility" ("Academic Accommodations," 2016, para. 1), are provided for students with disabilities to enable successful course completion. In addition to those general accommodations, specific accommodations must be provided in the laboratory for many students with BVI to enable them to actively participate in the exercises and learn the content of the laboratory component of the course. These can include tactile models (Caldwell & Teagarden, 2007; Derra, 2015; Hutson, 2009; Miecznikowski et al., 2015; Rule, 2011; Wedler et al., 2012; Winograd & Rankel, 2007), and audible technologies borrowed from other science disciplines (Supalo, Wohlers, & McEnnis, 2009).

There are no regulations regarding the specific accommodations that must be provided for students with BVI in the college biology laboratory (Moon et al., 2012), but the assumption in providing specific accommodations is that they conform to the intent of The Americans with Disabilities Act (ADA), which "prohibits discrimination and ensures equal opportunity" for all students ("The Americans," n.d., para. 1). Further, the accommodations must enable the academic standards of the course to be maintained ("Reasonable," 2016). Supalo (2010) noted that few researchers have investigated the effectiveness of specific accommodations for students with BVI, and indicated that the lack of research significantly impacts the ability to support students with BVI in the science laboratory. One research study was located that evaluated the effectiveness of tactile accommodations in the college biology laboratory (de Souza et al., 2012). The specific accommodations provided for students with BVI must be effective to provide an equal opportunity for success. Therefore, the purpose of this study was to evaluate the effectiveness of the specific accommodations provided for students with BVI in the college biology laboratory.

This review of the literature forms the scaffolding of this research study. The sources informing this literature review represent scholarly journal articles, dissertations, websites, and books. Resources date 1980 through 2016, and were gathered from library databases, the Internet, and references cited in other sources. Each was mined for information pertaining to students with disabilities, students with BVI in college and college science courses, accommodations for students with BVI in college in general and in STEM and biology courses in particular, general college biology course information, methods of grading and assessment in biology, studies of student and instructor perceptions, and theories informing this research.

The chapter is organized in a "*general to specific*" structure as highlighted by Roberts (2010) so that necessary background information is presented first (p. 103), followed by research specific to the topic of accommodations for students with BVI in the college biology laboratory. Four general topics comprise this literature review: (a) examination of the reasons more students with BVI are attending college, (b) discussion of the general and specific accommodations provided for students with BVI, (c) consideration of the effectiveness of accommodations, and (d) the conceptual framework guiding this research. Concluding remarks complete this chapter.

More students with disabilities are attending college (Adams & Proctor, 2010; Ebert as cited in Duranczyk & Fayon, 2008; "How the Americans," 2015; Milligan, 2010; Reinschmiedt et al., 2013; Summers, White, Zhang, & Gordon, 2014; Webb, Patterson, Syverud & Seabrooks-Blackmore, 2008). As a result, more students with BVI are seeking post-secondary education (Callahan, 2011; Scott, 2009). Several factors contributed to that increase.

Enrollment of Students With BVI in Higher Education

Many factors have influenced the number of students with BVI attending colleges and universities. This section begins by providing the legal definitions of BVI, followed by an exploration of many of the factors affecting the enrollment of students with BVI in higher education. The section concludes with a discussion of current trends in the attendance of students with BVI at colleges and universities.

Legal Definition of BVI

The Individuals with Disabilities Education Act (IDEA) defines a visual impairment as a visual challenge that causes educational difficulties for a student ("Section 300.8," n.d.). Dandona and Dandona (2006) preferred designations other than low vision for "visual impairment less than severe blindness," suggesting use of the terms mild visual impairment and moderate visual impairment instead (p. 1). Thus, the authors proposed the categories of visual impairment be defined as:

- Blindness in a person (severe blindness; very severe blindness; total blindness);
- Moderate visual impairment in a person;
- Mild visual impairment in a person;
- Unspecified visual impairment in a person;

- Blindness in one eye of a person (severe blindness, very severe blindness, or total blindness);
- Moderate visual impairment in one eye of a person;
- Mild visual impairment in one eye of a person;
- Unspecified visual impairment in one eye of a person. (p. 5).

For the purposes of this study, students with BVI fell somewhere along that spectrum. Students ranged from those with some visual ability to individuals with total blindness.

A separate problem that can confront biology students is color blindness. While some would not classify color blindness as a visual disability ("Visual Disabilities," 2016), the condition can cause difficulties in the biology laboratory. Color change forms the basis for the interpretation of the results of various tests, such as biochemical media and cellular stains, and can cause difficulties for students unable to distinguish among different colors. According to the National Eye Institute, three different types of color blindness exist. "Red-green color blindness is the most common, followed by blue-yellow color blindness. A complete absence of color vision - total color blindness - is rare" ("Facts About," 2015, para. 3). Students with color blindness also have difficulty distinguishing colors on printed pages and on websites, so designers must ensure that color distinction is not the "only method of conveying important information" ("Visual Disabilities," 2016, para. 11).

Legal Mandates

The United States has passed several important pieces of legislation pertaining to individuals with disabilities. Some of the laws affecting students with BVI apply to elementary and secondary schools. They were included in this discussion under the assumption that as more students with BVI realize educational success in their primary and secondary education, more are likely to seek higher education.

Section 504 of the Rehabilitation Act of 1973. Section 504 of the Rehabilitation Act of 1973 pertains to educational institutions. The Act states that "no qualified individual with a disability in the United States shall be excluded from, denied the benefits of, or be subjected to discrimination" ("A Guide," 2009, para. 47). In higher education, the term "qualified" indicates that a student with a disability "meets the academic and technical standards requisite for admission or participation in the institution's educational program or activity" ("Protecting Students," 2015, para. 25).

The Americans with Disabilities Act. In 1990, the Americans with Disabilities Act (ADA) became law ("ADA Amendments," 2008), and applied even to institutions not receiving financial assistance from the United States government (Meyer, 2008). The law mandated that no public institutions could discriminate against individuals with disabilities. According to the ADA, an individual with a disability is someone with "a physical or mental impairment that substantially limits one or more major life activities, a person who has a history or record of such an impairment, or a person who is perceived by others as having such an impairment" ("A Guide," 2009, para. 3). Amendments to this law were enacted with the ADA Amendments Act of 2008 to "restore the intent and protections of the Americans with Disabilities Act of 1990" ("ADA Amendments," 2008, para. 1).

Title II and III of the ADA required post-secondary institutions to provide accommodations for students with disabilities. To receive accommodations, students must disclose their disability to the institution. Further, students may have to provide documentation of their disability in order to qualify for accommodations (Leuchovius, 2015).

Assistive technology acts. The United States government acknowledged the benefit of technology to individuals with disabilities with the passage of the Assistive Technology Act ("Assistive Technology," 1998). The Act was first passed in 1998, and was amended in 2004. The goal of the Act is to "support programs of grants to States to address the assistive technology needs of individuals with disabilities" ("An Act," 2004, para. 1).

Public school laws. Several laws pertain to children in the public school system. The IDEA mandated that public schools devise free plans for disabled children enabling them to receive their education "in the least restrictive environment appropriate to their individual needs" ("A Guide," 2009, para. 41). Another law, Goals 2000, required studies on ways to facilitate learning for children (Wild & Allen, 2009, p. 113). The No Child Left Behind Act of 2001 mandated rules for science education and improved instruction methods, while the Education Science Reform Act of 2002 required studies on science education and created a body to investigate the methods used in science education (p. 113).

Lawsuits

The laws described directly influenced the number of individuals with disabilities seeking higher education (Summers et al., 2014), and with the laws came lawsuits. There have been many suits filed against institutions of higher education by students with disabilities ("Category Archives," 2013; Danielsen, 2010; Danielson, 2015; Grasgreen, 2013; Lee, 2014; Pant, 2014; Parry, 2010; Solovieva & Bock, 2014), though none were located that involved a student with BVI filing a suit due to an experience in a science laboratory. As a result of the lawsuits, though, institutions of higher education have developed policies to ensure that accommodations are provided for their students with disabilities ("Example Policies," 2015).

The legal mandates require inclusion. However, laws cannot remove obstacles that make attendance difficult for students with disabilities, and therefore discourage them from attending college. Programs, technological innovations, universal design, and universal instructional design are addressing those obstacles.

Programs

The National Science Foundation administers the Research in Disabilities Education program. It was founded in 1994 with the goal of enabling access to educational opportunities for students with disabilities. Because of the program, more students with disabilities are realizing success in their educational endeavors (Moon et al., 2012). The program strives to improve "the participation and achievement of postsecondary students with disabilities in STEM" ("Research," n.d., para. 2).

Another program aimed at increasing the number of students with disabilities in STEM is administered by the University of Washington. Termed AccessSTEM, the program coordinates the efforts of stakeholders nationwide to improve the representation of individuals with disabilities in STEM fields ("AccessSTEM," 2016). The program includes the University of Washington's DO-IT Center, which "is dedicated to empowering people with disabilities through technology and education" ("Overview," 2016, para. 1).

Technological Innovations

The United States’ government acknowledged the significant influence of technological innovations on this country and the world ("Assistive Technology," 1998). Helping individuals with disabilities utilize available technological innovations is assistive technology. Devices and materials that enable access to the technologies used in higher education for students with BVI, such as software that audibly recites content and other software that converts spoken words into text (Nielsen, 2011), constitute only a portion of the assistive technology available. Some recent developments that may help students who are disabled include "3 D printing," "learning analytics," and "wearable technology" (Briggs, 2013, paras. 28, 37, 46). Technologies devised for an alternate purpose may have application for individuals with disabilities as well. An innovation with application to students who are disabled and non-disabled alike is a pen capable not only of writing notes and recording lectures, but when tapped on specific content written on special paper, it will play back what was recorded at the time the student wrote those particular notes (Rossman, 2014).

However, not all technology is inherently accessible. Websites, Prezi™, PowerPoint® lectures, videos, and online documents must be carefully constructed or they are inaccessible (Duranczyk, Myers, Couillard, Schoen, & Higbee, 2013), and at colleges and universities across the country, some technology is not accessible. The problem has resulted in lawsuits against institutions of higher education by students with BVI who were unable to access technology used in their classes (Grasgreen, 2013, para. 7). The problem is so pervasive that in discussing a lawsuit against Penn State, Dr. Marc Maurer, president of the National Federation of the Blind, stated:

> There is simply no excuse for blind students . . . to be denied the same access to information and technology as their sighted peers. Sadly, this cavalier attitude toward accessibility is found . . . at many of our nation's colleges and universities. That is why we have asked the United States Department of Education to act swiftly and decisively to ensure that blind students . . . are given the same access and opportunity to succeed as their sighted peers. (as cited in Danielsen, 2010, para. 7)

Universal Design

Technology is not the only barrier confronted by students with disabilities. The physical structure of many buildings creates obstacles to students with disabilities as well, including campuses with older buildings (Censer, 2004; Wang, 2015). Borrowed from the field of architecture, the concept of universal design (UD) is a proactive concept in which adaptations are incorporated into the planning stages of a project rather than retrofitting structures for accessibility (Goff & Higbee, 2008). When UD is incorporated into architectural planning and building practices, the need for specialized equipment to help individuals with disabilities is reduced ("Assistive Technology," 1998).

An additional outcome of this concept's application is that the adaptations made for individuals with disabilities often benefit non-disabled individuals as well (Goff & Higbee, 2008). The most obvious example of this is the "curb cut," an accommodation as regularly used by mothers pushing strollers as by those using wheelchairs for mobility, the individuals for whom the adaptation was initially created (Johnson & Fox, 2003, p. 9). Another example is the "closed-caption decoders" for televisions designed originally for individuals with hearing impairments, but often used by non-disabled persons (Vanderheiden, 1996, para. 9).

Universal Instructional Design

Silver, Bourke, and Strehorn (1998) developed the concept of universal instructional design (UID). Growing out of UD, UID as applied to education urges post-secondary education teachers to incorporate adaptations for individuals who are disabled during the course development stage so that accommodations are not created specifically for each student, or in haste once notice is received that a student with a disability will be in the class (Goff & Higbee, 2008, pp. 1-2). Courses are therefore inclusive, which is an important supportive component for students who are disabled (Higbee, Chung, & Hsu, 2008, p. 63).

Examples of UID include teaching material in different ways, having handouts in digital format, ensuring that all classroom materials are accessible ("Open Learning," n.d.), providing captions on videos, and using large font sizes in presentations (Duranczyk et al., 2013). Instructors adopting this concept have no need to revise course materials to make them accessible. This is important because "when accommodations are individual to a student the message of 'difference' is conveyed" (Duranczyk & Fayon, 2008, p. 138). Unfortunately, Moon et al. (2012) remarked that faculty members often create courses without consideration to accessibility, and may lack knowledge of methods and/or adequate institutional support.

An additional benefit of UID is that when teachers apply the concept, the practice benefits more than just the students with disabilities (Duranczyk & Fayon, 2008, p. 138). Lectures that are videotaped enable all students to re-listen to particular passages for better understanding and to pause the recording to write more detailed notes (Higbee & Eaton, 2008, p.220). Captions on videos aid students for whom English is a second language or for those who learn best by reading (Myers, Wood, & Pousson, 2008).

Current Trends

Professors from Ryerson and York Universities in Canada examined perceptions of teachers of high school students with BVI regarding the students' college attendance (Reed & Curtis, 2011). Only six percent of the teachers indicated that the majority of their students with BVI continued their education past high school. Forty-one percent of the teachers noted that students with BVI choose not to attend college because of insufficient self-assurance and support (pp. 554-5). For those students with BVI choosing to seek higher education, Reed and Curtis

(2012) found that professors' negative attitudes toward inclusion, trouble obtaining accessible materials, and problems with assistive devices presented obstacles. Marson, Harrington, and Walls (2012) expounded on instructor attitudes by indicating that, "the attitude of the instructor towards the student plays a significant role in student learning and levels of student satisfaction with the learning experience" (p. 23). Further, Reed and Curtis (2012) noted that the increased use of their limited vision to read print and access electronic media caused more than half of the students with BVI to suffer visual fatigue and headaches.

Despite the potential barriers, an increased number of individuals with disabilities are attending colleges and universities (Adams & Proctor, 2010; Ebert as cited in Duranczyk & Fayon, 2008; "How the Americans," 2015; Milligan, 2010; Reinschmiedt et al., 2013; Summers et al., 2014; Webb et al., 2008). Further, more students with BVI are seeking higher education (Callahan, 2011; Scott, 2009). According to the 2008 National Postsecondary Student Aid Study, less than three percent of postsecondary students disclosing a disability, or about 56,000 students, exhibited "blindness or visual impairment" ("Higher Education," 2009, p. 38). In the 2011-2012 school year, that number increased to 3.6% of undergraduates with disabilities who disclosed a visual impairment, or approximately 104,000 students ("Profile of Undergraduate Students," 2014).

Historical perspectives viewed individuals with disabilities as "deficient" (Higbee et al., 2008, p. 63). That perspective is changing because of legal mandates, lawsuits, programs, technological innovations, UD, and UID. Obstacles to the success of students with BVI are being removed.

Enrollment of Students With BVI in STEM Courses

Dr. Judith Ramaley, a biologist and former university president ("Judith Ramaley," 2016), devised the term "STEM" while working for the National Science Foundation (Christenson, 2011, para. 2). She noted the importance of science and mathematics, indicating that, "science and math are critical to a basic understanding of the universe, while engineering and technology are means for people to interact with the universe" (para. 6). The term STEM is now used throughout the United States (Christenson, 2011).

Increasing Interest in STEM

In 2012, approximately 39% of college freshmen declared a science or engineering major, a figure that has risen steadily since 2007 ("Stem Education," 2014). STEM fields offer promising career prospects for individuals with disabilities (Basham and Marino as cited in Basham & Marino, 2013). Additionally, Supalo et al. (2007) noted that the characteristics and abilities that develop as a result of overcoming the many challenges of living with a disability translate into "a great potential for this population to make significant intellectual contributions to the scientific community" (p. 31). Despite the possibilities, and the increase in enrollment of students with BVI in higher education, though, there has not been a corresponding increase in the number of students with disabilities entering the STEM professions (Duranczyk & Fayon, 2008; Moon et al., 2012; Supalo, 2010). As noted by Booksh, Century, Gallagher, Mateo, and Pagano (2014), "persons with disabilities are severely underrepresented in STEM fields" (p. 63). Aligning with that observation, the authors noted that there has not been a significant increase in the number of individuals with disabilities earning doctoral degrees in a STEM discipline. Several explanations exist. STEM courses are traditionally taught in a highly "visual format" (Rule, 2011, p. 205), and there has historically been a paucity of accommodating tools and technology to support that population of individuals (Supalo, Wohlers, & Humphrey, 2011). Rather than receiving encouragement, individuals with disabilities are persuaded not to consider the STEM fields (Fraser & Maguvhe, 2008; Supalo, 2010; Supalo et al., 2011). Fraser and Maguvhe (2008) remarked that "educators are not aware of what should be done to accommodate blind and visually-impaired learners . . . . [so] they discourage blind learners to take or consider science-related subjects" (p. 85). Supalo (2010) and Supalo (2013) offered that concern for their safety in the laboratory also contributes to students with BVI being dissuaded from the sciences. Booksh et al. (2014) recognized that because there are few individuals with disabilities in the STEM disciplines, there are few to serve as role models for students with disabilities. Also contributing to the low number of individuals with disabilities in STEM is the amount of governmental support directed to those with disabilities. While the U.S. government spends over $378 million dollars to increase the retention and success rates of "underrepresented minorities," only $19.6 million is spent to improve success rates for individuals with disabilities (p. 65).

The United States government increased efforts to improve the representation of individuals with disabilities in STEM. The Committee on Equal Opportunities in Science and Engineering began as a result of the Science and Engineering Equal Opportunities Act of 1980. In its 2011-2012 report, committee members proposed measures that would improve "participation of underrepresented groups in STEM" ("CEOSE," 2013, p. v). Additionally, several programs attempted to increase the number of individuals with BVI entering STEM professions by piquing their interest as children. Beck-Winchatz and Riccobono (2008) described the work of the National Center for Blind Youth in Science, and a project at Yerkes Observatory for middle school and high school students who are blind. The authors also discussed the efforts of the National Federation of the Blind working in conjunction with the American Association for the Advancement of Science and NASA to develop a program called "NFB Excellence through Challenging Exploration and Leadership" (p. 1856). Additionally, Supalo (2012) argued that efforts to increase the autonomy of students with BVI in the science laboratory would translate to more students with BVI choosing STEM professions.

Increased Number of Students With BVI in STEM Courses

Perhaps the efforts of the government and organizations to increase interest in STEM are beginning to succeed. The National Science Foundation's National Center for Science and Engineering Statistics indicated that in 2012 the number of students in college disclosing a disability was approximately 11% ("National Science Foundation," 2015). It remains at 11% in 2015 ("Briefing Paper," 2015). Of that percentage, over 23% indicated a science and engineering field of study in 2012, a number consistent with that of students without disabilities ("National Science Foundation," 2015).

As mandated by state laws, such as those in Maryland, New Jersey, and Oklahoma, many institutions of higher education routinely require their degree-seeking students to take one general education laboratory science course ("A General Education," 2007; "Policy," 2016; "Student Guide," n.d.). Successful completion of introductory courses in chemistry, physics, and biology, among others, meets that requirement. While an increase does not necessarily imply that increased numbers of students with disabilities are majoring in STEM fields, enrollment in STEM courses to satisfy general education requirements should increase as a direct result of increasing enrollment of students with BVI in higher education.

The literature reveals that as a result of laws, lawsuits, technological innovations, UD, and UID, the number of individuals with disabilities seeking higher education has increased

(Adams & Proctor, 2010; Ebert as cited in Duranczyk & Fayon, 2008; "How the Americans," 2015; Milligan, 2010; Reinschmiedt et al., 2013; Summers et al., 2014; Webb et al., 2008). As a result, more students with BVI are attending college (Callahan, 2011; Scott, 2009). Therefore, institutions at which the students with BVI matriculate must provide accommodations "in order for students to be engaged fully as learners" (Moon et al., 2012, p. 25).

Accommodations for Students With BVI

Though anti-discrimination laws apply to all individuals, laws giving rights to individuals with disabilities apply only if the individual can prove that he or she has a disability (Wentz et al., 2011). Consequently, students must reveal their disability to the institution in order to qualify for accommodations (Leuchovius, 2015; Stodden, Jones, & Chang, 2002). Students who are disabled sometimes choose not to disclose their disability (Alexandrin, Schreiber, & Henry, 2008; Kioko & Makoelle, 2014; Milligan, 2010) for various reasons. Those with a hidden disability do not know what the reaction will be to their disclosure. Students can be accused of fabricating their disability to gain "unfair advantages" (Alexandrin et al., 2008, p. 377), or not disclose due to fear they may be "stigmatized" (Kioko & Makoelle, 2014, p. 111). Some students may believe that their disability does not merit accommodations (Richardson, 2009). Further, individuals ignorant of the reasons necessitating accommodations for students with disabilities can consider them "privileges" instead of needs (Byrd, 2010, p. 92). Those who choose to disclose their disability, however, find that there are many accommodations available to them.

Reasonable Accommodations

The ADA requires that institutions provide "reasonable accommodations," or alterations to the "tasks, environment or to the way things are usually done," for their students who are disabled ("Reasonable," 2016, para. 1). This means that institutions must ensure students with disabilities have "equal access to educational opportunities" (Meyer, 2008, p. 23). In short, institutions of higher education are required to make their academic programs accessible to students who are disabled and to supply necessary materials to ensure that accessibility (p. 23). As a result, most institutions of higher education in the United States now offer some form of support services for their students with disabilities (Lee, 2014; Raue & Lewis, 2011).

In certain instances, institutions are not required to make adaptations for a student with a disability. Accommodations not considered reasonable fall into one of four categories. A change is not considered reasonable if it would:

- fundamentally alter the essential nature of the course, curriculum or program,
- constitute services of a personal nature (such as private tutoring)
- result in an undue administrative or financial burden for the institution
- result in posing a direct threat to the health or safety of self or others. (Johnson, 2012, para. 5)

Unless the situation falls under one of those categories, however, accommodations must be provided. "Students with disabilities rely on academic accommodations in order to have the necessary adjustments that compensate for the nature of the disability" (Byrd, 2010, p. 92). Reasonable accommodations take different forms, and are developed for each student individually (Johnson, 2012). Both general accommodations, and specific accommodations for the laboratory, have been developed for students with BVI.

General Accommodations for Students With BVI

Despite the difficulties they may encounter, the number of students with BVI attending higher education is increasing (Callahan, 2011; Scott, 2009), so accommodations must be available that meet each student's individualized needs. Accommodations can include "special lighting" (Horvath, Kampfer-Bohach, & Kearns, 2005, p. 177), additional time to complete assignments, note takers, tape recorders ("Accommodations," 2015; Sharpe et al., 2005), large print, and Braille materials (Horvath et al., 2005; Sharpe et al., 2005). Additionally, special consideration must be given to those with medical conditions that are progressive as this may cause the need to alter accommodations across time (Horvath et al., 2005).

Technological innovations also contribute to the success of students with BVI in higher education. Examples of such assistive technologies for students with BVI include "electronic organizer[s], magnifier[s], and tape recorders", in addition to screen reading software such as "Kurzweil, JAWS, and ZoomText" (Reed & Curtis, 2012, p. 420). Hutson (2009) remarked that improved screen readers are better able to read information on the Internet, a development that enables web accessibility for individuals with disabilities (p. 478). Other examples include "voice input devices" and "assistive listening devices" (Duquaine-Watson, 2003, p. 439). So many new technologies exist that Power and Jürgensen (2010) noted the difficulties experienced in trying to decipher which technology tools would be most helpful for students with BVI.

Though helpful, new technologies are not always accessible to students with disabilities. Time is often required for new technologies to be made in an accessible form (Mazrui, 2012). Wentz, Jaeger, and Lazar (2011) remarked on the excessive amount of time required for accessible forms of new technologies to be developed. Though the amount of time has decreased in recent years, over two years was often required before newly introduced technologies were available in accessible forms (Silverstone, Lang & Rosenthal, 2000). Wentz et al. (2011) commented that new technologies are introduced so quickly that prior to their being adapted for use by the disabled they are often already outdated. Additionally, Lazar and Jaeger (2011) stated that despite requirements for website accessibility, most websites have "major access barriers" (p. 70).

While there are many general accommodations available to students with BVI, more specific technologies are required in the science laboratory. This is due in part to the extensive use of "diagrams, illustrations, maps, plots, and schematics" (Mathewson, 2005, p. 530). Assisting students with BVI in the STEM disciplines requires basic adaptations. Audible (Moon et al., 2012), and other specialized laboratory equipment, are required to support students with BVI as well.

Accommodations for Students With BVI in STEM Courses

According to the National Science Teachers Association, laboratory exercises comprise a vital portion of science courses ("The Integral Role," 2007, para. 2). To enable many students with BVI to participate in and learn from the laboratory component of STEM courses, the students must be provided with specific accommodations (Moon et al., 2012, p. 109). Specific accommodations are vital, because "few laboratory instruments were originally designed to utilize the hands, skin, ears, or nose to convey quantitative information" (p. 28).

One consideration concerns the height of laboratory tables in many science classrooms. The line of sight of an individual in a wheelchair is not quite one foot above the height of most laboratory benches (Hutson, 2009, p. 478). Therefore, a basic, mandatory accommodation for disabled individuals in the sciences is lower, or adjustable, lab benches. This is an especially important consideration for students with BVI because some use wheelchairs or scooters for mobility (J. Xu, personal communication, December, 2014).

Caldwell and Teagarden (2007) indicated that canes and guide dogs were permitted in the biology laboratory for students with BVI. Special consideration was given to ensure that pathways the student navigated were not obstructed. The authors noted that extra precautions were taken to ensure pathways were clear and no hazards existed on the classroom floor that would pose a safety hazard for the dog. In some situations, though, while canes would be permitted, a guide dog would not. Regarding microbiology and biomedical laboratories, the Office of Safety, Health, and Environment of the Centers for Disease Control and Prevention indicates that, "Animal [sic] and plants not associated with the work being performed must not be permitted in the laboratory" ("Section IV," 2015, p. 36). Additionally, should other students in the class be allergic to the dog, other options must be considered (Johnson, 2012).

Mathewson (2005) remarked that student learning in science is highly visual, incorporating "observational skills, levels of visual abstraction, and the use of models" (p. 535). Conveying complex concepts in science utilizes visual representations; "the entire fabric of science is laced with these tacit master images" (p. 530). Since many students with BVI cannot see or use those resources, it is necessary for instructors to verbally describe them (Miecznikowski et al, 2015). It is also possible to provide graphs in an auditory form to help students with the interpretation of graphic materials (Sahyun, 2000, p. 134).

Lartec and Espique (2012) advised teaching students with BVI using their sense of touch. Those creating adaptations for students with BVI often take advantage of the tactile senses to improve student comprehension (Caldwell & Teagarden, 2007; Derra, 2015; Hutson, 2009; Miecznikowski et al., 2015; Rule, 2011; Wedler et al., 2012; Winograd & Rankel, 2007). Instructors routinely incorporate enlarged models, such as skeletons or molecules, in STEM courses (Moon et al., 2012) to enhance student learning. Moon et al. (2012) cautioned, however, that models for science labs were originally designed assuming their use by sighted individuals rather than those using other senses for interpretation. As an accommodation, three-dimensional pens ("3Doodler," 2016) or Braille labeling devices ("6dot Braille Label," 2016) would enable the addition of precise Braille markings to those existing models. Other creative strategies to assist comprehension of challenging material include "Braille-labeled magnetic letters and numbers" to teach chemical formulas (Boyd-Kimball, 2012, p. 1396), and "textured Lego® blocks" to convey concepts of gene sequencing to students with BVI (Butler, Bello, York, Orvis, & Pittendrigh, 2008, p. 52:1). A student with BVI was a biology major at Arizona State University, and was lead author on a project to create 3-D models to enable students with BVI "to independently learn about images found in textbooks, presentations and captured through a microscope" (Leander, 2012, para. 5). Three-dimensional printers can now produce tactile models for students with BVI (Van Gerven, 2015). Teachers of students with BVI can even request specific 3-D models free of charge from an Internet company ("Model Request," n.d.). Also helping students with BVI in the laboratory are computer software and hardware integrated with sensors enabling collected data to be converted into a tactile graph (Supalo et al., 2007).

Haptic technology, which incorporates the sense of touch and "human interaction with the external environment via touch," (Jones, Minogue, Oppewal, Cook, & Broadwell, 2006, pp. 346-7) is utilized for students in the sciences, including students with BVI (Jones et al., 2006; Moon et al., 2012). Examples of the general application of haptics include using a cane to explore one's surroundings, and using the fine sense of touch on the hands and feet to discern shapes and surfaces (Lahav & Mioduser, 2004, p. 16). Researchers have noted the importance of visual input to knowledge acquisition and understanding in the physical and especially the natural sciences (Fraser & Maguvhe, 2008, p. 85). Haptic technology can help students with BVI develop their ability to think conceptually about the material being learned without the need for visual cues (Wu, Krajcik, & Soloway, 2001). Students with BVI testing haptics reported that the "technology was engaging" (Jones et al., 2006, p. 350). As a result, Jones et al. (2014) utilized a hand-held haptic game controller in conjunction with specialized computer software to enable children with visual impairments to experience molecular motion.

Supalo et al. (2009) created many adaptations for students with BVI in the chemistry laboratory, some that incorporate the sense of hearing as advised by Lartec and Espique (2012). For instance, auditory devices to assist students with BVI were developed such that students could "observe temperature changes in real time" (Supalo et al., 2009, p. 588). The same technology enables students to know that liquids have "become cloudy or change[d] color during a reaction" (p. 588). Adaptations do not have to be technologically profound. One researcher used a salad spinner to enable a student with blindness to experience a cellular membrane process (Vollmer, 2012). Instructors found that the olfactory sense can be utilized to enable students with BVI to detect the formation of particular chemical compounds (Caldwell & Teagarden, 2006; Wedler et al., 2014). Educators also routinely adapt technology developed for different purposes to students' special needs in the laboratory. For example, "trip lasers used in security systems" were used to indicate when the correct level had been reached while pouring liquids into a beaker (Hutson, 2009, p. 477). Barcode scanners can convey important information, especially when laboratory gloves limit tactile sensations (Annis, 2011). Despite the number of technological innovations that have improved the ability of students with BVI to participate in college science laboratories, Smith and Amato (2012) urged the continued incorporation of new technologies to improve education for students with blindness.

In some instances, the instructors provide one-on-one instruction either during lab or office hours (J. Xu, personal communication, December, 2014; Womble & Walker, 2001). However, another accommodation often provided for students with BVI in the science laboratory is an aide to act as their eyes, performing the required tasks and describing what the student with BVI cannot see (Caldwell & Teagarden, 2007; Harshman et al., 2013; Hutson, 2009; Miecznikowski et al., 2015; Moon et al., 2012; Pence et al., 2003; Supalo, 2012). That individual must have a solid understanding of laboratory safety procedures (Supalo, 2010). One college routinely hired a knowledgeable undergraduate to act as an aide, believing that "relying on the goodwill (and level of understanding) of undergraduate volunteers is neither reliable nor fair to other students enrolled in the course" (Caldwell & Teagarden, 2007, p. 358). Meeting the needs of students who are disabled in that manner, though, is an expensive proposition. One individual with a disability estimated that his institution spent over one quarter of a million dollars meeting his needs as he earned his degrees and completed his postdoctoral work, most of that money funding the aides to assist him (Hutson, 2009, p. 479).

Supalo, Isaacson, and Lombardi (2014) cautioned that despite advances in technology there would still be times that an aide would be necessary, but noted that using an aide does not elevate students with BVI from a passive to an active role in the laboratory. Researchers have warned that an aide can "diminish the laboratory experience for the student . . . . [and] undermines principles of inclusivity" (Moon et al., 2012, p. 28). Further, students with BVI assuming passive roles in the laboratory do not experience the mental stimulation that results from active participation (Supalo, 2010) and do not contribute their own insights to the class (Supalo, 2012). Supalo et al. (2007) cautioned that "without special adaptive tools and techniques, [students with BVI] do not receive the educational benefit of the 'hands on' science experience, nor are they on equal footing with their sighted peers" (p. 27). To that end, Wedler et al. (2012) noted that when students were supplied with specific accommodations they were able to actively participate in the laboratory exercises (p. 1400). Miner, Nieman, Swanson, and

Woods (2001) emphasized the necessity of students with disabilities to be as active in the class as their disability and the accommodations permit. Duerstock et al. (2014) expanded on the importance of active participation, indicating that while enabling physical access is vital, independent participation by the students with BVI in the activities of the laboratory must also be the goal of accommodations. Active exploration is an effective method of instruction (Minogue & Jones, 2006), and in a laboratory setting has been noted to improve engagement and comprehension of scientific concepts by students with BVI (Mastropieri & Scruggs, 1992). Barnes and Libertini (2013) noted that exercises in which students actively participated enabled not only improved engagement and understanding of fundamentals, it reinforced learning of more difficult course content as well. Therefore, while an aide may be necessary at times, it is essential to provide specific accommodations to support students with BVI in college science laboratories so that they can participate independently whenever possible.

Even though the number of students with BVI pursuing college degrees has increased, there are still few students with BVI who take STEM courses. Therefore, it is possible that they will feel a sense of isolation (Beck-Winchatz & Riccobono, 2008). Considered by some to be an accommodation (Moon et al., 2012), being part of a group can address that difficulty. Group work is common in the science laboratory (Supalo et al., 2014). An added benefit of group work is that interaction with and explanations by peers can enable increased understanding, because peers can relay information, act as tutors, and explain concepts in a different way to the student with BVI (Lartec & Espique, 2012). One study noted that creating relationships with other students at the institution improved the success of students with disabilities (Scott, 2009). Canadian researchers, however, revealed that students with BVI believed "they often cannot contribute (especially when reading is involved) and that other students were apprehensive about including them in groups" (Reed & Curtis, 2012, p. 421). With reference to group interaction, Moon et al. (2012) cautioned that, "it is unclear whether it simultaneously distances students with disabilities from the material experience upon which hands-on education is premised" (p. 113). When the other students in the laboratory group of the student with BVI are reminded to help only when required or for safety reasons, however, the student with BVI can be a contributing member of the group and gain the positive benefits of group interactions (J. Xu, personal communication, December, 2014).

Though some students with BVI choose a different laboratory science course, such as earth science, to satisfy their general education science requirement, some students with BVI choose to take biology (Caldwell & Teagarden, 2007; D. Huey, personal communication, November, 2014; Hutson, 2009; J. Xu, personal communication, July, 2014). Many of the accommodations made in other STEM laboratories can be used in biology. Supporting the student with BVI in biology, however, requires additional accommodations.

Accommodations for Students With BVI in Biology

Whether a student takes a biology course to fulfill a general education science requirement or as part of a STEM degree, performing experiments in the biology laboratory is vital to a student's educational experience. A professor once described the laboratory component of biology as the "heart and soul" of his classes (V. Mills, personal communication, September, 2005). Yet students with BVI face a daunting challenge in biology.

Wedler et al. (2014) noted that, "nobody can see atoms" (p. 188). Nor can people see electricity or sound waves. Biology, however, is "that most visual of all the sciences" (Vermeij, n.d., para. 2). Caldwell and Teagarden (2007) expounded on the highly visual nature of biology, indicating that the activities of the biology laboratory rely on visual cues that can be difficult for students with BVI to comprehend solely from verbal descriptions. Jones et al. (2006) and Jones et al. (2014) also remarked on the extensive use of vision in biology. Hutson (2009) agreed, stating that the "biological sciences present a special challenge" (p. 476).

Despite the challenges students with BVI confront in biology, students with BVI are registering for college biology classes (Caldwell & Teagarden, 2007; D. Huey, personal communication, November, 2014; Hutson, 2009; J. Xu, personal communication, July, 2014). Adapting biology laboratory exercises so that students with BVI do not sit as inactive bystanders listening to a narrated account of the activities in the laboratory is a difficult challenge. In addition to activities required in other STEM courses, in the biology laboratory students hone their microscopy skills (Fitch, 2007), perform animal dissection (Almroth, 2015), record behavioral observations of living animals (Miller & Naples, 2002), measure shells (Metz, 2008), identify the sex and eye color of fruit flies ("Drosophila," n.d.), determine plant growth (Trautmann et al., 1996), work with microorganisms (Brocklesby, Smith, & Sharp, 2012; Krist & Showsh, 2007), participate in fieldwork exercises (Moon et al., 2012), and perform gel electrophoresis (Fitch, 2007; Supalo, 2010). Further, some instructors grade students on their ability to demonstrate appropriate laboratory skills (Di Trapani & Clarke, 2012; Fitch, 2007). Hunt et al. (2012) argued that, "if the aim is to teach practical laboratory skills, then this may be best achieved by assessing those skills in the laboratory rather than using written laboratory reports or answers to examination questions" (p. 862). Demonstration of those skills, though, can be difficult for students with BVI.

Technology is addressing some of those difficulties. Fitch (2007) noted that learning and honing microscopy skills is standard in the biology laboratory. Students with some vision may be able to view images in a standard light microscope. Interpretation of those images, however, can require that the images be projected onto a large screen (J. Xu, personal communication, December, 2014), something that is now possible because microscopic images can be digitized (Spring & Davidson, 2015). Another technological innovation enabling those with some vision to manipulate a microscope is the AccessScope, which enables visually impaired individuals to operate a light microscope through the Internet (Mansoor et al., 2010). Duerstock (2015) described a technologically advanced microscope the enables those with paralysis or poor vision to perform many analyses that were previously impossible. For those unable to view even projected images, tactile images can be created. Caldwell and Teagarden (2007) noted that comprehension of microscopic images was a challenge for their students with BVI. In their lab, exercises that relied heavily on vision were modified to enable students with BVI to instead use tactile cues to learn concepts. Often, though, even with tactile models the students with BVI required "good verbal description[s] and guidance from the sighted assistant" to comprehend the information (p. 359). Fortunately, there are now three-dimensional models that enable students with BVI to construct animal cells and explore the shape and structure of microorganisms without a microscope (Annis, 2011).

In microbiology, it is necessary to sterilize inoculating loops and needles prior to and after working with live microorganisms. An alternative to the Bunsen burner for that purpose is the Bacti-Cinerator® ("Bacti-Cinerator," 2015). This device, which is an "infrared heat chamber," can sterilize microbiological tools without the need for "gas and open flames" (para. 1). That technology enables individuals with partial visual ability to participate in some of the microbiology laboratory activities. Although, Dr. Cary Supalo demonstrated that individuals who are completely blind are able to safely use a Bunsen burner with the proper training and safety precautions ("Independence Science," 2012), and Vollmer (2012) noted that students with BVI can successfully complete a microbiology course.

Some biology laboratory exercises require students to distinguish colors, such as discerning the eye color of fruit flies in genetics or color changes in biochemical media in the microbiology lab. Yet individuals with blindness cannot distinguish colors, and those blind from birth have no concept of color. As Victor Wong, a graduate student with blindness, stated, "there is no way that I can think of to give an exact idea of color to someone who has never seen before" (Brand, 2005, para. 2). Technology may surmount that limitation, however. Apple® has an application for the iPhone that will name colors ("GreenGar Studios," 2016), and a scientist has developed a product called EyeMusic that enables individuals to discern color through sound (Abboud, Hanassy, Levy-Tzedek, Maidenbaum & Amedi, 2014; Sumner, 2014). Google glass, which enables the user to verbally interact with a computer fashioned into eyeglasses, has been shown to assist individuals with visual impairments (Duffy, 2013). There is also a "talking color detector" that can name colors ("The Talking," 2016, para. 1).

Fieldwork is often part of biology courses. Moon et al. (2012) noted that fieldwork can be a significant obstacle to students with BVI. The authors noted research indicating that, "students with disabilities shy away from field work because they feel inadequate or awkward trying to undertake it" (p. 111). Prior planning is required to ensure that the sites can accommodate a wheelchair (Burgstahler, 2012). Consideration must also be given to guide dogs that may need to accompany the student with BVI ("Students," 2016). Aides or a student partner can assist the student with BVI, but care must be taken to ensure that the students with BVI are not excused from tasks that form a fundamental part of the fieldwork experience. Moon et al. (2012) acknowledged the challenge instructors confront in designing fieldwork exercises for students with BVI that enable their participation yet do not compromise the intended learning goals of the activity. The authors surmised that, "ultimately, this contradiction between goals and accommodation may be worked out" (p. 142).

In light of the many adaptations and technologies described it is clear that specific accommodations are being provided for students with BVI in college science classes. The accommodations are possible largely because of "advancements in tools and materials" (Childers, Watson, Jones, Williamson, & Hoette, 2015, p. 26). Instructors are modifying existing exercises to enable comprehension of concepts and development of laboratory skills. Wide variety in the adaptations and technological innovations exists because accommodations must be provided relative to each student's particular needs, required activities of different courses in the biological sciences vary significantly, and because there are no regulations regarding accommodations specific to the biology laboratory (Moon et al., 2012). But as a result of the combined efforts of so many, students with BVI are successfully completing biology courses.

Successful course completion does not necessarily mean that the students with BVI have acquired the same level of understanding as their sighted peers, however. It is logical to question whether the students with BVI are learning what they need to be learning. Research regarding the specific accommodations would be required address that question.

Are Accommodations Meeting Needs?

According to the ADA, "an institution has flexibility in choosing the specific aid or service it provides to the student, as long as the aid or service selected is effective" ("Auxiliary Aids," 2011, para. 9). In that context, effective is determined relative to "whether the accommodation will provide an opportunity for a person with a disability to achieve the same level of performance and to enjoy benefits equal to those of an average, similarly situated person without a disability" ("Americans," 2001, para. 24). Consequently, accommodations for students with BVI in the college biology laboratory must be effective. They must enable the students with BVI to have a similar experience and the opportunity to learn at a level comparable to that of their sighted peers. Because there are no regulations regarding which accommodations specific to the college biology laboratory must be provided for students with BVI (Moon et al., 2012), instructors must determine which accommodations they believe will support each student's specific needs, and provide them relative to their own knowledge of required methods and their access to the necessary materials. The laboratory activities of each biology course vary as well. It is possible that some students with total blindness could successfully participate in the laboratory activities of some biology courses, while those with a milder visual impairment could be unable to participate in the activities of a different course. Thus, laboratory accommodations specific to the college biology laboratory for students with BVI that enable them to participate in and learn from the laboratory exercises can vary by institution and by course.

Due to that variation, evaluation of the effectiveness of accommodations cannot focus solely on the types of accommodations offered in the biology laboratory. Another method by which to assess the effectiveness of the accommodations would be required. Exploration of the literature disclosed seven different criteria that instructors and students judged as vital to their laboratory experiences. Collectively, those seven criteria characterize a classroom environment conducive to learning and one that maintains the academic standards of the course.

Of significant importance is that the students must be able to safely and actively participate in the laboratory (Duerstock et al., 2014; "The Integral Role," 2007). Safety applies to every individual in every science laboratory. Altabbakh, AlKazimi, Murray, and Grantham (2015) warned of the severe and often tragic consequences when students are not safe in the laboratory. The authors observed that, "college students lack minimum safety awareness and training in safe work habits" (p. 38). In addition to issues of safety, the students must be able to actively participate. Supalo (2010) and Moon et al. (2012) noted the importance of active participation by students with BVI in science laboratories. For many students with BVI, specific accommodations are required for active participation. "Hands-on approaches to learning sciences or related subjects may increase students' interest and comprehension in the classroom, both for students who are blind and those who are sighted" (Supalo, 2010, p. 66).

Students must also be engaged in the science laboratory (Gormally et al., 2011; Sinatra et al., 2015). Axelson and Flick (2011) defined student engagement as "how involved or interested students appear to be in their learning and how connected they are to their classes, their institutions, and each other" (p. 38). Engagement is described as having a "multifaceted nature" because there are different aspects of engagement (Fredricks, Blumenfeld, & Paris, 2004, p. 60). "Behavioral engagement" involves participation; "emotional engagement" is reflected by student responses to others in the classroom and institution; and "cognitive engagement" includes the individual's endeavors to grasp conceptually challenging content and learn required skills (p. 60). Student engagement has been linked to successful learning outcomes (Sinatra et al., 2015). In a laboratory setting, active participation has been noted to improve engagement and comprehension of scientific concepts by students with BVI (Mastropieri & Scruggs, 1992). Thus, specific accommodations enable active participation, which promotes learning and engagement.

Children with disabilities are "generally less accepted" by classmates (Frederickson, 2011). Acceptance by classmates has been shown to positively influence academic success (Supalo, 2010). Further, Scruggs and Mastropieri (2007) urged that, among other requirements, students with disabilities learn best in a classroom in which they feel accepted. The literature supports a relationship between active participation and peer acceptance (Supalo, 2010; Supalo et al., 2014). That active participation requires specific accommodations for many students with BVI. Another criterion, therefore, is that the students must be accepted by classmates (Scruggs and Mastropieri, 2007; Supalo, 2010).

In addition to feeling accepted, students must contribute to group activities (Barbosa et al., 2004; Gaudet et al., 2010; Gormally et al., 2011). Active participation is required to be a contributing member of a group, making specific accommodations essential for many students with BVI. Group activities are common in the science laboratory ("Laboratory," n.d.). Some groups may be comprised of two students; some classes are conducive to larger groups (DiBartolomeis, 2011). Additionally, research has demonstrated that student involvement in class discussion and learning increased as a result of group interactions (Gormally et al., 2011).

Many activities in the biology laboratory require students to attain mastery of appropriate skills (Di Trapani & Clarke, 2012; Fitch, 2007; Hunt et al., 2012). Gaining competence in techniques and the proper and safe use of materials and equipment necessitates active participation, and for students with BVI specific accommodations are often required to enable that participation. Students who do not acquire competency in required skills can struggle in subsequent laboratory coursework. Additionally, students can be assessed on their skills proficiency as part of the laboratory grade. "Practical skills and competencies are critical to student engagement and effective learning in laboratory courses" (Di Trapani & Clarke, 2012, p. 29).

The sixth criterion requires that students meet all academic requirements of the course ("Reasonable," 2016). To meet the academic requirements of a course, it is necessary to actively participate in the course activities, necessitating specific accommodations for many students wiht

BVI. According to the American Psychological Association's explanation of reasonable accommodations, accommodations required by the Americans with Disabilities Act "do not compromise the essential elements of a course or curriculum; nor do they weaken the academic standards or integrity of a course" ("Reasonable," 2016, para. 2). Ashworth, Bloxham, and Pearce (2010) remarked that as more students with disabilities enter college, institutions of higher education must find balance between maintaining the academic standards of their courses and providing accommodations for the students, including adaptations to assessments. A grade of C or better is often used to determine whether a student successfully completed a course ("Prerequisites," n.d.; "Understanding," 2015). Therefore, students earning a C or better can be considered to have met the academic requirements of a course.

The final criterion associated with student learning is that the students must acquire knowledge commensurate with that of their sighted classmates (Duerstock, 2015). It is important to ensure that the students with BVI learn the curricular content of a course as well as the students in the class without a disability. In order to acquire learning equivalent to sighted students who are actively participating, students with BVI must actively participate. Many activities in the college biology laboratory are visually based, such as determining the eye color of fruit flies, observing the breathing rates of fish, and identifying microscopic organisms. Depending on the severity of the student's visual impairment, he or she may not be able to participate, or may have limited participation, in visually based activities. Those students may not acquire an equivalent level of learning without the same hands-on experiences as others in the class. DiTrapani and Clarke (2012) noted that acquisition of practical skills improves student learning.

Specific accommodations enabling a student with BVI to meet each of those criteria would afford the student an equal opportunity to learn. Therefore specific accommodations could be considered effective if they enabled the opportunity for a student with BVI to: (a) safely and actively participate in the laboratory activities (Duerstock et al., 2014; "The Integral Role," 2007), (b) be engaged in the class (Gormally et al., 2011; Sinatra et al., 2015), (c) be accepted by classmates (Scruggs and Mastropieri, 2007; Supalo, 2010), (d) contribute to group activities (Barbosa et al., 2004; Gaudet et al., 2010; Gormally et al., 2011), (e) demonstrate required skills (Di Trapani & Clarke, 2012; Fitch, 2007; Hunt et al., 2012), (f) meet all academic requirements ("Reasonable," 2016), and (g) acquire knowledge commensurate with that of their sighted classmates (Duerstock, 2015).

Those criteria, hereinafter referred to as the *seven criteria*, can serve as the basis for evaluating the effectiveness of the specific biology laboratory accommodations for students with BVI. An important thread unifying each of the *seven criteria* is active participation. In those courses necessitating specific accommodations for student involvement in laboratory activities, the focus of this study, the student could meet each of the *seven criteria* only if the specific accommodations enabled the student to actively participate in the laboratory activities.

An important consideration in this study is that students may confront challenges in biology classes that have nothing to do with specific accommodations for a visual impairment. Faculty members surveyed regarding student failure noted many factors causing students to struggle, including students not being academically or behaviorally prepared for college (Cherif, Adams, Movahedzadeh, Martyn, & Dunning, 2014, para. 7), lacking responsibility (para. 18), maintaining poor attitudes (para. 21), poor self-confidence (para. 24), and "life and socioeconomic issues" (para. 26). Further, in some courses the laboratory exercises performed illustrate a well-known concept. Students completing such activities may "never become cognitively engaged" because they simply follow a detailed procedure and already know the outcome (Johnson, 2009, p. 5). Certainly, though, "failures of the educational system" are responsible for some of the challenges that students confront (Cherif et al., 2015, para. 36). Specific accommodations for a student with BVI that are not effective would fall into that category.

Perceptions of students and instructors can yield insight into whether specific accommodations enabled the students to meet six of the *seven criteria*. There is one criterion that cannot be evaluated from student and instructor perceptions, however. Assessments are normally used to determine whether a student has met the academic requirements of a course. Therefore, as part of evaluating effectiveness, it is necessary to explore the assessments utilized in the biology laboratory.

Routine Assessment in Biology

Instructors use assessments to determine whether the students in the class met the learning outcomes of the course. Suskie (2010) urged that the overriding purpose of assessment is not "improvement or accountability" on which so much attention is focused (para. 15). Instead, the author argued that the ultimate goal of assessment is that, "everyone wants students to get the best possible education. Everyone wants them to learn what's most important" (para. 15). Goubeaud (2010) indicated that to effectively "assess the skills, knowledge and competencies students should demonstrate in college science" more than one type of assessment must be utilized (p. 239).

In biology courses, a variety of assessments are normally used to assess student learning in the laboratory, and both "direct" and "indirect assessments" of acquired knowledge and skills is possible (Harris et al., 2007, para. 6). According to each instructor's personal discretion, typical assessments include quizzes (Fitch, 2007; Harris et al., 2007; Heyborne, Clarke, & Perrett, 2011; Luckie et al., 2013); exams (Fitch, 2007; Goubeaud, 2010; Harris et al., 2007; Heyborne et al., 2011; Hunt et al., 2012; Luckie et al., 2013); lab reports (Fitch, 2007; Harris et al., 2007; Heyborne et al., 2011; Hunt et al., 2012); homework (Luckie et al., 2013); student laboratory notebooks (Harris et al., 2007; Heyborne et al., 2011); involvement in laboratory activities, adherence to safety procedures, data collection and interpretation, group work (Hunt et al., 2012); "evaluations of group discussions" (Moon et al., 2012 , p. 117); skills demonstration (Di Trapani & Clarke, 2012; Fitch, 2007; Harris et al., 2007; Hunt et al., 2012); drawings (Bland, 2004); "term or research papers" (Goubeaud, 2010, p. 241); and lab practicals (Bland, 2004; Harris et al., 2007; Pham, Higgs, Statham, & Schleiter, 2008; Ronsheim, Pregnall, Schwarz, Schlessman, & Raley-Susman, 2009; Womble & Walker, 2001).

General accommodations, such as enlarged font sizes, extended time, accessible formats, and screen readers, can often enable students with BVI to complete many of the assessments normally administered in the class, such as quizzes, exams, lab reports, homework, and term papers. Students with BVI could maintain their laboratory notebook in electronic format, if taking notes and recording data presented difficulty. The ADA requires "equal opportunity" ("A Guide," 2009, para. 9; "The Americans," n.d., para. 1) for students with disabilities. However, the ADA does not intend for instructors to lower academic standards as they support students with disabilities in their classrooms ("Reasonable," 2016). Though referencing students completing biology exercises in an online format, a practice for which he advocates, Fenrich's (2014) statement exemplifies the dilemma with which biology instructors of students with blindness could be confronted. He queried:

> Would it be reasonable for a student to get a biology degree without ever working with real specimens and a real microscope and other lab equipment? It is likely that most individuals would answer this question with a resounding "No." (p. 108)

Baumstark, Shanholtzer, and Michelich (2001) proposed that all students completing an introductory college biology course should be able to "use basic equipment in laboratory courses" (para. 6). In some situations, though, alterations to the original exercises are required for students with BVI, such that assessments used for sighted students would not be applicable. For example, a student with total blindness cannot see images with a microscope, yet "the light microscope is perhaps the single most important instrument used in cell biology" (Ledbetter, 1992, p. 4) and "proficient use" of the microscope can be an assessed learning outcome in biology courses ("Biology," n.d., p. 1; see also Fitch, 2007). It is possible to produce tactile models of microscopic specimens for students with BVI (Caldwell & Teagarden, 2007; Derra, 2015; J. Xu, personal communication, August 2014), but instructors face challenges in equivalently assessing the ability of a blind student to identify a tactile model of a specimen when the sighted students were required to first find the specimen under the microscope in order to identify it. Instructors must also determine how other skills requirements of the course can be assessed for students with BVI if they are unable to complete tasks and demonstrate skills in a manner similar to that of their sighted peers.

It is more challenging to assess students with BVI, especially students with total blindness, on some requirements of the laboratory. Challenges arise in evaluating the ability to accurately record data; whether they actively participated in the lab activities, such as animal dissection; their contributions during group exercises, as in outdoor fieldwork; and required observational drawings. However, advance planning can address some of those difficulties. For instance, an aide or group member could audibly recite test results to enable accurate data recording. Instructors could find and focus microscopic images for those students with BVI who also have manipulative difficulties or project them onto a large screen for those with some visual ability (J. Xu, personal communication, December 2014). A "dissecting microscope and closed circuit television" could enable students with partial vision to participate in animal dissection ("Visual," 2016, para. 8). Additionally, holding outdoor activities in a location suitable to the student's abilities could permit the student with BVI to actively contribute to group discussion of the field experience, and the student with BVI could describe his or her observations rather than draw them (Moon et al., 2012).

Other components of the lab experience that are often assessed in the biology lab may require more creative planning in order to competently assess students with BVI, notably skills assessment and laboratory practicals. Laboratory skills assessment can include demonstration of the ability to obtain isolated colonies on a streaked agar plate, describing the colony morphology of the isolates ("Identification," 2014), mastery of microscopy techniques ("Biology," n.d.; Fitch, 2007), and accurate pipetting of substances (Ronsheim et al., 2009). Harris et al. (2007) noted that skills in the biology laboratory could be assessed by

> direct assessment, where . . . the demonstration of the skills themselves are [sic] the object of assessment and [by] "indirect" assessment where a students' level of a practical skill has a bearing on a related, assessed activity (such as a lab report or a written practical test). (pp. 1-2)

Thus, in cases where direct assessment is not possible because the student cannot perform the skill, indirect assessment could substitute.

Lab practicals, which evaluate some of the "hands-on aspects" of the laboratory (Pham et al., 2008, p. 112), are often timed, can require students to circulate around the lab, and may incorporate "microscopes, . . . balances, and . . . other small equipment used throughout the semester" (Ronsheim et al., 2009, p. 18). Students with BVI could take the practical exam at a different time from the other students in the class to prevent navigation difficulties. Additionally, verbal descriptions could be provided by the instructor when necessary (Womble & Walker, 2001).

With advance planning, the routine assessments of the biology laboratory can be used to assess the learning of students with BVI to determine whether they meet the academic standards of the course, whether they have learned "what's most important" (Suskie, 2010, para. 15). However, grades based on assessments do not necessarily reflect the confidence of instructors that the student with BVI indeed met all of the academic requirements of the course and learned at a level comparable to sighted students in the class who earned the same grade. Nor do grades indicate whether the students with BVI felt safe in the laboratory, were engaged in the class, and felt accepted by classmates. Grades alone cannot determine whether the specific accommodations for students with BVI in the college biology laboratory were effective.

Assumption of Effectiveness

Adaptations to biology laboratory exercises are necessary for some students with BVI because of the visual nature of many of the required activities. At times, accommodations are provided based on the student's "category of disability" rather than the student's specific needs (Stodden et al. as cited in Stodden et al., 2002, p. 36). Regardless, the underlying assumption is that accommodations enable the opportunity for acquisition of equivalent skills and knowledge commensurate with the academic requirements of the course.

The students with BVI may receive a passing grade in biology because of successful completion enabled by specific accommodations provided. However, Wegwert (2012) cautioned that, "as a measure of student learning, grades are frequently invalid, as they commonly include criteria unrelated to evidence of student learning" (p. 413). Frechtling, Sharp, and Westat (1997) indicated that educators and school officials believe "traditional test results [are] . . . a poor tool for assessing true student learning" (para. 21). Additionally, Sadler (2009) emphasized that grades should be based on assessments that reflect a student's "academic achievement" (p. 807). The author noted that some instructors incorporate participation into their grading schemes, which some do not view as reflective of academic achievement. Examination of course grades must therefore acknowledge that at least a portion of some instructor's course grades may reflect non-achievement based assessments rather than reflecting actual academic learning.

Jones et al. (2006) cautioned that little research has investigated the ability of students with BVI to conceptualize and apply information involving visual imagery, how students with BVI absorb scientific knowledge, or how technological adaptations affect the learning of students with BVI. Similarly, Fraser and Maguvhe (2008) questioned, "to what extent do visually impaired learners achieve the learning outcomes specified for life-sciences/biology and which variables restrict effective teaching and learning in the life-sciences/biology classroom" (p. 84). Effectiveness cannot be assumed; evaluation of the effectiveness of the accommodations is necessary to address those concerns. Unless the specific accommodations are evaluated for effectiveness, whether the specific accommodations enabled the students with BVI to acquire the skills and master the concepts at a level equivalent to that of their sighted classmates remains unknown.

Perceptions of the Effectiveness of Accommodations

One student with blindness remarked, "faculty have no idea what it is like to be a student with a disability" (Brandt, 2011, p. 113). Research has indicated that successful accommodations require attention to the perceptions of the individuals with disabilities and whether the accommodations met their needs (Reinschmiedt et al., 2013). Studies determined that soliciting student input enabled determination of the effectiveness of tactile accommodations made for a biology unit (de Souza et al., 2012). Additionally, Tsinidou, Gerogiannis, & Fitsilis (2010) stressed that student perceptions provide valuable insight into program quality. The perceptions of the students with BVI regarding the accommodations are not measured by the standard assessments routinely administered in college biology classes. The routine assessments do not measure the engagement of students with BVI in the class, whether the students felt safe and accepted by sighted classmates, believed they learned as much as those who were sighted, or whether the students with BVI felt that they contributed to group learning. Therefore, student perceptions constitute an important component in an evaluation of the effectiveness of specific accommodations.

Under the assumption that the accommodations provided were effective, and based on the routine assessments of the course, instructors may determine that the student with BVI earned a passing grade. However, standard biology assessments do not routinely consider the instructor's perceptions as to whether the specific accommodations enabled the student with BVI to contribute to group activities, be engaged in the class and accepted by classmates, and to safely and actively participate in the lab activities at a level commensurate with the sighted students in the class. Importantly, they may not reflect the instructor's confidence that the students with BVI learned as much as sighted classmates who received the same grade.

Unlike the IDEA that guides accommodations for students during their primary and secondary education, the ADA's requirements for higher education do not require significant changes to curriculum or a reduction in course expectations (Dell, 2010). The intent of making accommodations for students with disabilities in higher education is not to "weaken the academic standards or integrity of a course" ("Reasonable," 2016, para. 2). In fact, high instructor expectations are correlated with increased student achievement (Ozturk & Debelak, 2005). Therefore, it is important to maintain academic standards in higher education ("Reasonable," 2016). Dill and Beerkens (2013), in an article advocating for policies ensuring academic standards in higher education, remarked that, "the most beneficial university education for students as well as for society still appears to be academic programs designed by and whose standards are assured through the collective actions of knowledgeable faculty members" (p. 354). Therefore, instructor perceptions are also an important ingredient in evaluating whether specific accommodations are effective.

The National Center on Educational Outcomes investigated inclusion practices resulting from the "Elementary and Secondary Education Act and the Individuals with Disabilities Education Act (IDEA)" in Grades K-12 in the United States (Christensen, Thurlow, & Wang, 2009, p. ii). Their recommendation included "the need to monitor accommodations" (p. iii). The authors of the report noted that an important outcome of evaluating accommodations was that "information from these reviews can be used to improve outcomes for students with disabilities" (p. 31). Accommodations provided for students with BVI at the college level should not be exempt from that advice.

Examining student and instructor perceptions of the specific accommodations in the college biology laboratory enabled evaluation of whether they permitted students with BVI to actively participate in the required activities of the biology course and the opportunity to learn at a level commensurate with their sighted peers. Instead of relying solely on the standard assessment techniques utilized in the biology laboratory, this research project evaluated the effectiveness of specific accommodations by gathering and analyzing the perceptions of both students with BVI who had completed college biology courses and college biology instructors who had taught students with BVI. Effectiveness was evaluated according to several criteria noted in the literature that were important to student learning in the biology laboratory. To be considered effective in this study, the specific accommodations had to enable the opportunity for a student with BVI to (a) safely and actively participate in the laboratory activities (Duerstock et al., 2014; "The Integral Role," 2007), (b) be engaged in the class (Gormally et al., 2011; Sinatra et al., 2015), (c) be accepted by classmates (Scruggs and Mastropieri, 2007; Supalo, 2010), (d) contribute to group activities (Barbosa et al., 2004; Gaudet et al., 2010; Gormally et al., 2011), (e) demonstrate required skills (Di Trapani & Clarke, 2012; Fitch, 2007; Hunt et al., 2012), (f) meet all academic requirements ("Reasonable," 2016), and (g) acquire knowledge commensurate with that of their sighted classmates (Duerstock, 2015). Those standards form the *seven criteria* against which the effectiveness of the accommodations was evaluated.

While laws require institutions of higher education to ensure that students with BVI are provided with the necessary tools and materials to achieve success, social justice champions that same goal. Miner et al. (2001) posited that, "instructors should provide accommodations because it is the right thing to do" (p. 6). Accordingly, institutions of higher education believe that supporting students with disabilities is morally sound ("Accessibility," 2015; Helmus, n.d.; "Student Counseling," 2016).

Theoretical Framework

Social justice education, transformative learning, and critical theories guided this research because of their advocacy in supporting what is right. College biology instructors are providing specific accommodations for students with BVI in the college biology laboratory (Caldwell & Teagarden, 2007; Derra, 2015; Vollmer, 2012; Womble & Walker, 2001). Therefore, it was necessary to evaluate whether the specific accommodations provided for those students enabled the opportunity to successfully meet the academic requirements of the course in an atmosphere conducive to active participation and learning.

Friere recognized the uniqueness of students and the importance of ensuring educational opportunities for each individual (Torres, 2008). Social justice education strives to achieve equity for students (Hackman, 2008), including minority students in institutions of higher education (Pliner & Johnson, 2004). "In the United States, people with disabilities are the largest minority group" (Lazar & Jaeger, 2011, p. 69). This research aligned with social justice education theory as it tried to ensure that students with BVI received accommodations that enabled the opportunity for them to be successful in the college biology laboratory.

An important lens through which evaluation of whether the accommodations enabled students with BVI to contribute to group activities and actively participate in the exercises was transformative learning theory. The theory addresses issues of group interaction and having an "equal opportunity for participation" (Mezirow, 1997, p. 11). Specific accommodations enabling students with BVI to actively participate in the laboratory may offer a new learning experience, as prior participation was likely not encouraged (Supalo et al., 2011). "It is experience, particularly prior experience . . . that is the primary medium of a transformation, and it is the revision of the meaning of experience that is the essence of learning" (Vittoria, Strollo, Brock, &

Romano, 2014, p. 6147). In this study, students with BVI were able to express their perceptions of the laboratory accommodations, aligning with the "emancipatory and liberating" learning possible with transformative learning (Dirkx, 1998, p. 3). Transformative learning theory also strives to understand how adults learn (Mezirow, 1997). On college campuses, evidence indicates that a "significant proportion of the undergraduate student body" is composed of adult learners (Ross-Gordon, 2011, para. 1), and college students with disabilities are, in general, older than their nondisabled classmates ("National Science Foundation," 2015). The average age of undergraduate students not reporting a disability in the 2011-2012 school year was 26.1; it was 28.8 for students indicating a disability ("Profile of Undergraduate Students: 2011-12," 2014). Therefore, transformative learning theory provided an important lens for this research.

Critical theory was another important component of this study, as researchers aligning with this theory seek to improve existing conditions rather than simply describing them (Mayo, 2007). Whether there was disparity between the intended goal of providing specific accommodations for students with BVI in the college biology laboratory, and what actually transpired, was the intent of this research project. Held (1980) claimed that one goal of critical theorists is to "expose the hiatus between the actual and the possible" (p. 22), making critical theory appropriate for this study.

Shields (2010) stated that, "transformative concepts and social justice are closely connected through the shared goal of identifying and restructuring frameworks that generate inequity and disadvantage" (p. 566). Mezirow (1997) remarked on the association of transformative learning with justice. Friere also advocated for social justice in education (Gibson, 1999). The overarching goal of critical theory is to effect change that promotes social justice as it strives to change conditions for the oppressed (Mayo, 2007). Social justice education, transformative learning, and critical theories are well-researched and respected theories. Each seeks to critique education through the lenses of equity and social justice. Those principles were consistent with the goals of this project.

Conclusion

Using a "transformative mixed methods" approach (Creswell, 2012, p. 546), this research study aimed to evaluate the effectiveness of the specific laboratory accommodations provided for students with BVI in the college biology laboratory. Instructors of students with BVI in the college biology laboratory and students with BVI who had successfully completed a college biology course that included a laboratory component were surveyed relative to their perceptions of the *seven criteria.* Answers to questions on the anonymous online questionnaires were evaluated with the intent to determine whether the specific accommodations for students with BVI enabled the opportunity for a laboratory experience similar to that of sighted students, and that instructors were confident that the academic standards of the course were maintained. Results were examined through the melded lenses of transformative learning theory, social justice education theory, and critical theory. The theories grounded this project and served as a sturdy scaffold. They provided the proper lens through which the results of the study were interpreted because each serves as a reminder that the ultimate reason for providing specific accommodations for students with BVI is to promote justice.

Many factors have led to an increase in the number of students with BVI attending higher education, and some of those students are registering for college biology courses. The pioneering work of many researchers in creating adaptations so that students with BVI can actively participate in science laboratory activities in general and biology laboratory activities in particular is evidence that it is possible to create adaptations for students with BVI in the college biology laboratory. To determine whether the specific accommodations met the needs of the students with BVI and their instructors, it was necessary to evaluate the effectiveness of those specific accommodations from the points of view of both students with BVI and instructors of students with BVI. The study enabled evaluation of whether the students had the opportunity to complete the course with skills and knowledge commensurate with that of their sighted peers receiving the same grade. One study was located that evaluated student perspectives regarding the effectiveness of tactile models (de Souza, et al., 2012). No studies were located that evaluated the effectiveness of specific accommodations in the college biology laboratory from the perspectives of both the students with BVI and instructors of students with BVI.

In his doctoral dissertation, Supalo (2010) focused on case studies of four high school students with blindness using new technologies developed at Penn State. He stated that, "the major limitation of these efforts to date is the general lack of rigorous research studies on the efficacy of the techniques and technologies illustrated, with the exception of a relative few" (p. 65). Wild and Allen (2009) similarly remarked that the determination of which accommodations institutions offer their students who are disabled should be grounded in the results of research studies that have evaluated the suitability of accommodations. Stodden et al. (2002) also recommended accountability for accommodations provided to students with disabilities.

This study sought to "give voice" (Creswell, 2012, p. 63) to students with BVI by enabling them to express their perspectives regarding the accommodations provided for them in the college biology laboratory. That vital information can be used to promote the development of alterations for the benefit of future students with BVI. The results of this study should be of interest to students with BVI, parents, administrators, and individuals in disability support services in addition to science educators. Results should "inform practice" (p. 63).

Leddy (2010) observed that in the United States, individuals with disabilities are not employed in the STEM fields at a rate comparable to that of nondisabled individuals. Moon et al. (2012) remarked that "only five percent of students with disabilities [are] pursuing graduate degrees in STEM disciplines . . . . [and] only one percent of recipients of STEM doctorate recipients has had a disability" (p. 11). Supalo et al. (2011) noted that, "very few persons with disabilities, and even fewer with visual impairments in particular, are employed in chemistry or other scientific fields" (p. 1). Wedler et al. (2014) remarked, "we believe that encouraging BVI students to pursue careers in STEM fields will contribute to rectifying the unemployment problem" (p. 188). In the United States in 2013, just over 36% of individuals with BVI who had earned a high school diploma or equivalent were employed. That number rises to just over 45% for those individuals who earned at least an associate's degree, and to just over 63% for individuals with a bachelor's degree ("Disability Statistics," 2013).Those statistics, though not specifically for STEM employment, are consistent with Wedler et al.'s prediction.

The success of students with BVI in the college biology laboratory can help students with BVI earn a college degree. A student with a disability remarked, "without practical experiences I was not getting the nuances of the subject matter or fully understanding technical procedures as well as my nondisabled classmates" (Duerstock, 2015, para. 7). When students with disabilities are active participants, they are able to "identify themselves as fellow science students, scientists, or engineers. This ability to self-identify as STEM professionals, along with independence, builds self-confidence to pursue a STEM career" (Duerstock et al., 2014, p. 25). Supalo (2010) proposed that the increasingly active role in the laboratory could lead to an increase in the number of students with BVI seeking STEM-related careers. This study aimed to evaluate whether the students with BVI were able to safely and actively participate in the exercises and have the opportunity to learn at a level comparable to that of their sighted classmates, or if they were passive bystanders listening to narrated accounts from lab partners or an aide. If students with BVI are able to safely and actively participate in college biology laboratory exercises, their positive experiences may impact the number of students with BVI choosing to pursue careers in the STEM disciplines.

As students with BVI take college biology courses, it is important that educators and students with BVI alike are confident that the course adaptations provided for them are effective. The specific accommodations must enable students with BVI the opportunity to safely and actively participate in the laboratory activities (Duerstock et al., 2014; "The Integral Role," 2007), be engaged in the class (Gormally et al., 2011; Sinatra et al., 2015), feel accepted by classmates (Scruggs and Mastropieri, 2007; Supalo, 2010), contribute to group activities (Barbosa et al., 2004; Gaudet et al., 2010; Gormally et al., 2011), demonstrate required skills (Di Trapani & Clarke, 2012; Fitch, 2007; Hunt et al., 2012), meet all academic requirements of the course ("Reasonable," 2016), and acquire knowledge commensurate with that of sighted classmates (Duerstock, 2015). This project attempted to ascertain whether the specific accommodations provided in the college biology laboratory met those criteria. Perceptions of students with BVI and instructors of students with BVI regarding the specific accommodations formed the basis of this study. How data was gathered and analyzed is discussed in the following chapter.

CHAPTER THREE: METHODOLOGY

Historically, students with blindness and visual impairments (BVI) were not encouraged to take courses in science (Scadden as cited in Supalo, 2013, p. 2). Recently though, as more students with BVI attend college (Callahan, 2011; Scott, 2009), some are choosing to enroll in college biology courses (Caldwell & Teagarden, 2007; D. Huey, personal communication, November, 2014; Hutson, 2009; J. Xu, personal communication, July, 2014). To complete laboratory exercises in biology, students are often required to hone their microscopy skills (Fitch, 2007), perform animal dissection (Almroth, 2015), record behavioral observations of living animals (Miller & Naples, 2002), measure shells (Metz, 2008), identify the sex and eye color of fruit flies ("Drosophila," n.d.), determine plant growth (Trautmann et al., 1996), work with microorganisms (Brocklesby et al., 2012; Krist & Showsh, 2007), participate in fieldwork exercises (Moon et al., 2012), and perform gel electrophoresis (Fitch, 2007; Supalo, 2010). Those can be challenging tasks for students with BVI.

The Americans with Disabilities Act (ADA) "prohibits discrimination and ensures equal opportunity" for all students ("The Americans," n.d., para. 1), and the National Science Teachers Association advocates for the safe inclusion of students with "physical needs" in laboratory experimentation ("The Integral Role," 2007, para. 2). Because STEM courses are traditionally taught in a highly "visual format" (Rule, 2011, p. 205), specific accommodations are required for students with BVI to enable them to complete many of the tasks required in the laboratory. Accommodations specific to science and biology are provided for students with BVI to enable successful completion of the laboratory portion of the course (Caldwell & Teagarden, 2007; Derra, 2015; Vollmer, 2012; Womble & Walker, 2001). One consideration in providing the specific accommodations is that they enable the students with BVI the "equal opportunity" required by the ADA ("A Guide," 2009, para. 9; "The Americans," n.d., para. 1). The ADA does not intend for the academic standards of the course to be lowered for students with disabilities, however ("Reasonable," 2016). Therefore, an additional consideration is whether course rigor is maintained as specific accommodations are provided.

To be effective, then, specific accommodations must enable access to the course and the opportunity for success ("The Americans," n.d., para. 1) without compromising the academic standards of the course ("Reasonable," 2016). There are no regulations regarding the specific accommodations that should be provided for students with BVI in the college biology laboratory (Moon et al., 2012), however. Further, no studies were located that determined whether the specific accommodations for students with BVI in the college biology laboratory were effective by examining the perspectives of students with BVI and college biology instructors who had taught students with BVI.

Study Design and Guiding Questions

Supalo (2010) indicated that a "major limitation" of efforts to support students with BVI in the science laboratory was the lack of research investigating the effectiveness of the specific accommodations provided (p. 65). The intent of this research study was to evaluate the effectiveness of specific accommodations for students with BVI in the college biology laboratory. In this study, whether the specific accommodations met student and instructor needs was evaluated according to several criteria noted in the literature that enabled student learning in the biology laboratory. To be considered effective, the specific accommodations must have enabled the opportunity for a student with BVI to (a) safely and actively participate in the laboratory activities (Duerstock et al., 2014; "The Integral Role," 2007), (b) be engaged in the class (Gormally et al., 2011; Sinatra et al., 2015), (c) be accepted by classmates (Scruggs and Mastropieri, 2007; Supalo, 2010), (d) contribute to group activities (Barbosa et al., 2004; Gaudet et al., 2010; Gormally et al., 2011), (e) demonstrate required skills (Di Trapani & Clarke, 2012; Fitch, 2007; Hunt et al., 2012), (f) meet all academic requirements ("Reasonable," 2016), and (g) acquire knowledge commensurate with that of their sighted classmates (Duerstock, 2015).

Those criteria are hereafter referred to as the *seven criteria*. Each is associated with student learning. Active participation is an integral component in meeting each of those criteria as well. The overriding question of this research study asked whether the specific accommodations provided for students with BVI in the college biology laboratory were effective. In this study, specific accommodations enabling students to meet each of the *seven criteria* were considered to be effective. Gathering the perceptions of students with BVI and instructors of students with BVI enabled evaluation of whether the students were able to meet each of the *seven criteria*, and by extension whether the specific accommodations were effective.

To guide this research, two primary research questions were formulated:

What are the perceptions of students with BVI regarding their experience in the laboratory portion of a college biology course?

What are the perceptions of college biology instructors regarding their experience teaching a student with BVI in the laboratory portion of a college biology course?

Three sub-questions extended the inquiry and provided pertinent data for the study:

To what extent do students with BVI believe that specific accommodations provided for them in the college biology laboratory enabled them to meet the *seven criteria*?

To what extent do instructors believe that specific accommodations provided for students with BVI in the college biology laboratory enabled them to meet the *seven criteria*?

What course and assessment modifications do college biology instructors believe should be made for students with BVI in the college biology laboratory?

Perceptions were also gathered regarding which specific accommodations were most beneficial to the students. Each student may have different needs depending on his or her particular visual challenge, necessitating that some accommodations be unique to that student. Therefore the specific accommodations most beneficial to one student might not be beneficial for another. However, the information gathered can inform future practice.

Participant perceptions of their experiences with the specific accommodations in the college biology laboratory were gathered through researcher-developed, anonymous online surveys. Separate surveys were created for students with BVI and for the instructors of students with BVI. The responses to the survey questions enabled evaluation of the effectiveness of the specific accommodations by determining whether the students with BVI were able to meet each of the *seven criteria*.

A mixed methods approach, which combines both quantitative and qualitative designs into one study (Creswell, 2012), was chosen for this research because both quantitative and qualitative data were necessary to address the research questions. A large population of individuals was desired to best reflect the target population, but narratives of individual experiences were important as well. Johnson and Onwuegbuzie (2004) stated that "mixed methods research can incorporate the strengths of both methodologies" and enhance the research (p. 23). Roberts (2010) explained that combining the two approaches "allows greater depth of understanding and insight than what is possible using just one approach . . . [and] helps overcome the biases inherent in each method" (p. 142). Further, results based on both qualitative and quantitative data yield broader application of the results of the study (Creswell, 2012).

To competently evaluate the effectiveness of the specific accommodations provided in the college biology laboratory, and achieve results that could inform best practices, it was necessary to gather perceptions from instructors and students that reflected a range of visual challenges. The number of instructors and students with BVI who qualified for this study was unknown. No statistics were available indicating the number of students with BVI who had completed a college biology course with a C or better between 2010 and 2015. Therefore, it was not possible to know the total number of potential participants. However, based on current literature stating that few college biology instructors have experience teaching students with BVI (Moon et al., 2012; Womble & Walker, 2001), and hence by extension a small number of students with BVI who have taken a college biology course, it was evident that the target population was small. Given an unknown population size, a confidence level of 95%, and a confidence interval of 10, a sample size calculator indicated that 96 participants from each group would be required for an accurate depiction of the target population. For a confidence interval of five, the calculator indicated that 384 participants would be required ("Sample Size," 2012).

With the exception of the schools mentioned in a few published articles regarding students with BVI in the biology classroom (Caldwell & Teagarden, 2007; Vollmer, 2012; Womble & Walker, 2001), no records were found identifying which institutions of higher education students with BVI had attended. Therefore, identifying students with BVI known to have taken a college biology course, or biology professors known to have taught a student with BVI, was impracticable. Because of the small number of potential participants, and that response rates can be as low as 2% when "contact information is unreliable" (Fryrear, 2015, para. 9), achieving 384 or even 96 participants in either group was highly improbable.

To contact as large a number of respondents as possible from the two limited populations, this study was offered in an online format. Although anonymity cannot be guaranteed, to protect the identity of study participants data was collected through anonymous, researcher-developed questionnaires posted on SurveyMonkey®. Surveys were utilized in order to gather "opinions, and survey geographically dispersed individuals" (Creswell, 2012, p. 405). Questionnaires were a good choice for this study as data generated from surveys yielded individual perceptions of the specific accommodations, and could be used to "evaluate . . . effectiveness" (Creswell, 2012, p. 403).

Separate surveys were developed for students with BVI and for instructors. The questionnaires, drafts of which are available in Appendices A and B, included both closed- and open-ended questions. Using closed- and open-ended questions in the same survey conformed to a "cross-sectional survey design" of collecting all study data at one time (Creswell, 2012, p. 377). A project manager at EvaluATE, the evaluation resource center for the National Science Foundation’s Advanced Technological Education program, reviewed the survey questions ("EvaluATE," 2015). The questionnaires were also reviewed by an individual from institutional research, a biology faculty member, and the vice president of student affairs at this researcher's college. Survey questions were modified according to their suggestions prior to implementation. To ensure accessibility, the final student survey was opened and completed with JAWS for Windows® screen reading software.

The study surveys were created in SurveyMonkey®. That platform offers accessible surveys that can be read by screen readers ("We're Proud," 2015) and permits their surveys to be used by researchers ("SurveyMonkey," 2015). The questionnaires were sectioned by pages so that only a portion of the questions appeared on the screen at one time. This method had been shown to be less intimidating to respondents than a long list of questions on one page through which the participant must scroll (E. Perk, personal communication, August, 2015).

Study surveys began with an informed consent page. Only those participants agreeing to participate in the study as outlined were permitted to continue. Qualitative data was collected through the open-ended questions on the surveys. Study participants were able to describe their perceptions concerning the specific laboratory accommodations in detail in their responses to those questions. SurveyMonkey permits responses of up to 32,000 characters for open-ended questions (Jeffrey at SurveyMonkey Support, personal communication, December 1, 2015), which enabled the collection of rich data pertaining to the experiences of the participants. Research has shown that the response rate to open-ended survey questions is low, especially if participants take the survey on a mobile device (Peytchev & Hill, 2008). For that reason, the open-ended questions were interspersed throughout the questionnaire, rather than being grouped together, with the intent of improving the response rate. The final open-ended question asked participants to relay their specific experiences in narrative form. This question was included to increase the amount of qualitative data. The possibility existed that response rates would be low for that question as well, but every response was helpful in evaluating the accommodations. The surveys included closed-ended questions as well, yielding quantifiable data.

Answers to the closed- and open-ended questions on the surveys permitted an exploration of student and instructor perceptions of the specific accommodations. Collecting student perspectives enabled evaluation of whether students believed that the specific accommodations provided for them met their needs by enabling them to meet the *seven criteria*. Given the small number of students with BVI who had completed a college biology course, and that each student with BVI would have a unique visual challenge, it was important to give voice to those students.

Reinschmiedt et al. (2013) noted that the perceptions of individuals with disabilities must be considered to determine whether accommodations met their needs. Instructor perspectives were also gathered, and were comparably evaluated. It was posited that those data would enable evaluation of the effectiveness of the accommodations by determining whether they enabled the students to meet the *seven criteria*.

One question asked participants to indicate whether the student earned a C or better as the final course grade. A grade of C or better can be used as an indication of successful course completion ("Prerequisites," n.d.; "Understanding," 2015). As the online surveys were anonymous, the student's academic record was not checked to verify the course grade. Responses of anyone not earning at least a C in the course were still collected for comparison to the responses of those students successfully completing the class, but both quantitative and qualitative data from those responses were analyzed separately and not used in evaluating the effectiveness of the accommodations.

This research conformed to a "transformative mixed methods" study (Creswell, 2012, p. 546). That methodology supported this research because its goal "is to address a social issue for a marginalized or underrepresented population" (p. 546), which applies to students with BVI in the college biology classroom. A "convergent design" as discussed by Creswell was applied in this study (p. 550) in that quantitative and qualitative data were simultaneously collected via anonymous, online questionnaires containing both closed- and open-ended questions. The qualitative and quantitative data were given equal weight in this study. The methodology allowed participant responses to related questions to be coalesced to determine whether each student met each of the *seven criteria*. Descriptions written in response to the open-ended questions provided extended support for the closed-ended responses, and enabled clarification in the case of conflicting responses to the closed- and open-ended questions.

The combination of numerical data from closed-ended questions and the text from open-ended questions provided details of students' and teacher's specific experiences with and perceptions of the specific accommodations. Those data were examined through the lenses of transformative learning, social justice education, and critical theories to determine whether the specific accommodations conformed to the tenets of social justice by enabling the students with BVI to meet the *seven criteria*. Each of the theories was important in evaluating the data to determine whether the accommodations provided for students with BVI in the college biology laboratory met the needs of both the students with BVI and the instructors. It was posited that if the accommodations enabled the students with BVI to meet the *seven criteria,* then they met the needs of both the students and the instructors, and were therefore effective.

Setting

This research study focused on college biology classes with a face-to-face laboratory component in higher education institutions in unknown geographic locations. Anonymity of the study participants was vital in this study, as were the identities of the institution at which the course was taken or taught and of other students in the class. Therefore, data was collected via anonymous, electronic surveys. Participants in the online surveys were assured that IP addresses were not available to this researcher and that SSL encryption was enabled ("SurveyMonkey," 2015), so that tracing an individual's identity would not be possible. Participants were ensured that any identifying information inadvertently included in their responses would be redacted. In light of the number of recent lawsuits filed against institutions of higher education by students with disabilities ("Category Archives," 2013; Danielsen, 2010; Danielson, 2015; Grasgreen, 2013; Lee, 2014; Pant, 2014; Parry, 2010; Solovieva & Bock, 2014), student and instructor reticence to participate in the study could have limited participant numbers. This made preserving participant anonymity and institutional affiliation crucial. Additionally, due to the low number of individuals with BVI who had successfully completed a college biology course, anonymity prevented tracing student identities.

Online questionnaires enabled participants to reside anywhere with Internet access. There were drawbacks to collecting data entirely through the Internet. Response rates to surveys soliciting participants via email are low. There had been optimism that surveys offered through the Internet would increase response rates, but that optimism has "given way to puzzlement" (Dillman, Smyth, & Christian, 2014, p. 11). Further, those checking email via a mobile device may choose not to participate in surveys because of the constrained size of the screen and keyboard (Peytchev & Hill, 2008). However, an alternate means of contacting students and instructors for this study was not determined.

College students have access to email and the Internet through their institutions. Further, "87% of American adults now use the Internet . . . . [and] 68% of adults connect to the Internet with mobile devices" (Fox & Rainie, 2014, para. 4). Though the college biology course must have included a laboratory component that met in a face-to-face format, the student could have taken the course at any institution of higher education. Those same criteria applied to the instructors. The study was open to any interested, qualified participant whose experience occurred at an institution of higher education between the years 2010 and 2015. Those specific years were chosen because of the increase in technological innovations during that five-year period. Spanning that number of years also increased the potential pool of participants.

Participants and Sampling

Student participants in this study must have been at least 18 years of age and have taken a college biology course with a laboratory component that met face-to-face at an institution of higher education between the years 2010 and 2015. The student must have had a disability of blindness or visual impairment documented by the disability support services (DSS) office (or equivalent) of the institution at the time they completed a college biology course taken at either a 2-year or a 4-year institution. Instructor participants must have taught a student with BVI who met the study criteria within that same time frame.

Multiple methods were used to recruit potential participants to the study. A website, created on WordPress®, used an accessible template in black and white for high contrast. The website explained the purpose and design of the research, and contained direct links to the instructor and student surveys, a brief biography of this researcher, and contact information to address any questions or concerns. On the start date of data collection, the DSS offices (or equivalent) of the two- and four-year institutions in Arizona, Michigan, and New Jersey were contacted by email and asked to forward the information and survey link to eligible students. This researcher had knowledge of institutions in those states with experience teaching students with BVI that could have increased the number of participants. The study's IRB approval included the requirement that the head of the DSS office provide a letter of support for the study prior to contacting students.

Instructors were recruited by emailing biology faculty members at each of those same institutions, asking those who taught a student with BVI meeting the study criteria to participate. Study information was also posted on this researcher's professional LinkedIn®, Twitter®, and Facebook® accounts. Additionally, four organizations involved in supporting individuals with

BVI were contacted, asking that they forward the study information to any eligible participants. "Snowball sampling" (Creswell, 2012, p. 146) also was incorporated into the study, as participants were advised that they could pass the study website link, or the direct survey links, to other individuals.

The initial study protocol indicated that (a) the surveys would remain open for six weeks, (b) the DSS offices and biology instructors in three states would be contacted, and (c) after two weeks, additional states would be contacted should participant numbers be below 96 for either group. After two weeks, though 17 individuals had accessed the instructor survey link, only six eligible participants had completed the survey. Results for the student survey remained at zero. Only one individual had accessed the student survey link after two weeks. That student had not continued even though he or she agreed to take the survey on the informed consent page.

A decision was made to expand the institutions surveyed to all states. In total, emails were sent to DSS offices and biology instructors at a total of 714 institutions of higher education across the United States. At least 10 institutions in all 50 states were included, with the exception of Rhode Island and Delaware. Only eight and six schools were contacted in those states, respectively. Nine institutions in the District of Columbia were also contacted. Emails to the DSS offices requested that eligible students be sent a researcher-provided email that outlined the study. The emails to biology instructors asked that they take the survey if eligible, and invited them to share the email with other individuals. Both emails contained direct links to the appropriate surveys and to the study website. Additionally, permission was obtained to allow the surveys to remain open for an additional two weeks, and to directly email the few students known to this researcher to be eligible for the survey. An additional eleven organizations associated with individuals with visual impairments were also contacted, and asked to send study information to eligible students and instructors. The emails that were sent to DSS offices, college biology faculty members, and organizations are included in Appendices C, D, and E, respectively.

All participation was voluntary. The first page of the questionnaire explained the study and required the respondent to check a box indicating their consent to participate in the study as designed. Anyone beginning an online questionnaire had the opportunity to stop at any time. Participants could also skip any question they chose not to answer, with the exception of answers to those questions required to determine study eligibility. One of the Likert scale responses for all but the eligibility questions enabled the respondent to choose not to answer the question. An "option to withdraw" from the study was the final choice on the survey ("SurveyMonkey," para. 9). Correspondence with SurveyMonkey indicated that responses from those choosing to withdraw from the study needed to be manually deleted by this researcher after the individuals submitted their results (Rainey at SurveyMonkey Support, personal communication, November 28, 2015).

It was not possible to guarantee participant anonymity. However, every attempt was made to protect the identity of participants, classmates, and of the institutions at which the biology course was taken/taught. The online questionnaires did not record IP addresses and SSL encryption was enabled ("SurveyMonkey," 2015), restricting the ability to trace respondents. Additionally, participants in the online questionnaire were asked not to reveal any identifying information in their answers to the open-ended questions, including identifying information about themselves, the institution at which they completed the college biology course, their instructor/student, or any classmates. Participants were assured that if their responses included identifying information, that information would be redacted from the documents.

The final question on the survey asked participants to tell their stories. Because participant experiences from both groups could vary significantly relative to the severity of the student's visual impairment, it was important to obtain detailed descriptions from participants that reflected a range of visual impairments. The initial study protocol stated that based on the answer to the survey question asking respondents to categorize the visual disability of the student, five student and five instructor responses for that final question would be selected for study inclusion to reflect visual challenges from mild to severe. That decision was based on advice from Creswell (2012) who noted that a qualitative study could include only one individual or many, but cautioned that, "the overall ability of a researcher to provide an in-depth picture diminishes with the addition of each new individual" (p. 209). However, due to the low response rates, study protocol was revised to include all responses to that final question.

Data and Analysis

Upon completion of data collection, all electronic files were transferred from SurveyMonkey to a flash drive. Data were not stored on a computer hard drive. The flash drive was stored in a locked safe kept in a secure location accessible only to this researcher. All records will be destroyed after five years from the time of publication of the dissertation. Publications arising from this research will include no identifying information.

Quantitative portions of the study were to be subjected to "descriptive statistics" (Creswell, 2012, p. 182), generating summaries of the central tendency, variability, and relative standing (p. 182). That portion of study protocol was amended, however. Percentages were calculated for the responses to several questions. They were not performed on most of the data generated from the surveys due to the low response rates.

Text from the open-ended questions was coded "to form descriptions and broad themes in the data" (Creswell, 2012, p. 243). Patton (2002) indicated that, "content analysis . . . involves identifying, coding, categorizing, classifying, and labeling the primary patterns in the data" (p. 463). According to Ryan and Bernard (2003), there are four components involved in analysis of qualitative data. They include determining common themes, identifying those most relevant to the study, prioritizing each, and relating each to the theoretical framework of the study (p. 85). Participants were questioned in this study relative to the *seven criteria*. Those criteria were used to initially categorize the data, and themes associated with each of those categories were coded. Coding was conducted by hand. Ryan and Bernard (2003) cautioned that novice researchers, such as this researcher, should not use all available methods of coding. For responses to open-ended questions on the online survey, the authors indicated that responses of only a few paragraphs or less could be coded by looking for "repetitions . . . similarities & differences . . . [and] cutting and sorting" (p. 102). Longer responses could include looking for "repetitions [and] transitions" (p. 102). The authors also mentioned using a "Key Words in Context (KWIC) technique" in addition to Word lists to identify important words within the context of the script (pp. 96-97) and to search for subthemes (p. 103).

Once the data were coded, data was triangulated to increase accuracy (Creswell, 2012), and to "validate findings" (Roberts, 2010, p. 161). Patton (2002) remarked that, "triangulation strengthens a study by combining methods" (p. 247). Of the four types of triangulation defined by Denzin (as cited in Patton, 2002), one applied to this study. Because results were evaluated through the lenses of transformative learning theory, social justice education theory, and critical theory, "*theory triangulation*, the use of multiple perspectives to interpret a single set of data," was applied in this study (p. 247). Additionally, a biology instructor crosschecked the longest narrative responses from one student and one instructor to ensure that no responses were misinterpreted or misrepresented.

Potential Limitations

Participants must have been able to comprehend a questionnaire written in English. Participants were required to craft their responses in English as well. English proficiency was therefore a requirement for participation. Because the surveys were available online, individuals in other countries could have participated in the research, but only if they spoke English fluently.

The questionnaires for the study were only available online, so everyone included in the study must have had access to a computer with Internet service. Current students would have had ready access to computers and the Internet on their college campuses. To protect their anonymity, some students may have wanted to complete the survey in a more private location, but may not have had computer and/or Internet service at that location. Those students may have chosen not to take the survey. Because the survey accepted students who had taken the biology course as far back as 2010, the individual may have graduated and no longer have had access to campus facilities. Additionally, "there are few reliable current statistics on the use of computers and the Internet by blind people in the United States" ("Blindness Statistics," 2015, para. 33). It would be possible for an individual to complete a college biology course, yet not be proficient in using a computer and navigating the Internet. Those individuals may not have been able to participate in the study.

Some students with BVI may have required a screen reader to access and complete the survey. The student survey was tested with a JAWS for Windows® screen reader prior to opening the survey to ensure that students could access the survey with a screen reader. However, results from a July 2015 screen reader survey indicated that only 50% of respondents characterized their expertise with a screen reader as "advanced," and 42% indicated a response of "intermediate" ("Screen Reader," 2015, para. 5). Those students requiring a screen reader and taking a college biology course could well number among the half of respondents who gauged their screen reader expertise to fall in one of those two categories, but that is not a certainty.

There was also the possibility that some respondents completed the questionnaire even though they did not qualify for the study. Because the surveys were completed anonymously, there was no way to guarantee that all responses were from participants who met the eligibility requirements. However, several questions at the beginning of the survey were set to automatically direct ineligible participants to a disqualification page based on their answers to those screening questions.

Each student with BVI has specific visual challenges. Some students with BVI have partial visual ability enabling them to actively participate in those laboratory exercises requiring visual ability to at least some degree in the same manner as sighted students. However, some students have total blindness and must participate through alternate means. It is also possible for students with BVI to face additional physical, intellectual, and/or emotional challenges that could affect their learning and their perceptions of the provided accommodations in the college biology laboratory. Additionally, though grades are used across the globe as a representation of student learning, some instructors include non achievement-based criteria in grades and some artificially inflate grades (Sadler, 2009). That implies that some students may have received a grade of C or better in the course even though their academic achievement alone would not have earned the students that same grade. Interpretation of instructor responses must include those considerations. Those factors make generalization of the results challenging at best.

Conclusion

Evaluation of the effectiveness of the specific accommodations provided for students with BVI in the college biology laboratory was the goal of this research study. To achieve that goal, the perceptions of college biology instructors who had taught a student with BVI, and students with BVI completing college biology courses, were collected via online surveys. A "transformative mixed methods" (Creswell, 2012, p. 546) approach was applied to ascertain whether the specific accommodations enabled this minority population of students to meet *seven criteria* identified as important to student learning. A portion of the quantitative data was subjected to descriptive statistics; qualitative data were coded and analyzed for themes. Qualitative and quantitative data were combined to determine whether each student was able to meet each of the *seven criteria*, thus determining whether the specific accommodations provided for the students were effective. Using the lenses of transformative learning theory, social justice education theory, and critical theory, results were analyzed to determine whether the specific accommodations enabled the students the "equal opportunity" required by law ("A Guide," 2009, para. 9; "The Americans," n.d., para. 1) while maintaining the academic standards of the course ("Reasonable," 2016). This research enabled students with BVI who had successfully completed a college biology course, and college biology instructors who had taught a student with BVI successfully completing their course, to express their opinions regarding the specific accommodations provided for them in the college biology laboratory.

This chapter included an overview of the study, the questions guiding this research, and an explanation of why this researcher chose to utilize a mixed methods approach. Information was also provided regarding the study location; how participants were identified and contacted; the types of data collected; how the data were collected, safeguarded, coded, and analyzed;

participant's rights; and potential limitations associated with the study. Results of the study are discussed in the following chapter.

CHAPTER FOUR: STUDY RESULTS AND OUTCOMES

This "transformative mixed methods" research study (Creswell, 2012, p. 546) aimed to evaluate the effectiveness of the specific accommodations provided for students with blindness and visual impairments (BVI) in the college biology laboratory. Students with BVI represent those with mild visual impairments, such as color blindness, to students with total blindness. Several criteria noted in the literature as important to student learning were used to enable evaluation of the effectiveness of the accommodations. Those criteria required that the specific accommodations enabled the student with BVI the opportunity to (a) safely and actively participate in the laboratory activities (Duerstock et al., 2014; "The Integral Role," 2007), (b) be engaged in the class (Gormally et al., 2011; Sinatra et al., 2015), (c) be accepted by classmates (Scruggs and Mastropieri, 2007; Supalo, 2010), (d) contribute to group activities (Barbosa et al., 2004; Gaudet et al., 2010; Gormally et al., 2011), (e) demonstrate required skills (Di Trapani & Clarke, 2012; Fitch, 2007; Hunt et al., 2012), (f) meet all academic requirements ("Reasonable," 2016), and (g) acquire knowledge commensurate with that of their sighted classmates (Duerstock, 2015). Collectively, those are referred to in this study as the *seven criteria*.

Data was gathered for this research entirely through researcher-developed, anonymous questionnaires posted on SurveyMonkey®. Several methods were used to recruit participants. The Disability Support Services (DSS) offices and biology instructors at 714 institutions of higher education in all 50 states, as well as 15 organizations, were contacted. Information was also provided through social media, a study website, and individuals were advised that they could share study information with others.

Of the institutions of higher education responding, eighteen declined to participate. Individuals at another eighty-one institutions indicated that they had no students with BVI, or no students with BVI who had taken a biology course. The Institutional Review Board approval for the study required that the head of the DSS office submit a letter in support of the study prior to sending emails to students with BVI. Five such letters were received. Additionally, the study website had visitors from 23 different countries, so it is not known where respondents resided.

Separate surveys were available for the students and the instructors. Both surveys contained a combination of closed- and open-ended questions. Participants responded to the closed-ended questions on either a yes/no basis, or by choosing their level of agreement from strongly agree to strongly disagree on a five-point Likert scale. Open-ended questions asked participants to type their answers to questions regarding their perceptions of various aspects of the specific accommodations of the course. The number of open-ended questions was minimized to improve the response rate (E. Perk, August, 2015, personal communication). Most participants provided a brief comment to all open-ended questions. Several wrote paragraphs detailing their experiences.

Included in the data analyzed for this study were the responses of students who were at least 18 years of age, and whose visual impairment was confirmed by the DSS office of the institution at which they took the college biology course. A student must have taken the course between 2010 and 2015, and earned a C or better. Additionally, the laboratory component of the course must have met in a face-to-face format.

Of the 12 students who began the survey, five students met all of the study criteria and completed it. One student indicated a visual impairment of severe/very severe/total blindness in one eye, and one indicated severe blindness. Two students had very severe blindness, and one student noted total blindness. All students indicated that they had taken either a 100- or 200-level biology course. Students took the course at both two- and four-year institutions. Students were asked for the course number and name in order to gain insight into the possible activity requirements of the course. Only one student indicated more than the course number, and the course name did not convey the desired information. Student responses were coded by the letter "S," followed by the number one through five. Therefore, identifiers for student participants are S1 through S5.

In addition to the five students, 15 instructors met all of the study criteria and completed the surveys, although 41 people began the survey. Some DSS office personnel indicated that they had looked at the informed consent of the survey, therefore some of the 41 individuals were not biology instructors who had taught a student with BVI. The responses from instructors were included if they taught a student who qualified for the study by the criteria listed. One of the instructors taught a student with mild visual impairment, six taught students with moderate visual impairment, two taught students with severe blindness, two taught students with very severe blindness, and four taught students with total blindness. Instructors from both two- and four-year institutions participated in the study. Instructors are identified by the letter "I" followed by sequential numbers. Hence, instructor identifiers are I1 through I15.

One individual identified the institution in his or her written narrative. That information was redacted from the survey. A potential sixteenth respondent indicated the desire to withdraw from the study following his or her completion of the survey. Individuals were able to edit their responses even after completing and submitting the survey, so that individual's responses were left undisturbed until after the data collection period closed. The responses were then deleted.

Examination of the collected data revealed the need to consider the results in light of the severity of the student's visual impairment. Students with a mild to moderate visual impairment may be less reliant on specific accommodations than students with a more severe visual impairment. Biology classes vary widely regarding the laboratory requirements of the course, so the severity of the student's visual impairment affected the student's experience and need for specific accommodations. As one instructor described:

> The students that I have taught with slight to moderate visual impairment do fine in the class . . . . I have yet to have students in my classroom that have complete blindness. I expect that a person with complete blindness would have to work with me in a different manner. (I3)

Therefore, study results had to be examined while considering the extent of the student's visual impairment.

Due to the small number of study participants, and because the data had to be interpreted in light of each student's particular visual impairment, descriptive statistics were not performed on much of the collected data. Tables were constructed to enable participant responses to be interpreted in light of the student's visual impairment. Participant letter-number combinations were not used in the tables to reduce crowding. Instead, letters were substituted, always beginning with the letter "a" in each visual impairment category. To enable discerning which individuals had experience in teaching students with BVI, the responses of those individuals with experience were capitalized within the tables in this chapter. For example, two students had very severe blindness (VSB). Those students were represented in the tables by "a" and "b." The responses of the four instructors who taught students with total blindness (TB) were coded as "A," "b," "C," and "d." Instructors denoted by "A" and "C" had prior experience.

Other than the degree of visual impairment, another factor that influenced the results was the laboratory activity requirements of the course. Courses taught by the biology instructors represented a wide range of possible biology classes. One hundred-level courses comprised most of the classes taught to the students with BVI, although three instructors taught 200-level courses, one instructor taught a 300-level course, and another taught a 500-level course. However, the latter instructor implied that the course was taught at a community college, which would not normally offer 500-level courses. It is possible that the course number was typed incorrectly. Though the term *biology* was used in the surveys, the study encompassed all disciplines within the biological sciences. Courses included botany, cellular and molecular biology, environmental science, general biology I and II, genetics, microbiology, molecular biology, non-majors organismal biology, principles of biology, and systems biology.

Instructors were asked to indicate the grading scheme for their courses. The percentage of the final course grade derived from the laboratory portion of the course ranged from 25% to 80%. Anywhere from 15% to 100% of the student's laboratory grade was based on assessments, such as lab practicals, quizzes, exams, and lab reports. Other assessments contributing to the student's laboratory grade included skills demonstration (0% to 60%), contributions to group understanding (0% to 75%), and active participation (0% to 100%). The instructors were also asked if a student could pass the course if the laboratory portion of the course were failed. Thirty-three percent of the instructors responded that students could pass the course if they failed the laboratory portion of the course. Therefore, in many biology courses, students would have difficulty passing the course if they could not actively participate in the laboratory activities, contribute to group understanding, and/or demonstrate the required skills.

There are other factors that could have influenced the study results as well. Institutional experience and available resources number among the factors that affect students with disabilities in the biology classroom. One instructor wrote a lengthy narrative explaining his or her frustration because the campus DSS office did not have any resources that would help the student in a biology laboratory (I8). The instructor was left on his or her own to support the student. Instructor 10 relayed a similar story:

> She was the first totally blind student that we had had in a biology class. Disability services were not sure what to do for accommodations. The disability counselor was new and had no experience in this area, so she left it to my discretion.

Other than the information provided by those two instructors, there is no data regarding the institutional support the students or instructors received.

Another variable that could have contributed to the student experiences included whether the instructor had experience in teaching students with BVI. Instructors were asked to indicate whether they had prior experience teaching a student with BVI. Eight instructors participating in the study had taught a student with BVI prior to teaching the student about whom their survey responses were recorded.

The *Seven Criteria*

In this study, the *seven criteria* were used as a basis for evaluating the effectiveness of the specific accommodations for students with BVI in the college biology laboratory. To be considered effective, the specific accommodations had to enable the opportunity for the student with BVI to (a) safely and actively participate in the laboratory activities (Duerstock et al., 2014; "The Integral Role," 2007), (b) be engaged in the class (Gormally et al., 2011; Sinatra et al., 2015), (c) be accepted by classmates (Scruggs and Mastropieri, 2007; Supalo, 2010), (d) contribute to group activities (Barbosa et al., 2004; Gaudet et al., 2010; Gormally et al., 2011), (e) demonstrate required skills (Di Trapani & Clarke, 2012; Fitch, 2007; Hunt et al., 2012), (f) meet all academic requirements ("Reasonable," 2016), and (g) acquire knowledge commensurate with that of their sighted classmates (Duerstock, 2015). Study results, therefore, were examined relative to each of those criteria.

Criterion One: Safely and Actively Participate in the Laboratory Activities

The first of the *seven criteria* required that a student have the opportunity to safely and actively participate in the laboratory exercises (Duerstock et al., 2014; "The Integral Role," 2007). In this study, students were asked to respond to the statement, "I felt safe in the laboratory." All of the student participants either agreed or strongly agreed with that statement.

Additionally, several questions on the student survey pertained to the student's ability to actively participate in the laboratory exercises (see Appendix A). A student with very severe blindness remarked that:

> Going into a biology class I was very worried that I would have a hard time participating . . . . and I thought that for sure I would have to just sit around and get the information from my lab partners. (S5)

Table 1 depicts student responses to pertinent closed-ended questions. The table includes the visual impairment designation of individual respondents in each category so that responses for each question can be interpreted in light of the severity of each student's visual challenge. The asterisk indicates that responses from one student with very severe blindness conflict for the two questions. Other than that discrepancy, all but one student felt that specific accommodations were necessary in order to participate in one or more of the lab activities. Student 2, who had severe/very severe/total blindness in one eye, disagreed that specific accommodations were necessary for active participation. That student wrote, however, that he or she had difficulty "identifying various colors of things; [and] finding where objects were through a microscope." A student whose visual impairment was very severe blindness wrote that:

> Gram staining was particularly difficult and boring for me because I wasn't allowed to stain my own slide. I tend to do everything myself, even if it's with adaptions, it's me that's doing it, so to have someone else make up my slides was super annoying. (S5)

Additionally, Student 3, a student with severe blindness, noted that participation was difficult in "labs that required [the] use of active chemical agents that were potentially harmful." The student did not offer any additional information to clarify the remark.

Despite the above comments, all students indicated that they were able to actively participate in at least a portion of the lab activities, four requiring specific accommodations. As one student commented, "I loved being able to participate and not just having someone else do everything for me" (S5). The students felt that they could safely and actively participate in the laboratory activities.

Table 1

Student Perceptions of Active Participation

Question	Visual impairment	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Could participate without specific accommodations	SVSTB1		a			
	SB					a
	VSB	b*				a
	TB					a
Specific accommodations needed for active participation	SVSTB1				a	
	SB	a				
	VSB	a, b*				
	TB	a				

Note. Total (n=5). SVSTB1 = Severe/Very severe/Total blindness in one eye (n=1); SB = Severe blindness (n=1); VSB = Very severe blindness (n=2); TB = Total blindness (n=1); * denotes disagreement between responses.

Biology courses vary significantly in the types of activities in which students participate. Therefore, student safety poses fewer challenges in some courses. One instructor cautioned that, "safety was less of an issue because of the nature of the course - a cell/molecular course or a microbiology course would likely have been much more challenging" (I7). Despite the variety of courses represented by the instructor respondents, every instructor agreed or strongly agreed that the students were safe in the laboratory.

In contrast, instructor responses to the questions regarding active participation varied. Data from two of those questions is presented in Table 2.

Table 2

Instructor Perceptions of Active Participation

Question	Visual impairment	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Student actively participated without specific accommodations	MiVI	A				
	MoVI			c, D	a, B, E	f
	SB				B	a
	VSB		a*, B			
	TB	A, b, d			C	
Specific accommodations needed for active participation	MiVI				A	
	MoVI	E	B, f	D	c	
	SB	a, B				
	VSB		a*		B	
	TB		C		d	A, b

Note. Total (n=15). MiVI = Mild visual impairment (n=1); MoVI = Moderate visual impairment (n=6); SB = severe blindness (n = 2); VSB - Very severe blindness (n=2); TB = Total blindness (n=4). Letters enable tracking responses of the instructors who taught individuals with the same visual impairment. Responses of instructors with prior experience teaching a student with BVI are capitalized. One instructor (MoVI - a) did not answer the second question. * denotes that responses do not agree.

One instructor conveyed what students with BVI could experience in the biology laboratory by writing the following in his or her narrative:

> She was a psychology major who had been blind since birth. She desperately wanted to participate in this class, especially the lab. When she took Biology 1, she could not

> participate at all. She could not take part in the experiments, since she could not measure solutions or see the results. She told me that her Biology 1 instructor basically told her to sit down and stay out of the way. (I10)

The responses from one instructor for the two questions do not agree. If the responses from that instructor are excluded, five instructors indicated that students could actively participate without the need for specific accommodations. Six instructors indicated they were required. Two instructors left neutral responses to the first question; one left a neutral response to the second. Three instructors of students with total blindness indicated that no specific accommodations were required; responses from two of those instructors to open-ended questions detailed activities in which the students could not participate. Instructors' open-ended responses, though, revealed that specific accommodations were provided for 13 of the 15 students.

Further examination of the instructors' open-ended responses revealed that to gauge active participation in the laboratory exercises, it was necessary to couple the extent of the student's visual challenge with the activities required in the laboratory exercises of the course, as noted in the narratives. For those courses that did not rely on visual ability in the laboratory, the instructors noted that specific accommodations were largely unnecessary. Instructor 2, whose student had severe blindness, noted that the student required no specific accommodations. Similarly, a student with moderate visual impairment was able to participate in all activities because, according to Instructor 3, "we didn't do anything that would be a danger to the visually impaired students in the introductory biology class." An instructor of a student with severe blindness wrote that

> with accommodations in place, the student was able to participate in all laboratory activities. It took the student a little longer to complete the exercises due to the need to

> enlarge each item before it was large enough to visualize, but the student was willing to work with that just to be able to see things they had never been able to see before. (I8)

For those courses that relied heavily on visual ability, however, the written responses illuminated several problems. Laboratory exercises that included activities such as animal dissection, plant identification, microscopy, or the recording of digital readouts posed challenges. Instructor 7 indicated that for a student with moderate visual impairment, "dissection was difficult - the student was present but did not physically participate." Instructor 10, who taught a totally blind student, remarked that the student had difficulty with "herbarium specimens that were thin and flat, so she could not identify them by touch." Several instructors, including three who taught students with total blindness, noted microscopy as an activity in which the students were unable to participate. In fact, Instructor 11, who taught a student with total blindness wrote, "working with the microscope in class was a challenge. The student would sit at the microscope, and his group mates would describe what they were seeing." Instructor 12 commented regarding his student with total blindness that, "any microscope images cannot be done. I find images of similar specimens and the aide will use the 3D pen to highlight important features." Even students with moderate visual impairment had difficulty with microscopy, as Instructor 13 noted by writing that "viewing moving microscopic specimens" was an activity in which the student could not participate. The microscope was not the only piece of equipment that posed challenges. An instructor of a student with very severe blindness mentioned that the student "could not read the spectrophotometer or the number dial on pipetmen" (I6), and the instructor of a student with very severe blindness noted difficulty with "manipulation of devices" (I5).

One instructor enabled a student with very severe blindness to participate by instructing the student to pipette water instead of the enzyme during an enzyme assay. Additionally, the student "placed samples into the spectrophotometer - others read the number. He was fully participatory" (I6). That instructor indicated on the closed-ended question that the student did not require any specific accommodations in order to participate.

While the instructors were in agreement that the students were safe in the laboratory, participation in the laboratory activities depended on the severity of the student's visual impairment and the activities in which he or she was required to participate. For some, the instructors indicated that the students were both safe and actively participated. Responses to open-ended questions indicated that eight instructors felt that though the students were safe, there were some activities in which the students had difficulty participating, or in which the student could not participate.

Criterion Two: Be Engaged in the Class

Criterion two required that the students be engaged in the class (Gormally et al., 2011). For the purposes of this research, student engagement was assessed through two questions. One asked about the student's interest in the activities. The second inquired as to their curiosity about the results that would be obtained in the laboratory exercises.

As indicated in Table 3, all of the students either agreed or strongly agreed that they were interested in the class. Further, each felt that he or she was curious about the results of the lab activities. Therefore, by the criteria for assessing student engagement in this study, each student believed that he or she was engaged in the class regardless of the student's visual impairment.

Instructor 1 of a student with a moderate visual impairment indicated that the student might not have been engaged by indicating a response of neutral to both questions. As revealed in Table 4, with that one exception the instructors responded that the students were engaged in the course.

Table 3

Student Perceptions of Engagement

Question	Visual impairment	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I was interested in the lab activities	SVSTB1		a			
	SB	a				
	VSB	a, b				
	TB		a			
I was curious about the results we would obtain	SVSTB1		a			
	SB	a				
	VSB		a, b			
	TB		a			

Note. Total (n=5). SVSTB1 = Severe/Very severe/Total blindness in one eye (n=1); SB = Severe blindness (n=1); VSB = Very severe blindness (n=2); TB = Total blindness (n=1).

Table 4

Instructor Perceptions of Engagement

Question	Visual impairment	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Student appeared interested in the lab activities	MiVI	A				
	MoVI	B	c, D, E, f	a		
	SB	a, B				
	VSB	a, B				
	TB	A, b, C, d				
Student appeared curious about experimental results	MiVI	A				
	MoVI	B	c, D, E, f	a		
	SB	a, B				
	VSB	a, B				
	TB	A, b, C, d				

Note. Total (n=15). MiVI = Mild visual impairment (n=1); MoVI = Moderate visual impairment (n=6); SB = severe blindness (n = 2); VSB - Very severe blindness (n=2); TB = Total blindness (n=4). Letters enable tracking responses of the instructors who taught individuals with the same visual impairment. Responses of instructors with prior experience teaching a student with BVI are capitalized.

Except for one instructor's perception of one student, both the students and the instructors agreed that the students were engaged in the laboratory activities. As a student with total blindness commented, "it was a great experience" (S1). Even though this criterion was met for most individuals, it was not met for one student.

Criterion Three: Be Accepted by Classmates

The third criterion required that the specific accommodations enabled the student with BVI to be accepted by classmates. To address the question of acceptance, the survey contained a question that asked students if they felt that their classmates treated them the same as everyone else in the class. Four of the five students agreed with that statement. A student wrote in his or her narrative at the end of the survey that, "I was not alienated or treated any differently due to my disability" (S2). The student who disagreed wrote, "I never felt belittled" (S5), but added in his or her narrative:

> Earlier in this survey you mentioned a question about how I feel I was treated in lab. It's hard when you have a visual impairment in a lab. People are never going to treat you "normal". They asked questions all of the time. Even the lab TA who led the normal lab sessions asked questions. The thing is you learn to live with questions and people doubting your ability to do things. Living blind, you get a lot of that. (S5)

All instructors but one either agreed or strongly agreed with the statement that the student was treated by classmates the same as everyone else. The instructors were evenly split between agree and strongly agree in responding to that question. It was the instructor of a student with moderate visual impairment who indicated a response of neutral to that question (I7). The instructor did not provide an explanation.

Four of the students and 14 instructors felt that the student with BVI was treated by classmates the same as everyone else, and therefore accepted. Not all felt that way, though.

Because a student participant and an instructor of a student felt otherwise, those two individuals did not believe that this criterion was met.

Criterion Four: Contribute to Group Activities

Two questions on the surveys queried respondents about the student's contributions to group activities. On the survey, the students were first asked whether they contributed to the group as the activities were completed. The second question asked if the students contributed to the group's understanding as the results of the activities were discussed. Four of the five students either agreed or strongly agreed that they contributed to the group as the activities were completed. One student with very severe blindness indicated a neutral response to that question. That student left no comment indicating why. On the second question, though, all students agreed or strongly agreed that they contributed to the group's understanding.

Table 5

Student Perceptions of Group Contributions

Question	Visual impairment	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I contributed as group completed lab activities	SVSTB1		a			
	SB	a				
	VSB	a		b		
	TB	a				
I contributed to group understanding of results obtained	SVSTB1		a			
	SB	a, b				
	VSB	a				
	TB	a				

Note. Total (n=5). SVSTB1 = Severe/Very severe/Total blindness in one eye (n=1); SB = Severe blindness (n=1); VSB = Very severe blindness (n=2); TB = Total blindness (n=1).

Table 6 displays the instructor responses to similar questions. While 13 instructors agreed or strongly agreed that the students made contributions to the group during the activities and when discussing the results, two of the instructors were not as confident. The instructor who recorded a neutral response regarding his or her student with moderate visual impairment contributing to the group's understanding left no comments (I7). The instructor who disagreed with both questions noted that, "students of her group were extremely kind. They took lots of their time helping her" (I1). The instructor left no other comment, so the cause of the instructor's disagreement is unknown. There was not full agreement by the students or the instructors that the students with BVI contributed to the group as the laboratory activities were completed.

Table 6

Instructor Perceptions of Group Contributions

Question	Visual impairment	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Student contributed to group lab activities	MiVI	A				
	MoVI	B	c, D, E, f		a	
	SB	a, B				
	VSB	a, B				
	TB	A, b, C, d				
Student contributed to group's understanding	MiVI	A				
	MoVI	B	c, E, f	D	a	
	SB	a, B				
	VSB	a, B				
	TB	A, b, C, d				

Note. Total (n=15). MiVI = Mild visual impairment (n=1); MoVI = Moderate visual impairment (n=6); SB = severe blindness (n = 2); VSB - Very severe blindness (n=2); TB = Total blindness (n=4). Letters enable tracking responses of the instructors who taught individuals with the same visual impairment. Responses of instructors with prior experience teaching a student with BVI are capitalized.

One student indicated a lack of confidence that he or she contributed as group activities were completed, while all students agreed that they contributed to the group's understanding as the results of the activities were discussed. One instructor disagreed with both questions, and another recorded a neutral response for the second. Therefore, criterion four was not met for all students.

Criterion Five: Demonstrate Required Skills

The fifth of the seven criteria required that the specific accommodations enabled the student the opportunity to demonstrate skills that are required in the course (Di Trapani &

Clarke, 2012; Fitch, 2007; Hunt et al., 2012). Nine questions on the student and instructor surveys asked respondents to rate the student's ability to demonstrate competency in the required skills of the course. Individuals were questioned as to whether the student could successfully find images with a microscope; interpret images under a microscope; assist in animal dissection; safely use a Bunsen burner and/or hot plate; accurately determine results of tests requiring color interpretation; accurately construct graphs; accurately interpret graphs; accurately pipette, pour, and measure liquids; and take notes and record data without assistance. Due to differences in the students' visual abilities, results from both the students and the instructors varied considerably. Some of the courses did not require particular activities, so for some individuals certain questions were not applicable. One of the students chose not to answer the first two questions.

Table 7 reveals that four of the students were not confident in their ability to find images with a microscope. Though the student with very severe blindness felt able to interpret images under a microscope, two of the students did not. The student with total blindness did not answer either question. A student with severe blindness was the only one required to assist in animal dissection, and strongly disagreed with his or her ability to participate. Only two of the four students who used them in lab felt comfortable operating a Bunsen burner and/or hot plate. One of those students had total blindness. The student with severe/very severe/total blindness in one eye felt neutral toward the ability to interpret results requiring color interpretation. The only other student responding to the question strongly disagreed. Students required to construct and interpret graphs felt able to do so. Even the student with total blindness felt able to pipette, pour, and measure liquids, but only the student with blindness in one eye felt able to take notes and record data without assistance.

Table 7

Student Perceptions of Skills Demonstration

Question	Visual impairment	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Not applicable
Found images with microscope	SVSTB1			a			
	SB					a	
	VSB					b	a
	TB						
Interpreted images under microscope	SVSTB1			a			
	SB					a	
	VSB		a			b	
	TB						
Assisted in animal dissection	SVSTB1						a
	SB					a	
	VSB						a, b
	TB						a
Safely used Bunsen burner/hot plate	SVSTB1		a				
	SB					a	
	VSB					b	a
	TB	a					
Determined results by color	SVSTB1			a			
	SB						a
	VSB					b	a
	TB						a
Constructed graphs	SVSTB1		a				
	SB						a
	VSB	a	b				
	TB	a					
Interpreted graphs	SVSTB1		a				
	SB						a
	VSB	b	a				
	TB	a					
Pipette, pour, measure liquids	SVSTB1		a				
	SB						a
	VSB			b			a
	TB	a					
Took notes/ recorded data without assistance	SVSTB1		a				
	SB				a		
	VSB				a	b	
	TB				a		

Note. Total (n=5). SVSTB1 = Severe/Very severe/Total blindness in one eye (n=1); SB = Severe blindness (n=1); VSB = Very severe blindness (n=2); TB = Total blindness (n=1).

To the final statement inquiring whether they learned the laboratory skills as well as their classmates, all five students either agreed or strongly agreed.

Instructor responses to similar questions are reflected in Table 8. As in examination of active participation in the laboratory exercises, the student's visual impairment alone did not explain the variation in the instructor responses. For those questions, even correlation of the responses with the requirements of the course and the instructors' prior experience did not explain some of the results. Four instructors participating in the survey did not require students to use a microscope, but in those courses that did five of the students with BVI had difficulty finding images with a microscope. One instructor left a neutral response. An instructor of a student with total blindness wrote, "I did not test to see if the student could properly focus the slide image on the microscope" (I12). Responses regarding students with moderate visual impairment ranged from agree to disagree. Instructor 1 indicated that the student "could see colored, high-resolution images under microscopes, but had trouble seeing small images such as bacteria." Instructor 15 did not provide any remarks as to how the student with total blindness was able to use the microscope, nor why the student was not required to then interpret images under the microscope.

Regarding other skills, few of the courses taught by the instructors included animal dissection as a laboratory activity. In those courses in which animal dissection was required, some students with moderate visual impairment were unable to assist, while students with total blindness were able to assist in the dissections. Of those courses using Bunsen burners and/or hot plates, results are also mixed as to whether the students were able to use that equipment.

Table 8

Instructor Perceptions of Skills Demonstration

Question	Visual impairment	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Not applicable
Found images with microscope	MiVI	A					
	MoVI		B, c	E	a, D		f
	SB	B					a
	VSB					a	B
	TB	d				b, C	A
Interpreted images under microscope	MiVI	A					
	MoVI		c, E	a, B	D		f
	SB	B					a
	VSB					a	B
	TB					b, C	A, d
Assisted in animal dissection	MiVI						A
	MoVI		B	c, D	a, E		f
	SB						a, B
	VSB			a			B
	TB		A, b				C, d
Safely used Bunsen burner/hot plate	MiVI	A					
	MoVI		f		c	a	B, D, E
	SB	a					B
	VSB					a	B
	TB			b			A, C, d
Determined results by color	MiVI	A					
	MoVI		B, c	a, E	f		D
	SB		B				a
	VSB				B	a	
	TB					A, b, C	d
Constructed graphs	MiVI	A					
	MoVI		a,B,c,E,f		D		
	SB	a, B					
	VSB	B	a				
	TB	d			b, C		A
Interpreted graphs	MiVI	A					
	MoVI		a,B,c,E,f	D			
	SB	a, B					
	VSB	B	a				
	TB	d	C			b	A

Table 8 (continued)

Question	Visual impairment	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Not applicable
Pipette, pour, measure liquids	MiVI	A					
	MoVI			B, c	E, f	a	D
	SB	a					B
	VSB		B		a		
	TB				C	b	A, d
Took notes/ recorded data without assistance	MiVI	A					
	MoVI		a,c,E,f	B	D		
	SB	a	B				
	VSB		B	a			
	TB	d	A, C			b	

Note. Total (n=15). MiVI = Mild visual impairment (n=1); MoVI = Moderate visual impairment (n=6); SB = severe blindness (n = 2); VSB - Very severe blindness (n=2); TB = Total blindness (n=4). Letters enable tracking responses of the instructors who taught individuals with the same visual impairment. Responses of instructors with prior experience teaching a student with BVI are capitalized.

One instructor responded that a student with severe blindness could use a Bunsen burner and/or hot plate, while a student with a moderate visual impairment could not. Only students with some vision were able to interpret tests requiring color interpretation. Eleven of the students were able to construct graphs; thirteen were able to interpret them. Pipetting, pouring, and measuring liquids presented challenges to most of the students, especially those with limited vision. All but four students were able to take notes and record data without assistance. An instructor of a student with a moderate visual impairment remarked that he or she "had to not assess some skills, as the student could not perform them" (I14). Four instructors noted that no alterations were made to the assessment of laboratory skills. One indicated that skills assessment was not part of the course (I7).

Table 9 displays the results of the final question instructors were asked regarding the skills ability of their students. The results indicated that ten of the instructors felt that the students demonstrated skills as well as their sighted classmates. Three of those instructors taught students with total blindness. Because some individuals were not able to meet the skills requirements of the course, though, this criterion was not met for all of the students.

Table 9

Instructor Perceptions of Student's Skills Relative to That of Sighted Students

Question	Visual impairment	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Not applicable
Demonstrated skills comparable to sighted students	MiVI	A					
	MoVI		B, c, f		a, D, E		
	SB	B		a			
	VSB		a, B				
	TB	d	A, b		C		

Note: Total (n=15). MiVI = Mild visual impairment (n=1); MoVI = Moderate visual impairment (n=6); SB = severe blindness (n = 2); VSB - Very severe blindness (n=2); TB = Total blindness (n=4). Letters enable tracking responses of the instructors who taught individuals with the same visual impairment. Responses of instructors with prior experience teaching a student with BVI are capitalized.

Criterion Six: Meet All Academic Requirements

Students were required to meet all academic requirements of the course as the sixth criterion. A grade of C or better can be used to indicate that a course was successfully completed ("Prerequisites," n.d.; "Understanding," 2015). All participants indicated that the student met the academic requirements of the course, because respondents were asked to respond with a yes or no as to whether a C or better was earned as the final grade. That question was used to screen for eligible participants. Included in the data analysis are the responses only from individuals who indicated that the final grade was a C or better. Because the identity of the respondents was not known, student records were not consulted to confirm the final course grade. This criterion was met for all students.

Criterion Seven: Acquire Knowledge Commensurate With That of Their Sighted Classmates

The final criterion asked respondents if the students acquired knowledge commensurate with that of the sighted students in the class. To address this criterion in the study, students were asked if they felt that they learned the laboratory concepts as well as their classmates. Table 10 displays the student responses. Four students either agreed or strongly agreed.

Table 10

Student Perceptions of Their Learning

Question	Visual impairment	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Knowledge of lab concepts comparable to sighted students	SVSTB1		a			
	SB	a				
	VSB	b				
	TB	a				
I learned as much as sighted students with same grade	SVSTB1	a				
	SB			a		
	VSB	a, b				
	TB	a				

Note. Total (n=5). SVSTB1 = Severe/Very severe/Total blindness in one eye (n=1); SB = Severe blindness (n=1); VSB = Very severe blindness (n=2); TB = Total blindness (n=1). One student (VSB-a) skipped the first question.

A student with very severe blindness did not answer the question. Students were also asked if they believed that they learned as much as their sighted classmates who earned the same grade. Four of the students strongly agreed. The response of the student with severe blindness was neutral.

Responses from the instructors to those questions appear in Table 11. Most instructors felt that their students demonstrated knowledge of the laboratory concepts at a level comparable to the sighted students in the class. Most also felt that the student with BVI learned as much as his or her classmates who received the same grade in the course. Although as depicted in Table

11, not all instructors agreed that the students learned the concepts as well, or learned as much as the sighted students in the class.

Table 11

Instructor Perceptions of Student Learning

Question	Visual impairment	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Knowledge of lab concepts comparable to sighted students	MiVI	A				
	MoVI	B	a, c, E, f		D	
	SB	a, B				
	VSB	a, B				
	TB	A, b, C, d				
Student learned as much as sighted students receiving same grade	MiVI	A				
	MoVI	B	a, c, f	D	E	
	SB	a, B				
	VSB	a, B				
	TB	A, b, C, d				

Note. Total (n=15). MiVI = Mild visual impairment (n=1); MoVI = Moderate visual impairment (n=6); SB = severe blindness (n = 2); VSB - Very severe blindness (n=2); TB = Total blindness (n=4). Letters enable tracking responses of the instructors who taught individuals with the same visual impairment. Responses of instructors with prior experience teaching a student with BVI are capitalized.

Instructor 7, who taught a student with a moderate visual impairment, noted that, "she was involved but limited in her ability to get the same sort of information and then communicate that understanding relative to the sighted students." Two of the instructors of students with moderate visual impairment responded with neutral and disagree regarding their students learning as much as their sighted classmates who received the same grade. Those instructors both had prior experience teaching students with BVI. Therefore, though most of the students and instructors believed that the students with BVI learned the laboratory concepts as well as their classmates, and learned as much as the sighted students who earned the same grade, not all individuals perceived that this criterion was met.

The *Seven Criteria*: A Comprehensive Look

The participant responses for both closed- and open-ended questions regarding each of the *seven criteria* were evaluated and coalesced to determine whether each criterion was met for each student. Results were recorded with a yes, no, or neutral indicator relative to the student meeting the criterion. The determination enabled a comprehensive view of whether each participant met each of the *seven criteria*.

To determine whether there was a relationship between the number of criteria met and the student's visual impairment, the data were entered into table form relative to the student's visual impairment. Results of that evaluation are summarized in Table 12, and reveal which of the seven criteria each student was able, or not able, to meet. Those responses indicated with a "Y" met the criterion. Both the "N" and the "Neutral" responses were recorded as not meeting the criterion. Examination of the data reveals that three students met all seven criteria, seven students met six criteria, six students met five criteria, three students met four criteria, and one student met two criteria. However, one of the students who met all seven criteria, one who met six criteria, and one who met five criteria did not receive specific accommodations. Those students had disabilities of total blindness, severe/very severe/total blindness in one eye, and total blindness, respectively.

The data were also graphed to illustrate a possible relationship between the student's visual impairment and the total number of criteria met by each student. Figure 2 represents the number of criteria met relative to the student's visual impairment. Results did not indicate such a relationship. There was also no pattern regarding the number of criteria met according to the perceptions of students versus the perceptions of instructors.

Table 12

Individual Criteria Met for Each Student Relative to Visual Impairment

Visual Impairment	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6	Criterion 7	Sum
SVSTB1*	Y	Y	Y	Y	N	Y	Y	6
MiVI	Y	Y	Y	Y	Y	Y	Y	7
MoVI	Y	Neutral	Y	N	N	Y	Y	4
MoVI	Y	Y	Y	Y	Neutral	Y	Y	6
MoVI	Y	Y	Y	Y	N	Y	Y	6
MoVI	N	Y	Neutral	Neutral	N	Y	N	2
MoVI	N	Y	Y	Y	N	Y	N	4
MoVI	N	Y	Y	Y	N	Y	Y	5
SB	Y	Y	Y	Y	N	Y	Y	6
SB	Y	Y	Y	Y	Neutral	Y	Y	6
SB	Y	Y	Y	Y	Y	Y	Y	7
VSB	Y	Y	Y	Y	N	Y	Y	6
VSB	Y	Y	N	Neutral	N	Y	Y	4
VSB	N	Y	Y	Y	N	Y	Y	5
VSB	N	Y	Y	Y	N	Y	Y	5
TB	Y	Y	Y	Y	Neutral	Y	Y	6
TB*	N	Y	Y	Y	N	Y	Y	5
TB	N	Y	Y	Y	N	Y	Y	5
TB	N	Y	Y	Y	N	Y	Y	5
TB*	Y	Y	Y	Y	Y	Y	Y	7

Note. Total (n=20). SVSTB1 = severe/very severe/total blindness in one eye; MiVI = mild visual impairment; MoVI = moderate visual impairment; SB = severe blindness; VSB = very severe blindness; TB = total blindness. Y = yes. N = no. Both N and Neutral were recorded as student not meeting the criterion. * = no specific accommodations were provided.

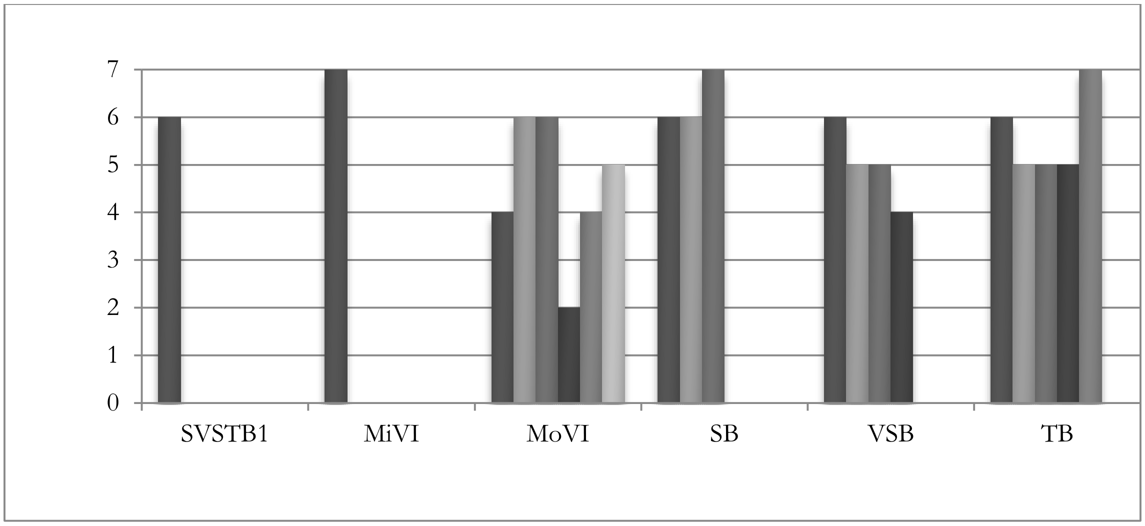

Figure 2. Number of seven criteria met relative to visual impairment. Total (n=20). SVSTB1 = severe/very severe/total blindness in one eye; MiVI = mild visual impairment; MoVI = moderate visual impairment; SB = severe blindness; VSB = very severe blindness; TB = total blindness.

Course and Assessment Modifications

In addition to the questions regarding the *seven criteria*, the instructors were asked questions regarding course and assessment modifications in their classes (see Appendix B). Table 13 displays the responses to three closed-ended questions requesting the instructor's opinions of alterations made to assessments for students with BVI. They were also asked about alterations they made to assessments of laboratory concepts and skills for their students.

Responses were quite mixed. One instructor did not answer the second question; two did not answer the third. Examination of Table 13 reveals that there is no consensus of opinion regarding the assessment of students with BVI, regardless of the nature of the visual impairment. Instructors with experience differed in their opinions, as did instructors with no experience. Five instructors commented that they made no alterations to assessments of laboratory concepts.

Because many biology courses include lab practicals as a form of assessment, several questions were included to determine how instructors dealt with laboratory practicals for students with BVI. In the classes represented by the instructor respondents, 60% indicated that lab practicals formed a portion of the assessments in the class taken by the student with BVI.

Table 13

Instructor Perceptions of Assessment Modification

Question	Visual impairment	Strongly agree	Agree	Neutral	Disagree	Strongly Disagree
Lab assessments should be altered so student with BVI can pass class	MiVI		A			
	MoVI		B, f	E	a, D	c
	SB	B			a	
	VSB			a	B	
	TB	d	A, C		b	
I made alterations to assessments of concepts, but equivalent assessment	MiVI					
	MoVI		B, E	f	a, c, D	
	SB	a, B				
	VSB	B	a			
	TB		A, C	b		d
I made alterations to assessments of skills, but equivalent assessment	MiVI					
	MoVI		B		a,c,D,E,f	
	SB					a
	VSB	B	a			
	TB			b, C	A	d

Note. Total (n=15). MiVI = Mild visual impairment (n=1); MoVI = Moderate visual impairment (n=6); SB = severe blindness (n = 2); VSB - Very severe blindness (n=2); TB = Total blindness (n=4). Letters enable tracking responses of the instructors who taught individuals with the same visual impairment. Responses of instructors with prior experience teaching a student with BVI are capitalized. One instructor did not answer the second question (MiVI-a); two did not answer the third (MiVI-A; SB-B).

Of that 60%, just over half indicated that the student with BVI was able to complete the lab practical with the other students in the class. Modifications that instructors made to the laboratory practicals included displaying the images on a computer screen (I13) or other "external monitor for enlargement of microscope images" (I4), and giving the student a "color guide to help them analyze colors observed on all assessments" (I9). Others noted that they provided detailed descriptions (I8; I11). One instructor accommodated the student by accompanying "the student through the lab practicals and she asked me questions related to the visual descriptors that were outside her visual ability" (I3). Another instructor permitted the student to take the lab practical "one-on-one with the instructor, rather than having her move around the room with the other students" (I10). Other instructors had the student take the practical at a time other than the normal class time (I5; I8; I11). One had materials the student might find difficult to view enlarged, and would state the questions or provide "a description of the material present . . . to help facilitate without giving away the answer" (I8). Another student was given "a more theoretical question about the slide" for microscope questions (I10). For example, if the sighted students had to identify the type of tissue under the microscope, the student with BVI could have been asked, "What tissue type contains matrix, and what is matrix?" (I10). The instructor of one student remarked that the student was permitted to revisit stations (I8). For questions on the practical that included dissection specimens, two instructors mentioned that they allowed the students to touch the specimens to identify them (I10; I11). One of those instructors noted that, "anything large enough for her to identify by touch was fair game" (I10).

The instructors were also asked several questions regarding grading in the laboratory portion of the course (see Appendix B). Seventy-three percent of the instructors did not modify the percentage of the laboratory grade derived from routine assessments for the student with BVI, while 60% indicated that they did not modify the percentage of the laboratory grade derived from skills demonstration for the student. One instructor noted that for "materials that were too small for her to see, I developed an analogous descriptor using something that had tactile similarity or shape" (I3). A different instructor indicated that he or she would "orally assess the students' understanding of the concepts taught during lab" (I8). For skills assessment, an instructor indicated that for students with some vision, images were "projected on the large screen so that she could make out the basic outline of the character in question" (I3), while another "described results, images, and colors" to the student (I5). Eighty-seven percent of the instructors did not modify the percentage of the laboratory grade derived from active participation, and 100% of the instructors responded that they did not modify the percentage attributed to group understanding of experiments and results.

Aide or Non-student of the Class Assistant

Several questions on the surveys asked the respondents their opinions of having an aide or other non-student of the class to assist the students with BVI (see Appendices A and B). Of the student respondents, only the student with severe/very severe/total blindness in one eye reported that he or she did not have an aide to assist with some or all of the laboratory activities. Though nine of the 15 instructors indicated that the student requested and was provided an aide, three of those noting that the student did not request an aide taught students with total blindness. When asked if an aide would have helped the student do better in the class, ten instructors either agreed or strongly agreed. One instructor remarked that, "a lab aide with sufficient knowledge of biology would have being [sic] very helpful" (I1). Instructors disagreeing, or strongly disagreeing, taught students with mild and moderate visual impairments, very severe blindness, and total blindness. When the results from this question were compared to responses indicating the level of student's participation in the laboratory activities, students with an aide still required specific accommodations for active participation.

Students Not Meeting Study Criteria

One student and four instructors completed the surveys after responding that the student did not earn a C or better in the course. Those data were not used to evaluate whether the accommodations enabled the students to meet the *seven criteria*, or to record instructor perceptions of assessment and grading modifications. However, the results were examined for information that could provide insight as to why some students with BVI might be unsuccessful in the biology laboratory.

The student respondent in this category had severe/very severe/total blindness in one eye. According to the student, specific accommodations were necessary for participation, but "absolutely none [were] . . . provided or offered" (S7). The student's response to feeling safe in the laboratory was neutral, and the student noted that he or she could not actively participate in many activities. Despite the lack of accommodations or active participation, the student indicated that he or she was engaged in the course; the student agreed to being interested in the lab activities and curious about the results that would be obtained. The student did not feel accepted by classmates, although the student did feel that he or she contributed to the group as exercises were completed and to the group's understanding as the results were discussed. While the student felt able to use a Bunsen burner and/or hot plate, he or she responded with disagree or strongly disagree to the ability to demonstrate any other laboratory skills. To the question asking whether the students learned the laboratory concepts as well as classmates, the student responded with neutral. To the question asking the students whether they believed they learned as much as sighted students receiving the same grade, the student disagreed. From those responses, the student did not meet five of the *seven criteria*. In the narrative, the student wrote:

> This was a horrible experience. Was ran [sic] by a student not a paid instructor or teacher of the University. If I am required to take this class again for graduation I refuse and I will not subject myself to that again. (S7)

Of the instructors teaching students who were not successful in the course, two taught students with a moderate visual impairment, one student had severe blindness, and one indicated an unspecified visual impairment. Two of the instructors had prior experience teaching students with BVI. The instructors felt that the students were safe and could actively participate in the activities. Accommodations provided by those instructors included aides (I25), enlarged printed materials (I36), instructor assistance with the microscope, "a separate, written lab practical" (I38), and "guided palpation of the dissected fetal pig" (I31).

Half of the instructors felt that the students were engaged in the course. Three instructors felt their students were accepted by classmates, and that the students contributed to the group during the laboratory activities. Two felt that the students contributed to the group's understanding as results were discussed. Results for the skills questions were quite mixed. Instructor 31 noted that the student could not find or interpret images with the microscope; determine results requiring color interpretation; pipette, pour, or measure liquids; or take notes. The instructor responded neutral to the student's ability to assist in animal dissection, and disagreed that the student demonstrated laboratory skills at a level comparable to other students. Five skills were not applicable for the student of Instructor 25. His or her student was able to demonstrate the other required skills. Students of the other two instructors were able to demonstrate all required skills with the exception of the ability to safely use a Bunsen burner and/or hot plate. Only one course required that activity; the student was unable to demonstrate that ability. One instructor believed the student demonstrated laboratory skills at a level comparable to that of the sighted students in the class, two felt neutral, and one disagreed. Two instructors felt the students learned the laboratory concepts as well as sighted students and that the students learned as much as their classmates. While one of those two instructors agreed with both statements, an instructor agreeing to the student's ability to demonstrate laboratory concepts at a comparable level recorded a response of neutral to the student learning as much as sighted classmates receiving the same grade. An instructor disagreeing with the student's ability to demonstrate knowledge of laboratory concepts at a comparable level nonetheless strongly agreed that the student learned as much as sighted classmates.

Three of the instructors wrote comments about their experiences. One instructor commented that, "I tried to treat him as a sighted student as far as possible because I didn't want him to feel bad. I offered him my sincere help" (I25). Another instructor wrote that, "he dropped the course because he had a job and he was overloaded with other study material. But generally he was happy the way he was spending his time in the classroom as well as in the lab" (I25). A third instructor noted that, "I tried to provide him and his assistant specific directions and help to make sure that he feels safe and comfortable" (I25).

Research Questions

One primary question prompted this study: Are the specific accommodations provided for students with BVI in the college biology laboratory effective in meeting the needs of both the students with BVI and the instructors? To address that query, this study was guided by two primary research questions:

> What are the perceptions of students with BVI regarding their experience in the laboratory portion of a college biology course?
>
> What are the perceptions of college biology instructors regarding their experience teaching a student with BVI in the laboratory portion of a college biology course?

Additionally, three sub-questions provided pertinent data for this study:

> To what extent do students with BVI believe that specific accommodations provided for them in the college biology laboratory enabled them to meet the *seven criteria*?
>
> To what extent do instructors believe that specific accommodations provided for students with BVI in the college biology laboratory enabled them to meet the *seven criteria*?

What course and assessment modifications do college biology instructors believe should be made for students with BVI in the college biology laboratory?

The perceptions of five students and 15 instructors regarding their experiences in the laboratory portion of a college biology class were collected to address the research questions in this study. The questions focused on the *seven criteria*, and instructors' perceptions regarding course and assessment modifications for students with BVI. Though all students were perceived to be safe, and all met the academic standards of the course, eight students were perceived as not actively participating in the class. One instructor felt his or her student was disengaged, two were perceived as not accepted by classmates, and three students were characterized as not contributing to group activities. Perceptions were that 17 students could not demonstrate required skills, and opinions were that the learning of two students was not commensurate with that of sighted classmates. Instructors did not agree as to whether assessment and grading modifications should be made for students with BVI in the college biology laboratory.

Conclusion

This "transformative mixed-methods" study (Creswell, 2012, p. 546) sought to evaluate the effectiveness of the specific accommodations provided for students with BVI in the college biology laboratory. Researcher-developed surveys were posted online for a period of eight weeks. Eligible respondents were asked a series of closed- and open-ended questions to ascertain their opinions of the student's experiences. Five students with BVI, and 15 instructors who had taught students with BVI, met study criteria and completed the surveys. The students had visual impairments ranging from a mild visual impairment to total blindness. Most of the courses represented were 100- and 200-level courses; courses were taught at both two- and four-year institutions. The results were organized relative to the *seven criteria*. Only one criterion was met for all students: They all received a C or better in the class. Opinions were gathered from study participants on providing an aide for the students with BVI, and instructors were queried regarding course assessment and grading modifications. Additionally, one student and four instructors completed the surveys even though the students had not successfully completed the course. Those results were examined for insight into why students with BVI might be unsuccessful in a college biology course.

This chapter summarized the data received from the twenty study participants, and from five individuals not meeting study criteria. The following chapter discusses study results, implications, and the accommodations provided for the students with BVI. Completing this dissertation are recommendations for action and continued research, and concluding remarks.

CHAPTER FIVE: DISCUSSION, SUMMARY, AND CONCLUSIONS

Biology, "that most visual of all the sciences" (Vermeij, n.d., para. 2), is the study of life. To complete college biology courses, most students are required to actively participate in laboratory exercises. The National Association of Biology Teachers stated that, "the most effective vehicle by which the process of inquiry can be learned appears to be a laboratory or field setting where the student experiences, firsthand, the inquiry process" ("Role," 2005, para. 3). Laboratory exercises enable students to master skills unique to each discipline of the biological sciences, thereby gaining increased conceptual understanding of course content that facilitates successful course completion and would be applicable in subsequent science courses (Hughes & Overton, 2008).

Many of the activities in which students participate in the college biology laboratory pose challenges for students with blindness and visual impairments (BVI), because the activities often rely on visual cues (Caldwell & Teagarden, 2007, Jones et al., 2006; Jones et al., 2014). In spite of the potential obstacles, however, students with BVI are enrolling in college in increasing numbers (Callahan, 2011; Scott, 2009) and they are taking college biology courses (Caldwell & Teagarden, 2007; D. Huey, personal communication, November, 2014; Hutson, 2009; J. Xu, personal communication, July, 2014; Vollmer, 2012; Womble & Walker, 2001). To enable their success in the biology laboratory, supportive measures are often necessary.

Institutions of higher education must provide "reasonable accommodations" for students with disabilities ("Reasonable," 2016, para. 1), including "special lighting" (Horvath et al., 2005, p. 177), extra time for assignments, note takers, tape recorders ("Accommodations," 2015; Sharpe et al., 2005), large print, and Braille materials (Horvath et al., 2005; Sharp et al., 2005).

In addition to general accommodations, students with BVI often require specific accommodations in the college biology laboratory, such as tactile models (Caldwell & Teagarden, 2007; Derra, 2015; Hutson, 2009; Miecznikowski et al., 2015; Rule, 2011; Wedler et al., 2012; Winograd & Rankel, 2007) and audible devices (Supalo et al., 2009). The intent of the specific accommodations is that they enable the student the opportunity to successfully complete the course, but there are no regulations regarding the specific accommodations that college biology instructors should provide for students with BVI. Additionally, there are no standards regarding science laboratory accessibility (Moon et al., 2012, p. 31). Though laws mandating "equal opportunity" for students with disabilities ("A Guide," 2009, para. 9; "The Americans," n.d., para. 1) are implemented, as in providing general and specific accommodations, there is no guarantee that the accommodations enable the students to actually realize the equal opportunity the laws mandate.

Many articles in the current literature detailed methods of accommodation for students with BVI in the college science laboratory. A few described instructor experiences accommodating students with BVI in the college biology laboratory. Though one study evaluated tactile models for students in the biology laboratory (de Souza et al., 2012), no studies were found that examined whether the specific accommodations provided for the students with BVI in the college biology laboratory were effective. Wild and Allen (2009) remarked that studies were needed to guide best practices in providing specific accommodations for students with BVI, and Supalo (2010) noted the paucity of research into the effectiveness of the support measures implemented for students with BVI. To begin evaluating the effectiveness of the specific accommodations provided for students with BVI in the college biology laboratory and accrue knowledge necessary to inform practice, this study examined the perceptions of those most directly involved: students with BVI and instructors who taught them.

Study Design and Research Questions

This research study explored the question of whether the specific accommodations provided for students with BVI in the college biology laboratory were effective. To address that question, it was necessary to develop a method by which effectiveness could be evaluated. Several criteria important to student learning were gleaned from the literature. Those criteria, termed the *seven criteria*, served as standards against which the effectiveness of the accommodations was evaluated. According to the *seven criteria*, effective specific accommodations permitted the opportunity for a student with BVI to (a) safely and actively participate in the laboratory activities (Duerstock et al., 2014; "The Integral Role," 2007), (b) be engaged in the class (Gormally et al., 2011; Sinatra et al., 2015), (c) be accepted by classmates (Scruggs and Mastropieri, 2007; Supalo, 2010), (d) contribute to group activities (Barbosa et al., 2004; Gaudet et al., 2010; Gormally et al., 2011), (e) demonstrate required skills (Di Trapani & Clarke, 2012; Fitch, 2007; Hunt et al., 2012), (f) meet all academic requirements ("Reasonable," 2016), and (g) acquire knowledge commensurate with that of their sighted classmates (Duerstock, 2015).

The perspectives of students with BVI who had completed a college biology laboratory course, and college biology instructors of students with BVI, were surveyed to gather their opinions of the specific accommodations provided for the students. Respondents were recruited from colleges and universities in all 50 states, from organizations, a study website, and through social media. Study participants responded anonymously to Internet surveys, one for students with BVI and one for instructors, that included a series of researcher-developed questions pertaining to the provided accommodations. Collected data were evaluated against the *seven criteria* in order to address the study's research questions. Additional data were collected regarding aides, and from the instructors regarding course and assessment modifications for students with BVI.

The primary question guiding this research study was whether the specific accommodations provided for students with BVI in the college biology laboratory were effective in meeting the needs of both the students with BVI and the instructors. To address that query, two primary research questions were formulated:

> What are the perceptions of students with BVI regarding their experience in the laboratory portion of a college biology course?
>
> What are the perceptions of college biology instructors regarding their experience teaching a student with BVI in the laboratory portion of a college biology course?

Three sub-questions extended the inquiry and provided pertinent data for this study:

> To what extent do students with BVI believe that specific accommodations provided for them in the college biology laboratory enabled them to meet the *seven criteria*?
>
> To what extent do instructors believe that specific accommodations provided for students with BVI in the college biology laboratory enabled them to meet the *seven criteria*?
>
> What course and assessment modifications do college biology instructors believe should be made for students with BVI in the college biology laboratory?

This research enabled students with BVI to voice their opinions of the provided specific accommodations relative to each of the *seven criteria*. College biology instructors were also able to articulate their perceptions of the specific accommodations. The surveys asked respondents to answer closed-ended questions regarding many aspects of their experiences in the college biology laboratory. Participants were also asked to leave written comments to open-ended questions to further describe those experiences. The data collected enabled examination of the perceptions of the students and instructors regarding the specific accommodations.

Five students and 15 instructors meeting all study requirements completed the surveys, many providing detailed accounts of their experiences. Study criteria required that the students be at least 18 years of age. The students must have disclosed their disability to the Disability Support Services (DSS) office, or equivalent, of the institution at which they completed a college biology course with a face-to-face laboratory component. Students must have earned a C or better in the course, and have taken the course between the years 2010 and 2015. Eligible instructors must have taught a student with BVI who met all study criteria. The course could have been taken at either a two- or four-year institution of higher education.

Student and Instructor Perceptions

Five students who met all study criteria completed the student survey. Visual impairments of the students included one student with severe/very severe/total blindness in one eye, one with severe blindness, two with very severe blindness, and one student with total blindness. Fifteen instructors meeting all study criteria completed the instructor survey. Of the students taught by those instructors, one student had a mild visual impairment, six had a moderate visual impairment, two had severe blindness, two had very severe blindness, and four students had total blindness.

Criterion One: Safely and Actively Participate in the Laboratory Activities

Safety in the laboratory is of paramount importance for all students. Students with BVI may have been discouraged from taking science courses due to safety concerns in the laboratory (Supalo, 2010; Supalo, 2013; Supalo et al., 2014). In discussing the need for safety in the laboratory, Altabbakh et al. (2015) discussed the number of severe injuries and even death that have occurred in the college science laboratory during the last decade.

In this study, all of the student and instructor participants either agreed or strongly agreed that the students were safe in the laboratory. As safety is the most important consideration in the science laboratory, those responses are consistent with accepted practice. One instructor commented on that consideration. The instructor wrote, "most importantly the student was assessed to ensure that there were no safety concerns" (I8).

A second stipulation of criterion one is that the student must have been able to actively participate in the laboratory activities. Active participation has been shown to be important to student learning in the sciences (Barnes & Libertini, 2013; Duerstock et al., 2014; Mastropieri & Scruggs, 1992; Miner et al., 2011; Minogue & Jones, 2006; Supalo, 2010; Supalo, 2012). Participation is mentally stimulating (Supalo, 2010), and students are able to voice their opinions during the activities (Supalo, 2012). Additionally, students who actively participate in laboratory activities are more engaged and more easily comprehend the scientific concepts (Mastropieri & Scruggs, 1992).

Students with BVI may previously have been dissuaded from taking a science course (Fraser & Maguvhe, 2008; Supalo, 2010; Supalo et al., 2011). It follows that some students with BVI may have had no prior experience with the science laboratory and have been uncertain of what to expect. Student 3 echoed that sentiment by writing that, "at first I never imagined I could take any science course."

Study results for the students indicated that four required specific accommodations to enable active participation while one did not, but all felt that active participation was possible for at least some of the activities. A comparison of the closed- and open-ended question responses of some students, however, conflicted regarding the students' active participation in activities. One student indicated that he or she was not able to participate, or had difficulty participating, in microscopy and color interpretation in his or her narrative, and indicated responses of neutral to the skills demonstration questions regarding microscopy and color interpretation (S2). Another commented that, "even when I wasn't able to use laboratory equipment, such as microscopes, my teacher made sure I looked at them in advance and got an idea of how they worked" (S1). A third student commented that he or she could not participate, or had difficulty participating in, "labs that required use of active chemical agents that were potentially harmful" (S3), and a student with very severe blindness was not permitted to stain his or her own slides (S5). Yet all of those students responded to a closed-ended question that with specific accommodations they were able to actively participate in all exercises.

The study definition of *active participation* provided to students indicated that the term "means that you worked with the equipment and/or materials and helped to perform the experiments and/or use the equipment." Additionally, the instructions for the surveys gave as examples of *specific accommodations* the use of tactile models and auditory devices. A possible explanation for the conflicting results is that despite those definitions, the students could have responded to the survey questions using their own interpretations of those two terms. It is also possible that the students perceived that despite struggling or not being able to successfully complete particular activities, they were, nonetheless, participating. In spite of the incongruent responses to closed- and open-ended questions, according to the students, criterion one was met. They felt safe, and felt the specific accommodations, if provided, enabled them to actively participate in all of the laboratory activities, even though they indicated that participation in some activities was limited or prohibited.

Results for the instructors indicated all were not in agreement that students could actively participate, even with specific accommodations. In some of the courses, instructors noted that specific accommodations were not required for students with any degree of visual impairment. Instructor 10, who taught a student with total blindness, wrote that, "[this course] is the survey of life on earth, with essentially no experiments." Data were examined to determine whether the laboratory portion of courses similar to that also enabled the students to actively participate in the activities without specific accommodations. Results of that examination revealed no such relationship. Some instructors who taught courses titled Cellular and Molecular Biology, General Biology I, and Principles of Biology did not believe that specific accommodations were necessary, while others teaching courses similarly titled did, regardless of the severity of the student's visual impairment. Other variables must have influenced the results. The discrepancy might have resided in each instructor's choice of curriculum. Despite teaching courses with similar titles, some instructors could have emphasized different aspects of the material, and the related laboratory exercises would have required different activities. Additionally, comparison of the closed- and open-ended responses indicated that despite answering that specific accommodations were not provided, most of the instructors wrote about specific accommodations provided for the students in their narratives. The mixed-methods design of this study enabled that clarification.

As indicated for the students, examples of specific accommodations were provided in the surveys for clarity. However, differing interpretations of the term *specific accommodations* also could explain some of the discrepant results from the instructors. It is possible that instructors did not classify some of the adaptations they made for the students with BVI as specific accommodations. For instance, one instructor enabled a student with very severe blindness to participate by instructing the student to pipette water instead of the enzyme during an enzyme assay. He or she also indicated that the student "placed samples into the spectrophotometer - others read the number. He was fully participatory" (I6). The instructor indicated on the closed-ended question that the student did not require any specific accommodations in order to participate. Therefore, the instructor did not perceive that allowing the student to pipette water instead of the enzyme was a specific accommodation. There is likely disagreement as to how that situation would be classified, and highlights why there may appear to be disagreement in some of the instructor responses. The definition of *specific accommodations* proved problematic for participants.

One instructor provided conflicting responses to closed- and open-ended questions. While one of Instructor 6's written comments indicated that the student was fully participatory despite writing of the student's inability to "read the number," the same instructor wrote that activities in which his or her student could not participate, or had difficulty participating, included the inability to "read the spectrophotometer" (I6). Instructor 5 commented that his or her student could not participate in "manipulation of devices," indicating that he or she would interpret that inability as a lack of participation. Thus, instructor interpretations of similar scenarios differed as well.

Instructor responses also could have varied due to the interpretation of the term *active participation.* The term was not defined for the instructors, which may have contributed to some of the variation in the results. As with the students, it is possible that instructors perceived that when a student was physically present, he or she was also actively participating. This could include, for example, a student with total blindness being unable to record results requiring color interpretation. One instructor might conclude that the student was actively participating if the student was present when a sighted group member interpreted results; another instructor could perceive that same scenario differently.

From the responses of a few students and instructors, there also was confusion between what would be classified as general versus specific accommodations. For instance, respondents noted the student's use of a screen-reader (I6), having the student sit in the front of the room (I14), or providing extra time on tests (S2) as examples of specific accommodations. Additionally, instructors could have been inaccurate in their determination that specific accommodations were not required for their student with BVI.

Criterion Two: Be Engaged in the Class

The second of the *seven criteria* required that the students be engaged in the class. Disagreement exists regarding what engagement is and how it should be measured (Sinatra et al., 2015). Researchers have offered that student engagement encompasses many different student, instructor, and institutional behaviors (Sinatra et al., 2015). Several characteristics have been offered as evidence of student engagement (Sinatra et al., 2015). This study did not explore all facets. Bakker, Vergel and Kuntze (2015) indicated that curiosity is a characteristic exhibited by engaged students, and Renninger and Bachrach (2015) remarked that, "the triggering of interest establishes engagement" (p. 58). Therefore, to assess engagement in this study participants were queried as to whether the students with BVI were interested in the laboratory activities and curious about the results they would obtain.

Students responded to the survey questions pertaining to interest and curiosity that they were both interested in and curious about the laboratory activities. Instructor 1 indicated responses of neutral to both questions. The other instructors all agreed or strongly agreed to both questions. Those results would indicate that except for the student of one instructor, all students were engaged in the course.

Student perceptions can be considered valid. However, interpretation of instructor perceptions must be considered in light of what Axelson and Flick (2011) noted regarding the behaviors associated with student engagement. The authors stated that:

> Some students, we know, may show outward signs of engagement but actually be mostly detached; some may be deeply curious about their course work or psychologically invested in it but, for whatever reasons, display few or none of the behavioral traits we associate with engagement." (p. 41)

Perhaps Instructor 1's student was actually interested in the laboratory activities and was curious about the results of the experiments, but the student's demeanor did not reflect those characteristics to the instructor. Similarly, it is possible that the students whose behaviors were reflective of engagement were actually quite disengaged. Study results regarding the instructor perceptions must be interpreted with respect to the many different aspects of student engagement, and the difficulties involved in its measurement (Sinatra et al., 2014).

There are other considerations affecting student engagement. Swap and Walter (2015) observed that instructors have a profound influence on the classroom environment, and therefore student engagement, because instructor attitudes and teaching effectiveness affect student interest and learning. Additionally, students have varying degrees of academic preparation and enthusiasm for the course material, which affect their engagement (Swap & Walter, 2015). Student and instructor attitudes, and teaching effectiveness, were variables that could not be controlled in this study.

Criterion Three: Be Accepted by Classmates

Acceptance has been shown to be important to student learning (Supalo, 2010). Supalo also remarked that in addition to active participation, "other factors that can encourage or squelch student interest and achievement in science learning include group dynamics and peer acceptance/rejection" (p. 84). Four student respondents indicated they were treated the same as everyone else in the class; they perceived acceptance by their classmates. One student disagreed, indicating in a written response that the questions asked by other students and the teaching assistant (TA) made him or her uncomfortable (S5). The student did not provide examples of the types of questions he or she was asked. It was surmised from the remarks that they did not pertain to the laboratory activities, but rather to the student personally. From the student's written clarification, it cannot be determined whether the student perceived that any specific accommodations provided, or lack thereof, caused the other students and the TA to ask questions. While the student's feelings are certainly valid and understandable, the comment invoked the question as to whether even the best of specific accommodations could prevent classmates and instructors from asking questions that could cause a student with BVI to feel uncomfortable. This study did not address that question.

All but one instructor agreed that their students were treated the same as the other students in the class. The instructor responding neutral to the question did not provide any explanation for the opinion. Nor did the other instructors expound on their perceptions regarding the students' acceptance. However, several instructors commented on the assistance offered by lab partners and other members of the student's lab group, as discussed within criterion four, lending support for the instructor's perceptions of the students' acceptance by their classmates.

Criterion Four: Contribute to Group Activities

Group work is common in the college biology laboratory, which is consistent with the experiences of career scientists who normally collaborate in groups ("Laboratory," n.d.). Researchers have shown that group interactions are important for student learning (Barbosa et al., 2004; Gaudet et al., 2010; Gormally et al., 2011). Barbosa et al. (2004) observed that, "small-group discussions should be used in science lessons as a means of helping students explore their ideas and move towards more scientific ideas and explanations" (p. 939). Research has demonstrated that group learning leads to improved student success (Gaudet et al., 2010), perhaps because students have greater retention of material learned in groups (Johnson, Johnson, & Smith, 1998).

Four of the students felt that they contributed to group activities as they were completed and all agreed that they contributed to the group's understanding as the results were discussed. The student who answered neutral to the first question is the same student not permitted to stain Gram stains. The information gathered was not sufficient to determine whether that was part of a group activity. Had it been, it is possible that because the student was not permitted to complete that exercise, the student felt that he or she was not contributing to the group activities. Another possibility is that the student was not permitted to complete portions of other group activities not disclosed in the survey, which could have led to the student's perception that he or she was not contributing. It is also possible the student perceived that group contributions were not made for other reasons not revealed in this study.

Instructors largely agreed with the questions. One instructor answered neutral to the second question, writing that the student struggled to earn a C in the course (I7). The student may have relied on the group for understanding rather than being able to offer insight to the interpretation of results. Another instructor disagreed with both questions. That instructor noted that the student's, "biggest problem was lacking fine motor control - she could not use a pipette to transfer liquid or focus the microscope" (I4). The instructor indicated that a lack of hand coordination unrelated to the student's visual impairment was problematic for the student. For that reason, the student was likely unable to contribute to several group activities. However, the instructor did not expound on why the student did not contribute to the group's understanding of the activity results. It is possible the student did not gain sufficient comprehension from the activities because he or she was not able to participate, and therefore was not able to contribute to the group's understanding of the results.

Criterion Five: Demonstrate Required Skills

Skills demonstration was the fifth criterion. The activities conducted in the biology laboratory are numerous and varied. Students may be required to hone their microscopy skills (Fitch, 2007), perform animal dissection (Almroth, 2015), record behavioral observations of living animals (Miller & Naples, 2002), measure shells (Metz, 2008), identify the sex and eye color of fruit flies ("Drosophila," n.d.), determine plant growth (Trautmann et al., 1996), work with microorganisms (Brocklesby et al., 2012; Krist & Showsh, 2007), participate in fieldwork exercises (Moon et al., 2012), and perform gel electrophoresis (Fitch, 2007; Supalo, 2010). In some biology courses, students are assessed on their ability to demonstrate mastery of the skills required in the course (Di Trapani & Clarke, 2012; Fitch, 2007). According to the instructors surveyed, the percentage of the laboratory grade based on skills demonstration ranged from 0% to 60%, indicating that if students were not able to demonstrate the required skills they could have difficulty passing the laboratory portion of some classes. Only 33% of the instructors indicated that a student could pass the course if the laboratory portion of the class were failed.

Therefore, failure to demonstrate required skills could be quite detrimental to the student's grade, making demonstration of laboratory skills an important consideration in providing specific accommodations.

From the student data, it is evident that the students did not feel they gained competence in at least some of the required activities of the course. Though none of the students agreed that they could demonstrate all required skills, all of the students indicated that they learned the laboratory skills as well as their classmates. For instance, student 3 strongly disagreed that he or she could participate in four skills activities, and disagreed for one. Yet that student strongly agreed that he or she learned the laboratory skills as well as classmates. That discrepancy could stem from the student's interpretation of the question to mean that for those skills he or she was able to demonstrate, his or her skills mastery was equivalent to that of sighted classmates.

Instructors noted several skills with which their students had difficulty. Activities requiring microscopy; animal dissection; use of Bunsen burners and/or hot plates; and pipetting, pouring, and measuring liquids were activities noted by several of the instructors as ones in which students with BVI could not participate, or in which they had difficulty participating. Yet those results did not reveal any correlation with the student's visual impairment or the required course activities. An instructor of a student with severe blindness indicated the student could find images with a microscope (I8), while instructors of students with moderate visual impairment indicated that their students could not (I1, I7, I14). A similar scenario was indicated for animal dissection. The instructor's designation of the student's visual impairment may explain the disagreement. Because the student would have completed the course in a prior semester, instructors were relying on memory to classify the student's visual impairment. It is possible, for instance, that an instructor could have indicated that the student had a moderate visual impairment, when in fact it should actually have been classified as a severe visual impairment.

Another skill that presented challenges to students was recording results requiring color interpretation. Color can be used as a basis for interpreting experimental results of many tests in the biology laboratory (Moon et al., 2012). Only two students responded to the color interpretation question. The student with severe/very severe/total blindness in one eye responded with neutral to the statement that he or she could determine results that required color interpretation, while the student with very severe blindness strongly disagreed. Those results suggested a negative correlation. Inspection of the instructor results supported that conclusion. Twelve instructors required that activity. Only four students could successfully complete the requirement. Instructors indicated that students with very severe blindness and total blindness were unable to participate in those exercises, while some with severe blindness, moderate-, and mild visual impairment could. To address the difficulty, color interpretation software exists (Moon et al., 2012), as do other assistive devices that could detect and audibly name colors for students unable to perceive them ("GreenGar Studios," 2014; "The Talking," 2016). Ensuring that students understand the cause of the color changes and the significance of the results must accompany use of those devices, however, as noted by an instructor's student. The instructor wrote of the experience of a student with total blindness in a previous class: "[the student was asked to] describe results based on the color of a solution but since those words were meaningless to her, she did not feel that she had learned anything" (I10).

Students with color blindness also have difficulty interpreting results that require color interpretation. One instructor indicated that, "color blindness is a challenge for students in the microbiology lab" (I9). To accommodate that student, the instructor provided verbal descriptions and a color guide. Microbiology is not the only class in which a student with color blindness would have difficulty because of the extensive use of color change to indicate experimental results in the biological sciences.

Three instructors indicated that their students were able to perform all of the skills that were required in the class. Instructor 8 taught a student with severe blindness, and had prior experience teaching students with BVI. The class activities did not include animal dissection, use of Bunsen burners and/or hot plates, or pipetting, pouring, or measuring liquids. Instructor 9, who also had previous experience, taught a student with color blindness able to participate in all required activities; the class did not include animal dissection. Instructor 15 taught a student with total blindness, and did not have prior experience teaching a student with BVI. Five of the skills assessed in the survey were not required in the course, including interpretation of images under the microscope; animal dissection; using Bunsen burners and/or hot plates; determining results through color interpretation; and pipetting, pouring, and measuring liquids. The instructor noted that the student was able to find images with a microscope; it is possible that the question was misinterpreted.

When asked whether the student's skills demonstration was comparable to that of the sighted students, 10 instructors agreed, despite that a few of those agreeing had indicated responses of neutral, disagree, or strongly disagree to some of the skills abilities. As an example, instructor 5 strongly disagreed that the student could find images using the microscope, interpret images under the microscope, determine results of tests requiring color interpretation, and safely use a Bunsen burner and/or hot plate. He or she disagreed with the student's ability to accurately pipette, pour, and measure liquids, and responded neutral to the student's ability to assist in animal dissection and take notes without assistance. Yet that instructor agreed that the student was able to demonstrate laboratory skills at a level comparable to that of the sighted students. It is possible that some of the instructors interpreted the question in the same manner as discussed above for the students: Some may have assessed the student's skills demonstration on only those skills the student was able to demonstrate, and for those skills the student's ability was comparable to that of the sighted students.

Criterion Six: Meet All Academic Requirements

The sixth criterion for evaluating the effectiveness of the specific accommodations required that the students meet all of the academic requirements of the course. To address that criterion, the informed consent indicated that students had to have earned at least a C or better in the course to qualify for the study. Further, a question on both the student and instructor surveys asked if the student received a grade of C or better. That grade was chosen in this study because institutions can use a grade of C to signify that a student successfully met the academic requirements of a course ("Prerequisites," n.d.; "Understanding," 2015). Although student records were not examined to verify the course grade, all participants indicated a yes response to that question. Criterion six was met for all study participants.

Criterion Seven: Acquire Knowledge Commensurate With That of Their Sighted Classmates

The last of the *seven criteria* required that the students acquire knowledge commensurate with that of their sighted classmates (Duerstock, 2015). Supalo et al. (2007) remarked that active participation in laboratory activities is required for students with BVI to be "on equal footing with their sighted peers" (p. 27). To evaluate whether student learning was equivalent with that of other students in the class, two questions on the student survey asked whether the students felt they learned as much as their sighted classmates. The students were asked if they learned the laboratory concepts as well as classmates, and if they believed they learned as much as sighted students who received the same grade in the class.

The student with severe blindness did not answer the first question and left a response of neutral to the second. That student wrote, "The accommodations provided together with the reader/writer made it possible for me to get an 'A' in all the biology classes I took" (S3). No additional clarification was provided that would explain why the student did not feel that he or she learned as much as other students who also received an "A" in the class. All other students strongly agreed with the statement. In fact, a student with very severe blindness wrote in his or her narrative, "I also think I learned more than other people in my lab" (S5).

Instructors were asked to respond to two similar statements. Thirteen instructors felt that student learning was equivalent to that of the sighted students in the class. Two instructors of students with moderate visual impairment did not agree with one or both of the statements. One of those two instructors disagreed with the first statement regarding the student's learning of laboratory concepts. That instructor wrote regarding the student's limited ability to express understanding that it was "not so much a measure of her intellectual or educational abilities but more because of her impairment with respect to the information required for the nature of this course" (I7). Accommodations in the form of verbal descriptions of figures by a learning assistant, physical specimens, and "digital images on a tablet" that also had a "magnification function" (I7) were provided for the student. The instructor responded neutral to the student learning as much as sighted students receiving the same grade.

The other instructor agreed that the student learned the laboratory concepts at a level consistent with that of sighted classmates, but disagreed that the student learned as much as sighted students earning the same grade. Instructor 13 explained:

> The student was very intelligent and motivated and could learn the concepts. The student however got very frustrated when expected to know how to do something or visual details. The student was not realistic in what she could and could not do based on her disability.

No details were provided by Instructor 13 as to what activity(ies) or what visual details caused the student frustration. The final sentence of Instructor 13's statement implies that the student could not actively participate in some activities, yet the instructor listed the observation of motile organisms with the microscope as the only activity in which the student was unable to participate. Instructor 13 provided specific accommodations in the form of computer enlargements of microscopic images and exercises printed in larger font sizes "when requested." For both instructors, it is possible that the specific accommodations provided did not meet the needs of the students, so they were unable to learn laboratory or course concepts at a level comparable to the sighted students in the class. That is especially possible in light of the fact that each instructor specified that the student was intellectually capable of learning the course material. Another possibility is that there are unknown circumstances not revealed by the data collected in this study.

The *Seven Criteria*: A Comprehensive Look

The *seven criteria* were used to evaluate the effectiveness of the specific accommodations. Therefore, every individual's overall perception of each of the *seven criteria*, based on responses to both the closed-and open-ended questions from the surveys, was determined. At times there was a discrepancy between a participant's responses to closed- and open-ended questions. The inconsistency between the closed- and open-ended responses highlights the benefit of using a mixed-methods approach (Creswell & Plano Clark, 2011).

Additional information gleaned from open-ended responses afforded better clarification of individual experiences.

When the responses conflicted, as occurred with answers regarding active participation, the overall response was recorded as meeting the criterion. Even though the closed- and open-ended responses were treated equally in this study, that choice was made because at this time there are certain activities prohibitive for some students with BVI, such as microscopy and recording results requiring color interpretation. Individuals might have concluded that because the students were present, they were participating, even if they could not be involved in the activity. For instance, one instructor of a student with total blindness noted microscopy as an activity problematic for the student, and indicated, "the student would sit at the microscope, and his group mates would describe what they were seeing" (I11). Yet that instructor noted that the student was actively participating in that activity. Others may have disagreed with that interpretation. Better explanation of the term *active participation* in the study might have precluded the discrepancy between an individual's responses to closed- and open-ended questions.

Results of that evaluation indicated that according to the perceptions of the participants, three students met all seven criteria. None of the student participants perceived that they met all *seven criteria*. Instructors teaching two of the three students had prior experience; one instructor did not. One of those three students was not provided with specific accommodations. Of the 17 participants who were provided specific accommodations in this study, 15 students were unable to meet at least one of the *seven criteria*. As a result, according to the stipulations of this study, the specific accommodations provided in the college biology laboratory were not effective for 15 of the 17 students with BVI who were provided with specific accommodations. One student not receiving specific accommodations met only five of the *seven criteria*. The student was not able to actively participate in all activities or demonstrate all required skills. The other student not provided with specific accommodations did not meet criterion 5, skills demonstration.

The number of criteria that each student met also was examined relative to the student's visual impairment. No relationship could be drawn between the number of criteria met and the severity of the student's visual impairment. There was also no discernable relationship between the perceptions of students versus the perceptions of instructors as to how many of the *seven criteria* were met. The activities required in the course had a strong influence as to whether the skills criterion was met. Also affecting how many of the *seven criteria* were met was each participant's interpretation of the terms *active participation* and *specific accommodations*.

Discussion

According to study criteria, specific accommodations were effective for only two of the 17 students represented in the study who received specific accommodations. Supporting study results that the specific accommodations were not effective is the student of Instructor 7, who met only two of the *seven criteria*. The student was engaged in the course, and received a C or better, although the student was unable to demonstrate six of the required skills. Instructor 7 noted that the student "barely passed but did get through the class." It is possible that the student had difficulty passing the class because the specific accommodations did not enable the student to actively participate in the laboratory activities. The inability to actively participate could have contributed to a lack of comprehension of the course material, because each of the *seven criteria* is associated with student learning. Specific accommodations provided for the student included a learning assistant, "physical objects (skulls, bones, feathers)", a tablet with magnification function, and verbal descriptions (I7). While specific accommodations were provided, they did not permit the student to actively participate in six activities of the course. For those activities, the specific accommodations were ineffective. The instructor agreed that there were specific accommodations he or she wanted to offer, but did not. Reasons were not provided.

Specific Accommodations Enable Active Participation

Moon et al. (2012) emphasized the importance of specific accommodations to support students with BVI in the science laboratory. Specific accommodations were provided for all but three students in this study. One was the student participant with severe/very severe/total blindness in one eye. Two were students with total blindness. One of the two instructors of those students had prior experience. The remaining 17 students represented in the study were provided with specific accommodations. However, those accommodations did not enable 15 of the 17 students to meet at least one of the *seven criteria*. Further, two of the students not provided specific accommodations were unable to meet all *seven criteria*.

For study participants, skills demonstration posed the most uniform challenge. Seventeen of the 20 students did not meet criterion five, skills demonstration. Active participation is necessary to attain mastery of skills in the biological sciences. Therefore skills demonstration is dependent on the student's active participation. Even though 12 of the 20 study participants indicated that the students could actively participate in the laboratory activities, the inability of so many to meet the skills requirements of their classes would indicate that the students could not actively participate in at least some of the activities of the course. Had the students been able to actively participate in all of the required activities of their courses, meeting criterion five, another seven students would have met all *seven criteria*. Specific accommodations were not provided for one of those seven students, so specific accommodations would have been found effective for 8 of the 17 students for whom they were provided.

Only the two students for whom the specific accommodations were effective according to the protocol of this study, and one student not receiving specific accommodations, were able to meet the skills demonstration criterion, however. Of those three students, the first was a student with total blindness; the instructor did not have previous experience teaching a student with BVI. Importantly, that student was not provided with specific accommodations. Though the student was able to meet each of the *seven criteria*, that classification is based almost entirely on responses to the closed-ended questions. Most of the open-ended questions were unanswered. Importantly, five of the skills represented on the survey did not number among the required activities of the course, including interpretation of images under the microscope; animal dissection; use of Bunsen burners and/or hot plates; color interpretation; and pipetting, pouring, and measuring liquids. The second was a student with the mild visual impairment of color blindness. The instructor had prior experience teaching a student with BVI. While color blindness certainly poses difficulties in color interpretation and requires specific accommodations, it would not prevent an individual from active participation in all activities and the opportunity to master each required skill. The third student was classified with severe blindness. Three of the skills activities represented on the survey were not required in the course taken by the student, including animal dissection; the use of Bunsen burners and/or hot plates; and pipetting, pouring, and measuring liquids. The instructor of that student not only had previous experience teaching students with BVI, he or she provided extensive information on the specific accommodations provided for that student to enable active participation. Study protocol indicated that the specific accommodations provided for the latter two students who met all *seven criteria* were effective.

There were two additional students for whom specific accommodations were not provided. One student, with a disability of total blindness, met five of the study criteria. Criterion 1, requiring safe and active participation, and criterion 5, skills demonstration, were not met. Both require active participation, supporting the importance of specific accommodations. The remaining student classified his or her visual impairment as severe/very severe/total blindness in one eye. The student had difficulty "identifying various colors of things; finding where objects were through a microscope" (S2). Student 2 did not meet the skills requirement, therefore meeting six of the criteria. Though not accepted for study participation, also supporting the necessity of specific accommodations were the responses of the student who did not meet the study criteria but completed the survey nonetheless. According to the student, he or she did not receive any specific accommodations despite his or her perception that they were required. Only two of the *seven criteria* were met: the student felt engaged in the class and that he or she contributed to group activities. The student felt neutral regarding his or her safety in the laboratory. Relative to laboratory skills, the only skill in which the student could participate was to use a Bunsen burner and/or hot plate. The student did not receive a C or better in the class. Further, the student termed the course a "horrible experience" (S7). The student's failure to succeed could have at least in part have been due to his or her inability to actively participate in the laboratory activities because specific accommodations were not provided.

Illustrating the benefits of active participation are the comments of Instructor 8, who taught a student with severe blindness. The instructor enabled the student to view microscopic images on a television screen. He or she described the important knowledge his or her student gained through active participation by writing:

> During another lab, we were looking at the parts of flowers. She put a flower under the camera on the tripod, sat down in front of the television, and told me that she never knew flowers had parts other than what she had been told during classes. She had never been able to see the individual petals of a flower. (I8)

Additionally, the opportunities students realized by actively participating in a laboratory environment conducive to their learning are evident in this student's comment:

> It proves that a blind person can learn biology and a blind person can do chemistry and a blind person can do physics. It's pretty amazing stuff and I feel really lucky to have that chance at the University where I go. (S5)

Role of the *Seven Criteria* in Student Learning

This study aimed to evaluate the effectiveness of specific accommodations provided for students with BVI in the college biology laboratory. Students may not be able to actively participate unless the specific accommodations provided are effective. Study protocol required that to be considered effective, the specific accommodations had to enable students to meet each of the *seven criteria*. Those criteria were chosen from the literature because each serves a role in student learning. Students must be safe in the laboratory (Duerstock et al., 2014; "The Integral Role," 2007) so that they are able to actively participate, and research has associated active participation with improved learning (Goubeaud, 2010; Mastropieri & Scruggs, 1992; Supalo, 2010). Sinatra et al. (2015) remarked that engagement promotes successful learning. Acceptance by classmates has been shown to improve learning for students with disabilities (Scruggs and Mastropieri, 2007). Group interactions also have been noted to improve student learning (Gormally et al., 2011). Di Trapani & Clarke (2012) offered that the development of laboratory skills is important to student learning in the laboratory. Course grades reflect student learning

(Suskie, 2010), and some assessment practices can promote student learning (Wilson & Scalise, 2006). Finally, students with disabilities must have the opportunity to achieve a level of learning that is equivalent to that achieved by sighted students actively participating in the class (Duerstock, 2015). Therefore, each of the *seven criteria* is positively associated with student learning.

Role of Specific Accommodations in Meeting the *Seven Criteria*

Though each of the *seven criteria* is connected with student learning, what role do specific accommodations serve in enabling students to meet each of the *seven criteria*? Active participation has been shown to improve student engagement (Mastropieri & Scruggs, 1992; Supalo, 2010). Research has demonstrated a relationship between active participation and peer acceptance in the science laboratory (Supalo, 2010; Supalo et al., 2014). Active participation has also been linked with improved contributions to group activities (Supalo, 2010). To acquire and demonstrate proficiency in the laboratory skills required in many laboratory exercises (Di Trapani & Clarke, 2012; Fitch, 2007; Hunt et al., 2012), active participation is necessary. Because many instructors grade students on skills demonstration (Di Trapani & Clarke, 2012; Fitch, 2007; Hunt et al., 2012), and because active participation improves learning (Moon et al., 2012), it contributes to academic success, criterion six ("Reasonable," 2016). To attain knowledge commensurate with that of classmates (Duerstock, 2015), students with BVI need the opportunity to be as actively involved as the sighted students in the class. Therefore, active participation is necessary to meet each of the *seven criteria*, and effective specific accommodations are necessary for many students with BVI to enable that active participation.

Importance of Active Participation

In this study, the student's ability to actively participate in the laboratory activities was crucial. Each of the *seven criteria* is predicated on the student's ability to actively participate in the laboratory exercises. If a student was not able to actively participate, the student would not have met each of the *seven criteria*. Study results are consistent with the advice of Miner et al. (2001) who stated that, "there is ample evidence to indicate that laboratory experiences enhance science learning. Therefore, laboratory participation is essential in providing students with disabilities an equal opportunity to learn" (p. 12).

For many students with BVI, active participation requires specific accommodations (Moon et al., 2012; Supalo, 2007). Students not receiving effective specific accommodations may not have been able to actively participate, and the lack of active participation could have affected student learning. Study results revealed that specific accommodations were provided for all but three of the students. One student was classified as having severe/very severe/total blindness in one eye. The other two were students with total blindness. All study participants indicated that their students completed the course with a C or better, however, indicating that they were able to learn at a level sufficient to pass the class.

Unexpected Results

Even though the specific accommodations provided for 15 of the 17 students were found to be ineffective according to the *seven criteria*, all 20 students received a C or better in the course. How was that possible given the association of active participation with both the *seven criteria* and with student learning? A possibility is that most of the students were able to actively participate in many of the laboratory activities and successfully master those required skills. Examination of the skills abilities of the students, as represented in Tables 7 and 8, revealed that all of the students were able to actively participate in at least some of the activities; several students were able to participate in most of the activities. Those laboratory skills then enabled exploration and understanding of laboratory concepts through student involvement in course activities. Student 5 summed up the importance of active participation in the biology laboratory by ending his or her narrative with this sentiment: "I felt empowered, and that is always, blind or not, a wonderful feeling." Sixteen of the 20 students were able to meet five or more of the *seven criteria*. Only three students, though, were able to meet each of the *seven criteria*. One instructor noted:

> I had had visually impaired students before, but never one who was totally blind. I was making it up as I went . . . . While I think she had a positive experience and learned a great deal, I also think that it could have been a much better class for her if we had some materials in place. (I10)

This study did not capture the information necessary to determine whether the students could have learned even more had they been able to actively participate in all of the laboratory activities.

Alternate Pathways to Success

Other reasons exist that could explain how the 17 students unable to meet each of the *seven criteria* completed the course with a C or better despite being unable to actively participate in one or more activities. The teaching style and attitude of the instructor affect student learning. A study by Scruggs and Mastropieri (2007) concluded that, "teacher effectiveness variables (e.g., time on task, direct questioning, pace of instruction, opportunities to respond) may be of greatest overall importance in science learning" (p. 68). Those variables could not be controlled or determined in this study, but likely influenced student success.

Another possibility is that, though all indicated that the altered assessments enabled equivalent assessment, some instructors made alterations in the course assessments for the students with BVI. Seven instructors believed that lab assessments should be altered so that the student with BVI can pass the class, eight made alterations to assessments of course concepts, and three made alterations to assessments of course skills. It is also possible that instructors awarded the students a passing grade based on effort, rather than actual learning.

The reason also could rest with the fact that the students had disabilities. Supalo et al. (2007) noted that students with disabilities have learned how to overcome challenges, and remarked that

> persons with disabilities are experienced in solving problems related to accessibility over the course of their lives; thus, problem-solving skills are well-developed within this population. This quality imparts a great potential for this population to make significant intellectual contributions to the scientific community. (p. 31)

Instructor 8 expressed a similar view:

> Most instructors consider a student with BVI a burden. I considered it a challenge. I wanted to make sure she had just as much opportunity to see everything looked at in lab that someone with normal vision did. During all the years I have taught, I have never had a BVI student or any disabled student perform at a lower level than the other students. They have faced challenges all their life and been successful. Why shouldn't they be successful in a biology laboratory course?

Additional Challenges

Certainly, there are reasons other than ineffective specific accommodations posing challenges to active participation for students with BVI, and those challenges can affect the opportunity for success in the biology laboratory. Even effective specific accommodations cannot remove the fear that students with BVI may harbor (Reed & Curtis, 2011), which would accompany them to the biology class. Instructor 8 echoed that sentiment by writing, "unfortunately some of the BVI students I have instructed told me they were afraid to take a biology laboratory course because of how visual most of them tend to be" (I19). The students with BVI could harbor negative attitudes from a prior laboratory experience (Duerstock et al., 2014). Consistent with attitudes from prior experience, Supalo (2010) warned that when students are not permitted to perform activities in the science laboratory, they could become afraid to use its tools and equipment.

Attitude figures prominently in student success. It is possible for counselors, parents, and teachers to project the belief that students with BVI may not be successful in science classes (Duerstock, 2015; Supalo, 2013). Duerstock (2015) commented that, "many students with disabilities, parents, teachers, and faculty researchers can only see the hurdles in science and engineering and not the opportunities" (para. 5). Duerstock et al. (2014) noted that students with disabilities may lack confidence in their ability to succeed in a STEM field. Student 3 revealed that attitude by expressing doubt in his or her ability to complete a science course. Marson et al. (2012) emphasized that instructor attitude contributes to a student's educational experience and learning. The ability of an instructor to engage his or her students also has a profound effect on student learning (Axelson & Flick, 2011). Additionally, Sinatra et al. (2015) noted that student attitudes affect their performance in science classes. The authors observed that students might lend science little credence, may have preconceived ideas about science, and may feel conflicted regarding some of the content of science courses, such as evolution and "genetically modified organisms" (p. 6).

There are activities in the biology laboratory that are currently prohibitive to some students with BVI. Specific accommodations for several activities in which students are required to actively participate in the biological sciences are currently unavailable. Students with total blindness, for instance, cannot use a microscope to locate and identify images. The inability of students to actively participate in those exercises does not result from ineffective specific accommodations.

Students with BVI also may have other disabilities that interfere with active participation in the laboratory exercises. Instructor 1 noted that his or her student could not actively participate due to other physical limitations, not the student's BVI. Additionally, instructors may lack sufficient knowledge of available technologies to support students with BVI (Duerstock et al., 2014; Moon et al., 2012), and students with other disabilities. That was substantiated by Instructor 10 who wrote, "I had no idea what technologies might be out there that could be helpful."

As is true for all college students, academic workload in other courses and/or responsibilities outside of college, such as family obligations or a job, often impinge on students' time and energy. The instructor of a student not qualifying for the study dropped the class due to circumstances that had nothing to do with the biology course. Instructor 25 noted that the student was happy. Ineffective specific accommodations were not responsible for the student's lack of success. Finally, as Supalo (2010) noted, "some students naturally have little interest or aptitude for science" (p. 351).

Implications

According to the criteria of this study, the specific accommodations provided were not effective for 15 of the 17 students represented who were provided specific accommodations.

Results of this study accurately reflect the perceived experiences of those 20 individuals, and the knowledge gained from study participants is informative. However, study results specifically reflect perceptions of instructors and students regarding different courses at a variety of institutions in unknown locations. Additionally, the students represented in the study had significant variation in their degree of visual impairment, which impacted their active participation in the laboratory exercises. Those considerations make generalizations regarding the results inadvisable. Nevertheless, outcomes were consistent with the need for students with BVI to actively participate in laboratory activities, thus necessitating specific accommodations that are effective. Results of the study may be of interest to biology instructors and DSS office personnel at colleges and universities. Administrators in higher education, parents of students with BVI, and students with BVI may also be interested in the results of this research. Information gleaned from study results can inform the development of methodologies for evaluating the effectiveness of specific accommodations for students with BVI. Study outcomes can also inform continued research into best practices in providing effective specific accommodations for students with BVI in the college biology laboratory.

Participant stories provided insight into what actually transpired in the college biology laboratory for 20 students. Despite study results indicating that for 15 of the 17 students the specific accommodations did not enable the students to meet the *seven criteria*, both student and instructor responses were generally positive. Therefore, in spite of limitations to active participation in particular activities of the laboratory, the students and the instructors generally perceived that the students with BVI were engaged, accepted, contributing members of the class who learned the laboratory skills as well as the other students in the class. All but one student and two instructors felt the students with BVI learned at a level equivalent to sighted classmates.

The narratives conveyed rich information regarding the experiences of the participants. Many revealed confidence in the students' learning and success, and the students' desire to actively participate in the laboratory exercises. One instructor commented on the pleasure he and his student with total blindness realized during class. He wrote, "I will never forget handing her a sea anemone. Her response was, 'So THAT'S where Nemo lived! I couldn't figure it out from the movie' " (I10). Another student's narrative illustrates how essential specific accommodations are in supporting students with BVI, and that successfully supporting a student's active participation does not require profound or costly technological innovations:

> The first week in class I was introduced to the adaptive lab instructor. She got me through everything in labs. There were times when I would read the lab manual to prepare for lab and I would wonder "How are we going to do this?" Some things just seemed really impossible for a blind person to do. But every week I would come in and my AL instructor would be waiting for me, usually with half a craft store in tow. I learned about cells with tactile images made with puffy paint. I learned about gram stains with stickers and pipe cleaners, and I learned about genes with buttons and beads. I found out that pretty much any lab is possible to do. There is some creative way to make it make sense. You just have to have someone who is really patient to help you out. (S5)

Creating specific accommodations requires advance preparation (Moon et al., 2012). Consistent with that statement is the clear message from Student 5's narrative: advance planning promotes effective specific accommodations. The benefits of advance planning for Student 5 were evident in his or her remarks. The student was able to actively participate and learn despite his or her doubt to the contrary.

A Synthesis of Voices

Study participants generously shared their personal experiences in this study. The following excerpts are from the narratives of student and instructor participants. Their observations serve as testament that the experience of supporting a student with BVI in the biology laboratory benefits not only the student.

Student 3: "After learning about the adapted lab section, I realized I had the opportunity to learn science related courses."

Student 4: "I had a very positive experience with my biology courses. My instructor was willing to learn."

Student 5: "I was pleasantly surprised."

Instructor 2: "The student was great (finished 6 of 60). Student went on to do an MS."

Instructor 5: "My student was motivated and an incredibly hard worker. He was an inspiration."

Instructor 6: "Great communication and in one case, he made an observation (based on touch) that other sighted students missed."

Instructor 8:

> Not only did the BVI student learn and comprehend as much as the other students in my biology laboratory course, but she helped me learn more about teaching BVI students. Our department is looking to purchase equipment to assist BVI students in our laboratory courses and they usually look to me for suggestions. All because I took some time, creativity, and student feedback to ensure my BVI student had equal opportunity to succeed in my laboratory course.

Instructor 10: "She desperately wanted to participate in this class [and] threw herself into the class with great enthusiasm."

Instructor 11:

> I had a very positive experience educating this particular student. This was the only blind student that I have had the opportunity to work with. He came to class with an excellent attitude and was very interested in what we were covering.

Instructor 12:

> I enjoy the challenge. With a good relationship, things can be worked out as they arise. The students I have had so far have all been very patient with me when I make mistakes or don't have something ready for them immediately. I usually ask them to prompt me to remember things for them.

Instructor 14: "I worked with the student after they brought their list of accommodations to the best of my abilities. We gave the student accommodations without it impeding the lab or group work."

Those statements exemplify the positive attitudes of the participants, and the genuine efforts of the instructors who participated in this study to support the students with BVI in their laboratories. Student participants also revealed their earnest endeavors to succeed in the course. Students and instructors alike exhibited concerted effort in the pursuit of success. Their enthusiasm may serve to encourage those reticent to effect change, and ease the trepidation of those dreading the day they receive notification from the DSS office that a student with BVI is enrolled in their class. The ten statements in Table 14 summarize information gleaned from study participants.

Table 14

A Synthesis of Voices

1	Students with BVI wanted to actively participate in biology laboratory activities.
2	Fellow students readily offered help to students with BVI.
3	Student and instructor participants indicated that an aide benefitted students with BVI.
4	Some instructors indicated they lacked knowledge of available technologies, and/or lacked access to assistive technologies to support students with BVI.
5	Some DSS office personnel were unaware of methods to support students with BVI, leaving instructors to support students with BVI without assistance.
6	Advance planning benefitted students with BVI.
7	Some students were fearful or expressed doubt about taking biology, and had negative experiences in previous biology courses.
8	Students with BVI successfully passed college biology courses with specific accommodations found ineffective in this study.
9	Instructors with no prior experience teaching students with BVI wanted to and succeeded in successfully supporting them.
10	Instructors did not agree whether assessments should be altered for students with BVI.

Specific Accommodations Provided

While specific accommodations were not found effective for 15 students according to study criteria, the students in this study were supported with a wide array of specific accommodations. Participants provided detailed descriptions of the types of accommodations that were provided. Students and instructors were asked which they felt were most beneficial, and those they felt were not particularly helpful. Finally, instructors were asked if there were accommodations they would like to have offered but did not, or could not. Reasons were not solicited for the final question. Results are summarized below.

The only accommodation noted by instructors that altered the physical environment of the laboratory was to supply a table at the front of the room that could accommodate the student's wheelchair (I1). Other accommodations included enlarged images (I8) and font sizes (I1; I4; I13; I14), a magnifier (I3; I8), and verbal descriptions (I5; I7; I9; I11, I12). Instructor 8 remarked that, "I made copies of the diagrams available to the student so they could be viewed on her enlarger in lab and her enlarger at home." Many students and instructors noted tactile accommodations in the form of charts (S5), diagrams of microscopic images (S4; S5), graphs (S5), and other materials (S3; I3). An instructor commented that tactile images could be created with a "3D pen that melts plastic, much like a glue gun would. Either I or the student's aide would go over images with this pen to make them tactile" (I12). A student noted a similar accommodation (S1).

Many other types of accommodations were noted. One instructor created a "Braille lab manual with tactile figures" (I2), and a student noted that, "all instructions and powerpoint [sic] slides were available in braille [sic] and audio for me" (S5). Other accommodations included images (I12) and beakers (S4) labeled with Braille. Others provided audio recordings (I3; I5), talking equipment (S4), and a "talking LabQuest to do things such as measuring O2 and CO2 levels" (S4). For microscopic images, several of the instructors projected the images onto a large screen or television (I1; I4; I8; I13). Respondents also mentioned the importance of models (S5), including "3-D models that were easily modified with a braille [sic] label maker" (I12), and other physical objects such as "skulls, bones, [and] feathers" (I7). One instructor mentioned the benefits of a 3D tablet on which the student viewed digital images with the magnification function "as well as possible" (I7).

Also noted by study participants was the importance of lab partners and group mates. Group work has been shown to be "critical to learning" (Gormally et al., 2011, p. 48), and is common in the science laboratory. Some individuals consider group work to be an accommodation (Moon et al., 2012). Lab partners and group mates can explain concepts in ways that differ from that of the instructor, and can act as tutors for students with BVI (Lartec & Espique, 2012). Several instructors (I1; I2; I7; & I11) commented on the important contributions that classmates freely made to the students with BVI. Instructor 12 wrote of his or her student with total blindness that, "all my labs are done in groups and so far all my students have been very willing to assist the BVI students." A consideration, however, is that Reed and Curtis (2012) noted that students with disabilities may believe that their group mates could be nervous around them.

The literature is replete with the mention of aides as a necessary accommodation for students with BVI (Caldwell & Teagarden, 2007; Harshman et al., 2013; Hutson, 2009; Miecznikowski et al., 2015; Moon et al., 2012; Pence et al., 2003; Supalo, 2012). Caldwell and Teagarden (2007) remarked that students with BVI "need individualized assistance in the lab to truly benefit from and fully participate in laboratory exercises . . . . [and] a single instructor cannot simultaneously teach 24 students and provide the needed time and assistance" (p. 358). Further, research on university faculty in India by Ambati (2013) noted, "lack of sufficient time to look after the individual needs" of students with BVI was a challenge commonly voiced (p. 134). Four students and nine instructors noted that the student requested and was provided an aide, or other non-student of the class, as an accommodation. Instructor 2 remarked that the "student had an aide (paid by the college's disability resource center) to be her hands." A similar story was relayed by Instructor 14 of his or her student's aide, who performed "small activities such as pipetting." Other instructors mentioned that the aide provided descriptions (I7; I12) and created tactile models with a 3D pen (I12). One student commented on the importance of the aide, writing that:

> [She] was super easy to understand. She would pretty much talk me through everything, but she didn't give me answers. I liked that, because I like to figure things out and ask why. If I didn't know the answer she almost always did. I pretty much taught my lab partner everything she learned in lab because I had someone really awesome to teach it to me. (S5)

Nine instructors indicated that an aide would have been of benefit to the student with BVI. One of the five instructors indicating that an aide would not have helped the student to do better in class taught a student with a mild visual impairment, one taught a student with moderate visual impairment, another taught a student with very severe blindness, and two taught students with total blindness. Interestingly, only the two instructors who taught students with total blindness did not have prior experience teaching students with BVI. Two of the instructors in the study with experience teaching students with BVI, who completed the study regarding students with total blindness, indicated that the students would have benefitted from an aide. The instructor of the student with very severe blindness who disagreed that the student would have done better in the class with an aide indicated that the student requested and was provided an aide. It is not possible to determine whether the instructor misinterpreted one or both of the questions, or believed that the aide provided was unnecessary.

In spite of the potential benefits, there are also many articles questioning whether an aide enables the student the full benefit of active participation (Moon et al., 2012; Supalo, 2010; Supalo, 2012; Supalo et al., 2007). "The use of assistants also runs counter to the culture of STEM education, predominant in higher education, that treats 'hands-on' participation as one of its most sacred tenets" (Moon et al., 2012, p. 158). Results of this study were consistent with the benefits of active participation noted by researchers. Though this study did not further address the topic, students and instructors were asked whether they believed that an aide would have enabled the student to do better in the class. A student with very severe blindness strongly agreed. That student had an aide for the course. The student with severe/very severe/total blindness in one eye, who did not have an aide for the course, responded neutral to that question. The other three students either skipped the question or noted that it was not applicable, likely because they had aides for the class. Supalo et al. (2014) remarked that reliance on aides "does not appear to encourage this population to consider career paths" in STEM (p. 195). The ability to actively participate in laboratory activities promotes confidence in all students. Only those students able to experience active participation would likely develop the confidence, or the interest, in pursuing a career in STEM. While at the present time aides may be necessary to ensure everyone's safety and to assist some students with BVI, progressing to more independent participation by students with BVI could promote the confidence necessary to continue in the sciences.

Finally, one instructor instituted a kind of role-play adaptation with his or her class that benefitted the student with BVI. The modified exercise is commonly applied to reinforce the benefit to an animal of blending in with its surroundings to avoid predation. The instructor described the activity in the following way:

> The predation lab was particularly difficult for this student because we use forceps to pick up small colored disks. The student had a difficult time finding the disks, but that was the point of the laboratory. We were looking at different foraging abilities based on abilities. I asked the students to forage with their eyes closed in another experiment and the student did this in an outstanding way. (I3)

Specific Accommodations Perceived Beneficial

Students and instructors were asked to specify those accommodations they found to be especially helpful. From the responses, students were provided with a variety of specific accommodations that they felt were beneficial. A student noted that his or her instructor rewrote labs "to make them similar and accessible" (S5). Other students noted the benefit of a "3D printing pen" (S1), "Brailled beakers" (S4), models (S1), a "reader/writer" (S3), "sensory supplements" (S4), and "talking equipment" (S4). Tactile material (S3) and slides (S4; S5) were also noted to be important to the students. One commented that:

> I loved the tactile diagrams of the slides I was supposed to see. It is really hard to understand the structure of something based only on a lab partners [sic] description. So having something I could feel myself made everything click just a little more. (S5)

Instructors noted many specific accommodations that were beneficial. They included the digital images on a tablet, a 3D pen (I12), the digital tablet magnification function (I7), extensive descriptions (I11), and "physical objects (skulls, bones, feathers) (I7). Other instructors mentioned that lab partners (I1) and the lab assistant (I5; I14) were helpful. One instructor commented on the importance of a "computer assisted microscope to enlarge images" (I13) and using digital cameras and a television to enlarge materials (I8). The latter instructor noted, though, that, "a drawback to the set up was the amount of space that it took up on a laboratory bench that could have been used for other purposes" (I8).

Specific Accommodations Not Perceived Beneficial

Students and instructors were also asked which of the specific accommodations provided were not helpful. A student commented that, "having someone describe exact images to me was super unhelpful. It required someone else to describe things verbally. Which is a very hard thing to do" (S5). One instructor warned that, "high quality tactile images from the textbook were ordered, but it took so long to arrive that they were not helpful" (I12). Four instructors commented that all of the accommodations provided were helpful. The remaining instructors did not answer the question. There is no way to determine whether those instructors felt that all, some, or none of the specific accommodations offered were beneficial.

Desired Accommodations

A question on the instructor survey asked if there were accommodations that the instructor wanted to offer but could not due to lack of time, lack of funds, or for other reasons. A variety of responses were received from five instructors. One instructor indicated that his or her lab would benefit from a 3-D printer. That instructor also mentioned that the course produces a lot of graphs, and "that is the most difficult thing we have not fixed yet" (I12). A "microscope designed for students with BVI and poor motor control," and "virtual labs using computer simulation" were desired by another instructor (I1). A different instructor wanted raised line diagrams (I8), while another felt that there was "inadequate software" provided for the student (I15). A last instructor wrote that, "science figures in the textbook which are a great resource, but often missed by the visually impaired students" (I3). The latter response may mean that tactile images of textbook figures would benefit the student.

Limitations of the Study

The ability to determine the total number of students with BVI who had completed a college biology course at institutions of higher education in the United States between 2010 and 2015 was impracticable. With an unknown population size, a sample size calculator indicated that at least 96 participants would be necessary to provide a meaningful representation of the target population. Participant numbers did not reach that amount. It is not possible to determine what percentage of the total population was sampled in this study, but participant numbers were small. Though the perceptions of study participants are nonetheless accurate and informative, results may have differed had a greater number of individuals participated in the study. Additionally, using anonymous online surveys precluded the ability to verify participant eligibility for the study.

It is also important to note that all results from this study were based on student and instructor perceptions. Different individuals can perceive similar experiences in an opposing manner, thus reinforcing the need for a study with greater participant numbers. Participants represented institutions from different locations across the United States, and perhaps from other countries as well. The combination of different courses, different instructors, and different institutions interjected additional uncontrolled variables into the study.

Individuals described specific accommodations provided, however there was no method to determine whether each enabled equivalent opportunity for participation. Not all tactile models are equal, for example. This study provided no means to determine which specific accommodation is best for a given laboratory activity or visual impairment. This study also did not examine student and instructor attitudes, which can both positively and negatively affect student success. Additionally, instructors may have inaccurately determined that students with BVI did not require specific accommodations.

Since the study included students who had taken or instructors who had taught the course since 2010, it is possible that recollections did not accurately reflect what actually transpired in the classroom. Another unknown variable in this study is any amount of extra time instructors may have devoted to the student with BVI. Research has indicated that instructors sometimes support students with BVI during extra office hours (Miecznikowski et al., 2015). Several instructors indicated that students took the required laboratory practicals outside of normal class hours (I5; I8; I11).

There were additional limitations in this study. Computer and Internet access were required for study participation, and students with BVI may have required a screen reader to access the survey. Though taking the student survey was possible with a screen reader, the student may not have had access to the necessary software. Those factors may have precluded individuals from participation. All of the study participants received a C or better in the course. Therefore, the study pre-selected for students who could be successful even if specific accommodations were not effective. There is also the possibility that those who volunteered to participate in the study were the most motivated or had the best experience in the class. The latter two limitations may account for the generally positive responses from study participants.

DSS offices were asked to contact eligible students via email, necessitating that students have a current email address. Because the study spanned the years 2010 to 2015, it is possible that institutions no longer had the contact information for graduates. That may have limited participants to students who were still attending or had only recently graduated, thus not representing all five years. Institutions are increasingly aware of the need to support students with BVI. Therefore, the study may have represented more recent efforts and technologies employed to support students with BVI.

Students and instructors also may have declined to participate for fear of their identity being disclosed, even though strict measures were instituted to make that possibility highly unlikely. It is possible that those students and instructors who had a difficult experience declined to participate in the study. Additionally, there have been many lawsuits filed against institutions of higher education in recent years, potentially leaving some institutions and instructors reticent to participate in this study.

Recommendations

Although students in this study all realized success by receiving a grade of C or better in the course, the specific accommodations were not found effective for 15 of the 17 participants provided with specific accommodations. Study results would indicate that the specific accommodations did not meet student and instructor needs for those 15 students. According to the premise of this study, those students may not have realized the "equal opportunity" required by the ADA ("A Guide," 2009, para. 9; "The Americans," n.d., para. 1), although they did meet the academic standards of the course ("Reasonable," 2016).

Despite the possibility that causes other than ineffective specific accommodations could be responsible for students failing to meet each of the *seven criteria*, the experience of the one unsuccessful student responding to the survey who received no specific accommodations highlights the need for instructors, DSS office personnel, and college administrators to prepare in advance to support students with BVI in the college biology laboratory. Duerstock et al. (2014) cautioned that, "to experience the same real-world and hands-on STEM learning opportunities that students without disabilities are typically afforded, efforts must be focused on curricular participation, not just institutional accessibility" (p. 3). Results of this study were consistent with the need for continued change.

Recommendations for Action

Critical theory seeks to determine if disparity exists between what was intended and what transpired (Held, 1980). Specific accommodations are provided for students with BVI in the college biology laboratory with the intent that they effectively enable the student's active participation in the laboratory exercises of the course. Proponents of critical theory advocate for change to address issues of social justice (Mayo, 2007). Pliner and Johnson (2004) echoed that sentiment regarding students with disabilities when they observed that despite laws requiring access, the educational system in higher education has failed to change obstacles that exist for students with disabilities (p. 106). Some of those obstacles are present in the college biology laboratory. In the time since that article was written, progress has been made. Supported by the results of this study is the need for continued progress.

The following recommendations do not represent an exhaustive list, nor are they original. They are an amalgam of information gathered from the literature, and gleaned from study participants. Each individual should determine which are applicable and appropriate for the curricular requirements of his or her particular course. Duerstock (2015) remarked that

> there is, of course, no single solution for determining what mix of accommodations is necessary for a student with a disability. Even with students without disabilities, some need intensive one-on-one mentoring and others work fine on their own with little oversight. (para. 10)

Implement Universal Instructional Design. The literature supported many best practices in supporting students with disabilities. Among them was the importance of Universal Instructional Design (UID). An action consistent with progress would be implementation of the tenets of UID into biology course design. Pliner and Johnson (2004) pronounced that, "universal instructional design offers a range of options and strategies to achieve . . . accessibility and inclusion" (p. 105). Application of UID would ensure that all materials are accessible, and benefit not just students with BVI. The practice would also benefit students in the class without disabilities (Duranczyk & Fayon, 2008; Pliner & Johnson, 2004). Applying the concepts of UID necessitates advance planning to prepare classrooms and materials supportive of all students (Pliner & Johnson, 2004).

Coordinate with DSS office. Harshman et al. (2013) revealed the need for coordination between the instructor and the DSS office as an additional consideration when creating accommodations for students. To facilitate advance preparation, it is suggested that instructors discuss general and specific accommodations requirements of their courses with the DSS office before a student with BVI registers. As Instructor 10 remarked, "Disability Services were not sure what to do for accommodations." Instructor 8 also noted that, "the equipment was not available at the time through the Disability Resource Center."

Ensure laboratory safety and accessibility. Safety is of paramount importance for all students. Though responses regarding all students in the survey indicated that the students were safe, the student completing the survey who did not qualify for the study responded neutral to feeling safe in the laboratory. Supalo et al. (2011) stressed that students with BVI must wear safety goggles and proper dress, and that "emergency exit procedures" must also be discussed (p. 6). Instructors are advised to check the lab for accessibility. Ensure that there is an adjustable table or lab bench in every lab. Instructor 1 noted that a table was supplied as an accommodation for his or her student. Duerstock et al. (2014) remarked that, "laboratory infrastructure is all too often unwelcoming, even inaccessible, to persons with physical disabilities" (p. 13).

Prepare class materials and assistive devices. In addition to physical considerations of the laboratory classroom, authors suggested that instructors ensure other aspects of the course are inclusive (Duranczyk & Fayon, 2008; Duranczyk et al., 2013; Goff & Higbee, 2008; Higbee et al., 2008; Higbee & Eaton, 2008; Myers et al., 2008; Silver et al., 1998). An instructor participant commented that, "I had no idea what technologies might be out there that could be helpful" (I10), exemplifying the need for advance planning so that materials and assistive devices are in place prior to students with BVI registering for a class. Instructors are advised to determine the types of specific accommodations that would be needed to support a student with BVI in the laboratory portion of the biology courses being taught. Methods of creating them "in-house" versus purchasing them from manufacturers could be compared, and funding sources secured, if necessary.

Skills in which some students with BVI could not participate, or in which they had difficulty participating, in this study included microscopy; animal dissection; pipetting, pouring, and measuring liquids; color interpretation; and using Bunsen burners and/or hot plates. Those results suggest that, consistent with advance planning, instructors should work with their institutions to prepare specific accommodations for students with BVI so they do not have to experience what Instructor 10 reported: "I was making it up as I went."

Instructors should ensure needed materials and assistive devices are available before a student with BVI is enrolled in the class. At the present time, there may not be solutions for students with total blindness that would enable them to participate in some activities. For example, though one student did not answer the question, only four of the 19 participants responding to the question were not required to use the microscope in their biology courses. For students with total blindness, traditional light microscopy is currently impossible. Students with some vision, though, can be supported by digitally projecting the images onto a screen. One instructor created the accommodation for his or her student in the following way:

> a digital camera [was] attached to a microscope and another digital camera [was] attached to a tripod. Both cameras were connected to a 22 inch television set and the student could switch between either camera using a push button switch box on top of the television.

> The student was able to view microscope slides using the digital camera attached to the microscope slide and larger objects using the digital camera on the tripod. (I8)

For students with total blindness, appropriate tactile models of microscopic images and other inaccessible materials should be prepared for the course. An instructor noted that textbook figures ordered from the publishers did not arrive in time to benefit the student (I12). Instructors should be prepared by creating appropriate alternatives that are already on hand. One student remarked that:

> I loved having tactile diagrams of the slides I was supposed to see. It is really hard to understand the structure of something based only on a lab partner’s description. So having something I could feel myself made everything click just a little more. (S5)

Students with BVI may not have used scalpels to perform dissection, but were encouraged to palpate dissected specimens for identification (I11). Lab assistants or lab partners may be the only solution for pipetting, pouring, and measuring liquids for some students with BVI (I14). Color interpretation remains a challenge for those with limited visual ability as well. Victor Wong, an individual with blindness who was sighted for a portion of his life, commented that he did not know how to explain the concept of color to someone blind from birth (Brand, 2005, p. 5). Software now exists that could ameliorate the difficulty, as it audibly recites colors (Moon et al., 2012). Instructors must not rely solely on that software for students without visual ability, however. According to Instructor 10, color has no meaning for students who have never seen. As long as the conceptual basis on which the color change is predicated is thoroughly explained to the student, though, the software could address even that difficulty. Alternatives to Bunsen burners and hot plates also exist that could remove the need for open flames or dangerous sources of heat ("Bacti-Cinerator," 2015).

Determine course modifications. Consistent with UID is the suggestion that instructors devote advance consideration to what course modifications they feel are warranted for students with BVI, and with other disabilities. There was wide disagreement among the instructors in this study as to whether course assessments should be modified for students with BVI. No correlation was found between the instructor's choice to modify assessments for the student with BVI and either a lack of DSS office assistance, instructor experience teaching students with BVI, or the student's visual impairment. The responses regarding assessments may have been more a reflection of the different assessments and skills requirements in various biology courses. Some instructors may not have needed to alter assessments for students. However, study results suggest that it would be prudent for college biology instructors to formulate a plan in advance of need for all aspects of course assessment for students with disabilities. Duerstock et al. (2014) noted that, "preparation is indispensable to teaching any practice-based subject with [students with disabilities]" (p. 10).

Mezirow (1991) remarked that adult learners should "have equality of opportunity to participate" (p. 198). Fraser and Maguvhe (2008) emphasized the importance of observation in biology, and stated that students with BVI "will only be able to be competitive when they are fully exposed to all biology phenomena" (p. 87). Active participation in the biology laboratory entails observation, whether identifying cells under the microscope, interpreting the migration bands on a gel electrophoresis, or counting the gill movements of goldfish. Specific accommodations enable students with some visual ability to participate in those observations. At the present time, however, there are activities in the biology laboratory in which some students with BVI, especially those with total blindness, cannot participate in the same manner as students with at least some visual ability. Therefore, a conversation that should occur within the biological sciences community concerns the extent to which activities can be altered yet remain consistent with the academic standards of a course. Concomitantly, assessment and grading adaptations should be formulated yielding results that provide confidence for the student and instructor that the content and skills of the course were legitimately mastered.

Develop policies. Also consistent with UID is that institutions and instructors are advised to develop policies regarding canes, wheelchairs, scooters, and guide dogs in the laboratory portion of every biology course. Guide dogs were not mentioned by any of the study participants, but could be problematic. Instructors should be aware of recommendations from the Centers for Disease Control and Prevention regarding animals in the laboratory. The following website contains important information: http://www.cdc.gov/biosafety/publications/bmbl5/index.htm (Section IV, p. 36). Wheelchairs and scooters also present specific challenges. The front is often too high to fit beneath lab benches and tables. If it does fit, the student's head is often barely above table height, as mentioned by an instructor participant in this study (I4). Additionally, it is suggested that departmental policies regarding the student's use of flames and toxic chemicals be developed. For students who are seated in a wheelchair, using chemicals may pose a safety hazard (T. Hamby, personal communication, December, 2015).

Request professional development. Instructors are advised to request professional development relative to students with BVI, and students with other disabilities. A few of the instructors commented that they had no prior experience and/or the DSS offices were unable to help. "Without appropriate knowledge, faculty are ill-prepared to make decisions about how to effectively implement accommodations in their classrooms" (Sniatecki, Perry, & Snell, 2015, p. 260). The following videos and websites may help. There are many other sites not listed that contain helpful information about teaching students with BVI as well as information about available technologies.

- Fitzpatrick, D. (2011, November 3). *I have a blind student in my maths/science class, should I panic?* [Video file]. Retrieved from https://www.youtube.com/watch?v=GJNj8vHI2zs
- Washington State School for the Blind. (2012, August 17). *Science techniques for the blind: Learn how to safely conduct and analyze experiments* [Video file]. Retrieved from https://www.youtube.com/watch?list=PLF126DB019FC5C859&v=Ok-2l2myqzw
- Independence Science. (2012, June 5). *How to prepare a student with visual impairments for safe access to the science laboratory* [Video file]. Retrieved from https://www.youtube.com/watch?v=6_PuCJjmYWc
- DO-IT: Disabilities, opportunities, internetworking, and technology. (2016). *University of Washington*. Retrieved from http://www.washington.edu/doit/
- Sullivan, G., Miller, C., & Goad, C. (2016). Helping students with visual impairments: Resources, tools and technology to foster school success. *Accredited Schools Online.* Retrieved from www.accreditedschoolsonline.org/resources/helping-students-with-visual-impairments/

Maintain a positive attitude. Instructor attitudes influence student learning. Many of the instructors who participated in this study offered more than specific accommodations for their students. Their responses indicate that they projected a positive, supportive attitude as well. Instructors need to believe that students with BVI can succeed in their courses (Harshman et al., 2013).

Recommendations for Further Study

Social justice education theory focuses on ensuring that minority populations realize equity in education (Mertens, 2007; Torres, 2008). Pliner and Johnson (2004) noted that social justice education seeks changes in the educational system that promote justice for individuals with disabilities. Mezirow (1997) promoted the idea of transformative learning theory to advocate the concept of equal opportunity for adult learners. To implement his suggestions, he advised educators to change their current methods of teaching. Critical theory also advocates for change to address issues of inequity (Mayo, 2007). Each of those theories is consistent with the need to provide specific accommodations in the college biology laboratory that enable students with BVI the opportunity for active participation, and therefore an equal opportunity for success. The results of this study are consistent with the need for continued change.

Every one of the 714 colleges and universities contacted by this researcher had a Disability Support Services office, or equivalent. Therefore, institutions of higher education are working to support students with disabilities. All twenty students in this study were successful in their classes. Many participants relayed remarkable stories of their experiences in the laboratory that suggested the significant amount of time and effort expended both by the students and instructors in support of student success. Others remarked on the significant student benefits the specific accommodations enabled. The results of this study were consistent with the need for continued change, however. Therefore, the following recommendations for further research are offered.

Continued research evaluating effectiveness. For those interested in continued research evaluating the effectiveness of specific accommodations for students with BVI in the college biology laboratory, this research provided insight into areas of improvement for future studies. The following suggestions are offered:

- Other methods of contacting student and instructor participants should be explored to improve participant numbers.
- Shorter surveys with fewer open-ended questions might enable increased participation.
- Students not earning a C or better in the class should be eligible to participate, as should college biology instructors who taught a student with BVI not earning a C or better.
- A better definition for the term *specific accommodations* is required since several participants described general accommodations when asked about those that were specific. Better descriptions of specific accommodations would also improve understanding.
- A few instructors responded that the student was actively participating despite indicating that the student was unable to participate in particular activities or to demonstrate particular skills. Some instructors might feel that a distinction between active participation and skills demonstration is unnecessary; others may lean toward keeping the two criteria separate. Supalo (2012) discussed the importance of students with BVI gaining "independence in the science laboratory" (p. 38). Use of the term *independent participation* might provide better clarity of intent with questions concerning a student's active participation.
- Asking instructors about professional development focused on teaching students with disabilities that they had received prior to teaching the student would be informative for those designing and delivering the programs.
- Check survey questions carefully. Those developing their own survey questions are cautioned that despite exerted efforts to the contrary, a portion of the survey questions

lacked sufficient clarity or were double barreled, thus failing to achieve the desired information.

- Dillman et al. (2014) advised that collecting data via multiple methods yields improved study participation. The surveys could be made available for download from a study website so that individuals could complete them offline in paper form. Surveys could be converted into Braille as well. Researchers could obtain a post office box for delivery of the surveys, if necessary. After receipt, the researcher could shred the envelopes to preserve participant anonymity.

Research effectiveness in other STEM courses. Research is needed that focuses on the effectiveness of specific accommodations for students with BVI in the laboratories of the other STEM disciplines. Students with BVI interested in any of the STEM professions confront challenges comparable to those encountered in the biology laboratory. Many of the articles conveying methods for accommodating students with disabilities in mathematics, chemistry, astronomy, and physics did not include evaluation of the effectiveness of those accommodations.

Continued research into specific accommodations. Study results are consistent with the need for continued research into specific accommodations that will support active participation of students with BVI in the college biology laboratory. Adaptations and alterations to those observational exercises that are currently prohibitive should be explored so that students with BVI can be as actively involved in the biology laboratory experience as their sighted classmates, or as their disability permits. Additionally, this study focused on the overall picture of whether the specific accommodations were effective. Research is needed exploring which specific accommodations are most effective for different types of activities, with a correlation of their use relative to the student's visual impairment. Not only should additional instructor perceptions be included in those studies, many more student voices are needed to align with the principles of social justice (Mertens, 2015; Reinschmiedt et al., 2013). In discussing transformative learning theory, Mezirow (1991) remarked on the importance of student perceptions regarding their experiences. Student perspectives provided invaluable insight in this study, and would be crucial to a study on the benefits of particular types of specific accommodations.

Research on commensurate learning. A question in this study asked participants their perceptions of whether a level of learning commensurate with that of sighted students in the class was achieved by the students with BVI. What was not evaluated in this study was whether those perceptions were correct. An approach to addressing that question would be to explore how the sighted students in a class perceived the contributions and learning of the students with BVI. Matching those answers with responses from the students with BVI and the instructors would provide valuable insight. A related question is whether students with BVI unable to actively participate are able to achieve a level of learning commensurate with that of sighted individuals, given the highly visual nature of biology. That topic was not addressed in this study, and merits research.

Research methods of equivalent assessment. Methods to equivalently assess activities that were adapted for students with BVI are needed. Biology instructors should consider, for instance, whether the ability of a student with BVI to identify a structure from a tactile model provided to the student measures a level of learning and skills development equivalent to the ability of a sighted student required to first find that structure under the microscope in order to identify it. Instructors not considering that scenario consistent with equivalent assessment need to develop alternate assessment methods. In developing a rubric for assessing competence in microscopy, Fitch (2007) remarked on the lack of "assessment tools for technical skills in biology" (p. 211). That observation applies to assessment measures for activities adapted for students with BVI. Continued research soliciting the opinions of biology instructors regarding assessment modifications for students with BVI is needed to explore methods that enable equivalent assessment of learning when activities have been altered. Results of that research would promote the maintenance of academic standards, consistent with the advice of Ashworth et al. (2010) who remarked on the challenge to colleges and universities to remain assured of the academic rigor of their programs as they provide alterations and adaptations for students with disabilities.

Students and instructors in this study indicated that skills demonstration was consistent with that of sighted students in the class despite the inability of students to successfully participate in many of the required activities. DiTrapani and Clarke (2012) noted the importance of "practical skills and competencies," and warned that a lack of practical laboratory skills hindered students as they progressed to higher-level courses (p. 29). Ozturk and Debelak (2005) also advised caution by stating that, "educators . . . must wrestle with students who are ill prepared for advanced studies because the expectations preceding their level of study have been low" (p. 2). If the goal is to increase the number of students with disabilities in the STEM professions, it is imperative that the students are held to standards comparable to those for their classmates without disabilities. To do otherwise jeopardizes learning, and could have "the potential to influence graduate employability" (Hunt et al., 2012, p. 862). It is important that the academic standards of courses are maintained ("Reasonable," 2016). Students and instructors must both be confident that equivalent learning is achieved, and comparably measured.

Research effectiveness of UID in STEM courses. The necessity of advance planning was reflected in this research. That prompted this researcher to suggest that instructors incorporate the tenets of UID into course design. Therefore, another recommendation is that research be conducted regarding the effectiveness of the implementation of UID into STEM courses, especially college biology courses.

Research engagement of students with BVI. This study evaluated only two aspects of the topic of student engagement. Student engagement is a complicated topic. Therefore, evaluation of the engagement of students with BVI in the college biology laboratory merits a research study of its own.

Concluding Remarks

This study explored whether specific accommodations provided for students with BVI in the college biology laboratory met the needs of the students with BVI and instructors of students with BVI according to the *seven criteria*. It was posited that if the specific accommodations enabled the students to meet the *seven criteria*, then they were effective because they met the needs of both the students and the instructors. Fifteen students in this study were able to successfully pass the class despite specific accommodations found in this study to be ineffective. Though successful course completion was possible without effective specific accommodations, results of the study were consistent with studies indicating that active participation is important to student success and to increasing the number of students with BVI pursuing STEM careers.

Supalo et al. (2014) offered that student engagement increases when students actively participate in laboratory activities. Students in this study could not participate in some of the activities in the biology laboratory, making continued progress necessary. Supalo et al. warned that, "inadequate hands-on science experiences may inhibit development of self-confidence concerning one's capacity to independently function in scientific endeavors" (p. 198). The authors further stated that the resultant lack of confidence causes many students with BVI to pursue careers in fields other than STEM.

As more students with BVI are supported through effective specific accommodations that enable successful completion of college biology classes, perhaps more students from this minority population will choose to pursue STEM careers. If the tenets of critical theory are applied and change is effected, then students with BVI may realize even greater success in the college biology laboratory and in other STEM courses. "Excellence and equity in STEM education are interrelated" (Moon et al., 2012, p. 10).

There are many reasons students fail to learn. Not being able to actively participate in the laboratory activities of a course should not be one of them. Despite the results of this study indicating that students can successfully complete a college biology course in which the specific accommodations are not effective for at least some of the activities, research should focus efforts on finding ways to support students with BVI in the science laboratory with specific accommodations that effectively enable active participation. It is important not because it is mandated by law, and not to avoid lawsuits. It is important because doing so may improve student learning and interest in science, and may increase the number of individuals with BVI in the STEM professions. Above all else, it is important simply because it is just.

For those passionate about biology, exploring life never ceases to inspire awe and humility. Individuals in the STEM professions experience exhilaration with each new discovery. With advance planning and the implementation of effective specific accommodations, students with BVI can experience that exhilaration. Instructor 8 enabled his or her student with severe blindness to view microscopic images by projecting them onto a television screen. The instructor's narrative illuminates the transformative learning that effective specific accommodations made possible, and exemplifies what exploring the newly opened and fascinating world of biology can mean to a student with BVI:

> One day she was sitting in front of the television looking at a slide of a water weed that we always use to show cytoplasmic streaming and I could see that she had a tear running down the side of her face. I asked her if she was ok and she told me that she had heard other students describe what she was looking at to her in other biology laboratory courses, but she had never actually seen it herself. She was so excited that she spent the next two hours looking at everything she could find to put on a slide that she had always heard other students or instructors describe to her, but never seen. (I8)

REFERENCES

3Doodler: The World's First 3D Printing Pen. (2016). *Kickstarter, Inc*. Retrieved 7/7/15 from https://www.kickstarter.com/projects/1351910088/3doodler-the-worlds-first-3d-printing-pen

6dot Braille Label Maker. (2016). *LoganTech*. Retrieved from http://logantech.com/products/6dot-braille-label-maker

A General Education Foundation for Associate in Arts, Associate in Science, Specialized Associate and Certificate Programs in New Jersey's Community Colleges. (2007). *General Education Foundation Policy, New Jersey Council of County Colleges*. Retrieved from http://www.njccc.org/pubs/GenEdFoundation.pdf

A Guide to Disability Rights Laws. (2009, July). *U. S. Department of Justice, Civil Rights Division, Disability Rights Section*. Retrieved from http://www.ada.gov/cguide.htm

Abboud, S., Hanassy, S., Levy-Tzedek, S., Maidenbaum, S., & Amedi, A. (2014). EyeMusic: Introducing a "visual" colorful experience for the blind using auditory sensory substitution. *Restorative Neurology and Neuroscience, 32*(2), 247-257.

Academic Accommodations. (2016). *Concordia University Irvine*. Retrieved from http://www.cui.edu/studentlife/disability-learning-resource-center/index/id/19341

Accessibility. (2015). *Oregon State University*. Retrieved 7/18/15 from http://oregonstate.edu/accessibility/policies

Accessible. (2016). *Oxford Dictionaries, Language Matters*. Retrieved from http://www.oxforddictionaries.com/us/definition/learner/accessible

AccessSTEM. (2016). *DO-IT, University of Washington*. Retrieved from http://www.washington.edu/doit/programs/accessstem/overview

Accommodations and Modifications at a Glance: Educational Accommodations for Students Who Are Blind or Visually Impaired. (2015). *American Foundation for the Blind*. Retrieved from http://www.afb.org/info/programs-and-services/professional-development/experts-guide/accommodations-and-modifications-at-a-glance/1235

ADA Amendments Act of 2008. (2008). *U.S. Equal Employment Opportunity Commission*. Retrieved from http://www.eeoc.gov/laws/statutes/adaaa.cfm

Adams, K. S., & Proctor, B. E. (2010). Adaptation to college for students with and without disabilities: Group differences and predictors. *Journal of Postsecondary Education and Disability, 22*(3), 166-184.

Alexandrin, J. R., Schreiber, I. L., & Henry, E. (2008). Why not disclose? In J. L. Higbee & E. Goff (Eds.), *Pedagogy and student services for institutional transformation: Implementing universal design in higher education* (pp. 377-392). Minneapolis, MN: Regents of the University of Minnesota.

Allen, J. D. (2005). Grades as valid measures of academic achievement of classroom learning. *The Clearing House, 78*(5), 218-223.

Almroth, B. C. (2015). The importance of laboratory exercises in biology teaching: Case study in an exotoxicology course. *Institution for Biological and Environmental Sciences, University of Gothenburg*, 1-11. Retrieved from http://pil.gu.se/digitalAssets/1550/1550056_carney-almroth-laboratory-studies-in-teaching.pdf

Altabbakh, H., AlKazimi, M. A., Murray, S., & Grantham, K. (2015). Safety awareness: Identifying a need for undergraduate engineering students. *Professional Safety*, 38-41.

Ambati, N. R. (2013). University teacher's attitudes and experience of teaching students with visual impairments (SVIs). *Asian Journal of Research in Social Sciences & Humanities, 3*(3), 125-140.

Americans with Disabilities Act: Questions and Answers. (2001, February). *U.S. Equal Employment Opportunity Commission, U.S. Department of Justice, Civil Rights Division*. Retrieved from http://www.ada.gov/qandaeng.htm

An Act, Public Law 108-364, 108th Congress. (2004). *United States Government Printing Office*. Retrieved from https://www.gpo.gov/fdsys/pkg/PLAW-108publ364/html/PLAW-108publ364.htm

Annis, T. (2011, July). Seeing the possibilities: An analysis of STEM resources available for people with vision loss. *AFB AccessWorld® Magazine, 12*(7). Retrieved from http://www.afb.org/afbpress/pub.asp?DocID=aw120702

Ashworth, M., Bloxham, S., & Pearce, L. (2010). Examining the tension between academic standards and inclusion for disabled students: The impact on marking of individual academics' frameworks for assessment. *Studies in Higher Education, 35*(2), 209-223.

Assistive Technology Act of 1998. (1998). *Section508.gov: Opening Doors to IT*. Retrieved from http://www.section508.gov/assistive-technology-act-1998

AT in Education. (2008). *Assistive Technology Partnership*. Retrieved from http://www.atp.ne.gov/techassist/def-legal.html

Auxiliary Aids and Services for Postsecondary Students With Disabilities. (2011, November 16). *U.S. Department of Education*. Retrieved from http://www2.ed.gov/about/offices/list/ocr/docs/auxaids.html

Axelson, R. D., & Flick, A. (2011). Defining student engagement. *Change: The Magazine of Higher Learning, 43*(1), 38-43.

Bacti-Cinerator®. (2015). *VWR: We Enable Science*. Retrieved 7/7/15 from https://us.vwr.com/store/catalog/product.jsp?product_id=4791978

Bakker, A. B., Vergel, A. I. S., & Kuntze, J. (2015). Student engagement and performance: A weekly diary study on the role of openness. *Motivation and Emotion, 39*, 49-62. doi: 10.1007/s11031-014-9422-5

Barbosa, R., Jófili, Z., & Watts, M. (2004). Cooperating in constructing knowledge: Case studies from chemistry and citizenship. *International Journal of Science Education, 26*(8), 935-949. doi: 10.1080/0950069032000138842

Barnes, J., & Libertini, J. (2013). Introduction to special issue on tactile learning activities. *PRIMUS, 23*(7), 585-589. doi: 10.1080/10511970.2013.813879

Basham, J. D., & Marino, M. T. (2013). Understanding STEM education and supporting students through universal design for learning. *TEACHING Exceptional Children, 45*(4), 8-15.

Baumstark, B., Shanholtzer, S., Michelich, V. (2001, September). Georgia State University - Georgia Perimeter College proposed standards for a non-majors biology course. *Quality in Undergraduate Education*. Retrieved from http://www2.gsu.edu/~wwwque/standards/biology/biologynonmajors.html

Beck-Winchatz, B., & Riccobono, M. A. (2008). Advancing participation of blind students in science, technology, engineering, and math. *Advances in Space Research, 42*, 1855-1858. doi:10.1016/j.asr.2007.05.080

Biology. (n.d.). *Rowan College at Burlington County*. Retrieved from http://www.bcc.edu/files/PDFFiles/CrsOutlines/BIO%20PDF/BIO104.pdf

Bland, M. W. (2004). *The effects of student-produced renderings on achievement in introductory biology* (Doctoral dissertation). Retrieved from UMI Microform. (3130522)

blind. (2016). *The American Heritage® dictionary of the English Language*. Retrieved September 27, 2015 from https://ahdictionary.com/word/search.html?q=blind

Blindness and Vision Impairment. (2011, February 8). *Centers for Disease Control and Prevention*. Retrieved from http://www.cdc.gov/healthcommunication/toolstemplates/entertainmented/tips/blindness.html

Blindness Statistics: Statistical Facts about Blindness in the United States. (2015, September). *National Federation of the Blind*. Retrieved from https://nfb.org/blindness-statistics

Booksh, K., Century, J., Gallagher, J., Mateo, J., & Pagano, T. (2014). On the sustainability of programs for students with disabilities: Observations and practical ideas. In B. S. Duerstock and C. A. Shingledecker, (Eds.), *From College to Careers: Fostering Inclusion of Persons with Disabilities in STEM* (pp. 61-71). Science/AAAS, Washington, DC. doi: 10.1126/science.opms.sb0002

Boyd-Kimball, D. (2012). Adaptive instructional aids for teaching a blind student in a nonmajors college chemistry course. *Journal of Chemical Education, 89*, 1395-1399. doi:10.1021/ed1000153

Brand, D. (2005, January 21). Blind engineering student 'reads' color-scaled weather maps using Cornell software that converts color into sound. *Cornell Chronicle*. Retrieved from http://www.news.cornell.edu/stories/2005/01/blind-engineering-student-reads-color-sound

Brandt, S. (2011). From policy to practice in higher education: The experiences of disabled students in Norway. *International Journal of Disability, Development and Education, 58*(2), 107-120. doi: 10.1080/1034912X.2011.570494

Briefing Paper: Reauthorization of the Higher Education Act (HEA): The Implications for Increasing the Employment of People with Disabilities. (2015, May 19). *National Council on Disability*. Retrieved from https://www.ncd.gov/publications/2015/05192015

Briggs, S. (2013). 10 emerging educational technologies & how they are being used across the globe. *Innovation Excellence*. Retrieved 7/17/15 from http://www.innovationexcellence.com/blog/2013/07/29/10-emerging-educational-technologies-how-they-are-being-used-across-the-globe/

Brocklesby, K., Smith, R., & Sharp, D. (2012). An interdisciplinary experiment: Azo-dye metabolism by *Staphylococcus aureus*. *Journal of Biological Education*, *46*(4), 247-251. doi: 10.1080/00219266.2012.702677

Burgstahler, S. (2012). Making science labs accessible to students with disabilities. *University of Washington, College of Engineering*. Retrieved from http://www.washington.edu/doit/making-science-labs-accessible-students-disabilities

Butler, C., Bello, J., York, A., Orvis, K., & Pittendrigh, B. R. (2008). Genomics analogy model for educators (GAME): Fuzzy DNA model to enable the learning of gene sequencing by visually-impaired and blind students. *The Science Education Review, 7*(2), 52:1-9.

Byrd, T. D. M. (2010). *East Tennessee State University faculty attitudes and student perceptions in providing accommodations to students with disabilities* (Doctoral dissertation). Retrieved from ProQuest Dissertations and Theses. (3424341)

Caldwell, J. E., & Teagarden, K. (2007). Adapting laboratory curricula for visually-impaired students. *Proceedings of the 28th Workshop/Conference of the Association for Biology Laboratory Education (ABLE), 28*, 357-361.

Callahan, M. (2011, September 25). Leading the way: Freshman Patrick Molloy is Muhlenberg College's first blind student since the 1970s. *Morning Call, Tribune Publishing Company*. Retrieved from http://articles.mcall.com/2011-09-24/news/mc---muhlenberg---blind---molloy-20110924_1_blind-student-chris-danielsen-blind-schools

Category Archives: National Federation of the Blind. (2013, August 27). Accessibility Lawsuits, Complaints, and Settlements. *Temple University*. Retrieved 8/27/13 from https://sites.temple.edu/a11ylawsuits/category/nfb/

Censer, J. (2004, January 19). University buildings present difficulties for disabled. *The Daily Princetonian*. Retrieved from http://dailyprincetonian.com/news/2004/01/university-buildings-present-difficulties-for-disabled/

CEOSE: Committee on Equal Opportunities in Science and Engineering. (2013, July). *2011-2012 Biennial Report to Congress, National Science Foundation*. Retrieved from http://www.nsf.gov/od/iia/activities/ceose/reports/Full_2011-2012_CEOSE_Report_to_Congress_Final_01-28-2014.pdf

Cherif, A. H., Adams, G. E., Movahedzadeh, F., Martyn, M. A., & Dunning, J. (2014). Why do students fail? Faculty's perspective. *Higher Learning Commission: Annual Conference,* *2014 Collection of Papers*. Retrieved from http://cop.hlcommission.org/Learning-Environments/cherif.html

Childers, G., Watson, K., Jones, M. G., Williamson, K., & Hoette, V. (2015). Touching the stars: Making astronomy accessible for students with visual impairments. *Science Scope, 38*(9), 20-26.

Christensen, L. L., Thurlow, M. L., & Wang, T. (2009). *Improving accommodations outcomes: Monitoring instructional and assessment accommodations for students with disabilities*. Minneapolis, MN: University of Minnesota, National Center on Educational Outcomes.

Christenson, J. (2011, November 13). Ramaley coined STEM term now used nationwide. *Winona Daily News.com*. Retrieved 7/17/15 from http://www.winonadailynews.com/news/local/ramaley-coined-stem-term-now-used-nationwide/article_457afe3e-0db3-11e1-abe0-001cc4c03286.html

Color blindness. (2015, May 11). *MedlinePlus: NIH, U.S. National Library of Medicine*. Retrieved from https://www.nlm.nih.gov/medlineplus/ency/article/001002.htm

Creswell, J. W. (2012). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (4th ed.). Boston, MA: Pearson Education.

Creswell, J. W., & Plano Clark, V. L. (2011). *Designing and conducting mixed methods research* (2nd ed.). Los Angeles, CA: SAGE Publications, Inc.

Dandona, L., & Dandona, R. (2006). Revision of visual impairment definitions in the international statistical classification of diseases. *BMC Medicine*, 1-7. doi:10.1186/1741-7015-4-7

Danielsen, C. (2010, November 12). Penn State discriminates against blind students and faculty: National Federation of the Blind files complaint against Penn State. *National Federation of the Blind*. Retrieved July 30, 2014 from https://nfb.org/node/1026

Danielson, C. (2015, June 1). ACCC to make technology accessible to blind students and take other measures to address alleged discrimination. *National Federation of the Blind*. Retrieved 7/17/15 from https://nfb.org/national-federation-blind-and-two-blind-students-resolve-complaint-against-atlantic-cape-community

de Souza, R., Delou, C. M. C., Côrtes, M. B. V., Mazza-Guimarães, I., Machado, S., Rodrigues, C. R., & Castro, H. C. (2012). Blindness and fungi kingdom: A new approach for teaching biological theme for students with special visual needs. *Creative Education, 3*(5), 674-678. doi: 10.4236/ce.2012.35100

Dell, A. (2010, January 20). Transition: There are no IEP's in college. *The College of New Jersey*. Retrieved from http://www.tcnj.edu/~technj/2004/transition.htm

Derra, S. (2015, May 8). Blind STEM student helps others learn in 3-D. *ASU News [Science & Tech], Arizona State University*. Retrieved 7/6/15 from https://asunews.asu.edu/20150508-stem-blind-student-tactile-boards

DiBartolomeis, S. M. (2011). Semester-long project for teaching basic techniques in molecular biology such as restriction fragment length polymorphism analysis to undergraduate and graduate students. *CBE—Life Sciences Education, 10*, 95-110. doi: 10.1187/cbe.10-07-0098

Di Trapani, G., & Clarke, F. (2012) Biotechniques laboratory: An enabling course in the biological sciences. *The International Union of Biochemistry and Molecular Biology, 40*(1), 29-36. doi: 10.1002/bmb.20573

Dill, D. D., & Beerkens, M. (2013). Designing the framework conditions for assuring academic standards: Lessons learned about professional, market, and government regulation of academic quality. *Higher Education: The International Journal of Higher Education and Educational Planning, 65*(3), 341-357. doi: 10.1007/s10734-012-9548-x

Dillman, D. A., Smyth, J. D., & Christian, L. M. (2014). *Internet, phone, mail, and mixed-mode surveys: The tailored design method* (4th ed.). Hoboken, NJ: John Wiley & Sons, Inc.

Dirkx, J. M. (1998). Transformative learning theory in the practice of adult education: An overview. *PAACE Journal of Lifelong Learning, 7*, 1-14.

Disability Statistics: Online Resource for U.S. Disability Statistics. (2013). *Cornell University*. Retrieved from http://www.disabilitystatistics.org/reports/acs.cfm?statistic=2

DO-IT: Disabilities, Opportunities, Internetworking, and Technology. (2016). *University of Washington*. Retrieved from http://www.washington.edu/doit/

Drosophila Oogenesis. (n.d.). *The Berg Lab*. Retrieved from http://depts.washington.edu/cberglab/wordpress/outreach/an-introduction-to-fruit-flies/

Duerstock, B. (2015). Inclusion of students with disabilities in the lab. *American Physiological Society*. Retrieved from http://www.the-aps.org/forum-disabilities

Duerstock, B. S., Hilliard, L., McDonagh, D., Thomas, J., Cooper, R., Goldberg, . . . Border, J. (2014). Technologies to facilitate the active participation and independence of persons with disabilities in STEM from college to careers. In B. S. Duerstock & C. A. Shingledecker, (Eds.), *From College to Careers: Fostering Inclusion of Persons with Disabilities in STEM* (pp. 5-30). Science/AAAS, Washington, DC.

Duffy, M. (2013, August 5). Google glass applications for blind and visually impaired users. *Vision Aware: Resources for Independent Living with Vision Loss*. Retrieved 7/7/15 from http://www.visionaware.org/blog/visionaware-blog/google-glass-applications-for-blind-and-visually-impaired-users/12

Duquaine-Watson, J. M. (2003). Computing technologies, the digital divide, and "universal" instructional methods. In J. L. Higbee (Ed.), *Curriculum transformation and disability: Implementing universal design in higher education* (pp. 437-449). Minneapolis: University of Minnesota, General Center for Research on Developmental Education and Urban Literacy. Retrieved from http://www.cehd.umn.edu/CRDEUL/books-ctad.html

Duranczyk, I. M., & Fayon, A. K. (2008). Successful undergraduate mathematics through universal design of essential course components, pedagogy, and assessment. In J. L. Higbee & E. Goff (Eds.), *Pedagogy and student services for institutional transformation: Implementing universal design in higher education* (pp. 137-154). Minneapolis, MN: Regents of the University of Minnesota.

Duranczyk, I. M., Myers, K. A., Couillard, E. K., Schoen, S., & Higbee, J. L. (2013). Enacting the spirit of the United Nations convention on the rights of persons with disabilities: The role of postsecondary faculty in ensuring access. *Journal of Diversity Management, 8*(2), 63-72.

EvaluATE. (2015). *The E C Evaluation Center, National Science Foundation*. Retrieved 10/1/15 from http://www.evalu-ate.org/

Example Policies in Higher Education. (2015). Accessible Technology. *University of Washington*. Retrieved 7/17/15 from http://www.washington.edu/accessibility/requirements/example-policies/

Facts About Color Blindness. (2015). *NIH: National Eye Institute*. Retrieved from https://nei.nih.gov/health/color_blindness/facts_about

Fenrich, P. (2014). *Practical principles of instructional design, media selection, and interface design with a focus on computer-based training/educational software*. Santa Rosa, CA: Informing Science Press.

Fitch, G. K. (2007). A rubric for assessing a student's ability to use the light microscope. *The American Biology Teacher, 69*(4), 211-214.

Fitzpatrick, D. (2011, November 3). I have a blind student in my maths/science class, should I panic? [Video file]. Retrieved from https://www.youtube.com/watch?v=GJNj8vHI2zs

Fox, S., & Rainie, L. (2014, February 27). The Web at 25 in the U.S. *Pew Research Center*. Retrieved from http://www.pewinternet.org/2014/02/27/the-web-at-25-in-the-u-s/

Fraser, W. J., & Maguvhe, M. O. (2008). Teaching life sciences to blind and visually impaired learners. *Educational Research*, *42*(2), 84-89. doi: 10.1080/00219266.2008.9656116

Frechtling, J., Sharp, L., Westat. (Eds.). (1997). User-friendly handbook for mixed method evaluations. *Directorate for Education and Human Resources*. Retrieved from http://www.nsf.gov/pubs/1997/nsf97153/chap_1.htm

Frederickson, N. (2010). Bullying or befriending? Children's responses to classmates with special needs. *British Journal of Special Education, 37*(1), 4-12.

Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School engagement: Potential of the concept, state of the evidence. *Review of Educational Research, 74*(1), 59-109.

Fryrear, A. (2015, July 27). Survey response rates. *Surveygizmo*. Retrieved from https://www.surveygizmo.com/survey-blog/survey-response-rates/

Gaudet, A. D., Ramer, L. M., Nakonechny, J., Cragg, J. J., & Ramer, M. S. (2010). Small-group learning in an upper-level university biology class enhances academic performance and student attitudes toward group work. *PLoS ONE, 5*(12): e15821, 1-10. doi: 10.1371/journal.pone.0015821

Gibson, R. (1999). Paulo Freire and pedagogy for social justice. *Theory and Research in Social Education.* Retrieved from http://richgibson.com/freireTRSSE.htm

Goff, E., & Higbee, J. L. (2008). Introduction. In J. L. Higbee & E. Goff (Eds.), *Pedagogy and student services for institutional transformation: Implementing universal design in higher education* (pp. 1-8). Minneapolis, MN: Regents of the University of Minnesota.

Gormally, C., Brickman, P., Hallar, B., Armstrong, N. (2011). Lessons learned about implementing an inquiry-based curriculum in a college biology laboratory classroom. *Journal of College Science Teaching, 40*(3), 45-51.

Goubeaud, K. (2010). How is science learning assessed at the postsecondary level? Assessment and grading practices in college biology, chemistry and physics. *Journal of Science Education and Technology, 19*(3), 237-245. doi: 10.1007/sl0956-009-9196

Grasgreen, A. (2013, July 26). Audiobooks aren't enough. *Inside Higher Education*. Retrieved from http://www.insidehighered.com/news/2013/07/26/settlements-put-colleges-duty-ensure-blind-students-access-materials-under-new#sthash.BNKOFLje.dpbs

GreenGar Studios. (2015). Color Identifier. *iTunes Preview, Apple, Inc*. Retrieved 7/18/15 from https://itunes.apple.com/us/app/color-identifier/id363346987?mt=8

Hackman, H. W. (2008). Broadening the pathway to academic success: The critical intersections of social justice education, critical multicultural education, and universal instructional design. In J. L. Higbee and E. Goff (Eds.), *Pedagogy and student services for institutional transformation: Implementing universal design in higher education* (pp. 25-48). Minneapolis, MN: Regents of the University of Minnesota.

Harris, K-L., Krause, K., Gleeson, D., Peat, M., Taylor, C., & Garnett, R. (2007). *Enhancing Assessment in the Biological Sciences: Ideas and resources for university educators*. Retrieved from http://www.bioassess.edu.au/assessment-types/practical-assessment

Harshman, J., Bretz, S. L., & Yezierski, E. (2013). Seeing chemistry through the eyes of the blind: A case study examining multiple gas law representations. *Journal of Chemical Education, 90*, 710-716. doi: 10.1021/ed3005903

Held, D. (1980). *Introduction to critical theory: Horkheimer to Habermas*. Berkeley, CA: University of California Press.

Helmus, A. (n.d.). Disability resource center. *University of North Carolina Wilmington*. Retrieved 7/18/15 from http://uncw.edu/disability/about/

Henry, S. H. (2005). Introduction to web accessibility. *W3C Web Accessibility Initiative*. Retrieved from https://www.w3.org/WAI/intro/accessibility.php

Heyborne, W. H., Clarke, J. A., & Perrett, J. J. (2011). A comparison of two forms of assessment in an introductory biology laboratory course. *Journal of College Science Teaching, 40*(5), 28-31.

Higbee, J. L., Chung, C. J., & Hsu, L. (2008). Enhancing the inclusiveness of first-year courses through universal instructional design. In J. L. Higbee & E. Goff (Eds.), *Pedagogy and student services for institutional transformation: Implementing universal design in higher education* (pp. 61-77). Minneapolis, MN: Regents of the University of Minnesota.

Higbee, J. L., & Eaton, S. B. (2008). Implementing universal design in learning centers. In J. L. Higbee & E. Goff (Eds.), *Pedagogy and student services for institutional transformation: Implementing universal design in higher education* (pp. 217-224). Minneapolis, MN: Regents of the University of Minnesota.

Higher Education and Disability: Education Needs a Coordinated Approach to Improve Its Assistance to Schools in Supporting Students. (2009). *GAO U.S. Government Accountability Office: GAO-10-33*. Retrieved from http://gao.gov/products/GAO-10-33

Horvath, L. S., Kampfer-Bohach, S., & Kearns, J. F. (2005). The use of accommodations among students with deafblindness in large-scale assessment systems. *Journal of Disability Policy Studies, 16*(3), 177-187.

How Are the Terms Low Vision, Visually Impaired and Blind Defined? (2015, August 24). *Disabilities, Opportunities, Internetworking, and Technology*. Retrieved 9/17/15 from http://www.washington.edu/doit/how-are-terms-low-vision-visually-impaired-and-blind-defined

How Blind People Use the Web. (2016). *WebAIM*. Retrieved from http://webaim.org/articles/visual/blind

How the Americans with Disabilities Act Might Affect Your College Student. (2015). *College Parents of America*. Retrieved 7/17/15 from http://www.collegeparents.org/members/resources/articles/how-americans-disabilities-act-might-affect-your-college-student

Hughes, I., & Overton, T. (2008). Key aspects of learning and teaching in experimental sciences. In H. Fry, S. Ketteridge, & S. Marshall (Eds.), *A handbook for teaching and learning in higher education: Enhancing academic practice* (3rd ed.). (pp. 226-245). New York, NY: Routledge.

Hunt, L., Koenders, A., & Gynnild, V. (2012). Assessing practical laboratory skills in undergraduate molecular biology courses. *Assessment & Evaluation in Higher Education, 37*(7), 861-874. doi: 10.1080/02602938.2011.576313

Hutson, S. (2009). Breakthroughs within reach. *Nature Medicine, 15*(5), 476-479.

Identification of Bacteria from a Mixed Culture. (2014). *Instructions*. Retrieved from http://web.clark.edu/rrausch/biolabs/260/Unknowns260_Instructions_Su14.pdf

Independence Science. (2012, June 5). *How to prepare a student with visual impairments for safe access to the science laboratory* [Video file]. Retrieved from https://www.youtube.com/watch?v=6_PuCJjmYWc

Jernigan, K. (2005). A definition of blindness. *National Federation of the Blind*. Retrieved 12/13/14 from https://nfb.org/images/nfb/publications/fr/fr19/fr05si03.htm

Johnson, A. D. (2009). *Inquiry exercises for the college biology lab*. Arlington, VA: NSTA Press. Retrieved from http://www.nsta.org/docs/pb232xweb.pdf

Johnson, D. M., & Fox, J. A. (2003). Creating curb cuts in the classroom: Adapting Universal Design principles to education. In J. L. Higbee (Ed.), *Curriculum transformation and disability: Implementing universal design in higher education* (pp. 7-21). Minneapolis: University of Minnesota, General Center for Research on Developmental Education and Urban Literacy. Retrieved from http://www.cehd.umn.edu/CRDEUL/books-ctad.html

Johnson, D. W., Johnson, R. T., & Smith, K. A. (1998). Cooperative learning returns to college. *Change, 30*(4), 26-35.

Johnson, K. (2012, September). Student accommodations: What is reasonable? *Graduate Management Admission Council*. Retrieved from http://www.gmac.com/why-gmac/gmac-news/gmnews/2012/september-2012/student-accommodations-what-is-reasonable.aspx

Johnson, R., & Onwuegbuzie, A. J. (2004). Mixed methods research: A research paradigm whose time has come. *Educational Researcher, 33*(7), 14-26.

Jones, M. G., Childers, G., Emig, B., Chevrier, J., Tan, H., Stevens, V., & List, J. (2014). The efficacy of haptic simulations to teach students with visual impairments about temperature and pressure. *Journal of Visual Impairment & Blindness, 108*(1), 55-61.

Jones, M. G., Minogue, J., Oppewal, T., Cook, M. P., & Broadwell, B. (2006). Visualizing without vision at the microscale: Students with visual impairments explore cells with touch. *Journal of Science Education and Technology*, *15*(5), p. 345-351. doi: 10.1007/s10956-006-9022-6

Judith Ramaley. (2015). *Portland State University: College of Urban & Public Affairs: Hatfield School of Government*. Retrieved 7/19/15 from https://www.pdx.edu/hatfieldschool/judith-ramaley

Kioko, V. K., & Makoelle, T. M. (2014). Inclusion in higher education: Learning experiences of disabled students at Winchester University. *International Education Studies, 7*(6), 106-116. doi: 10.5539/ies.v7n6p106

Krist, A. C., & Showsh, S. A. (2007). Experimental evolution of antibiotic resistance in bacteria. *The American Biology Teacher, 69*(2), 94-97.

Laboratory Teaching Guidelines. (n.d.). *Stanford University*. Retrieved from https://teachingcommons.stanford.edu/resources/teaching-resources/teaching-strategies/laboratory-teaching-guidelines

Lahav, O., & Mioduser, D. (2004). Exploration of unknown spaces by people who are blind using a multi-sensory virtual environment. *Journal of Special Education Technology, 19*(3), 15-23.

Lapsley, D. K., Rice, K. G., & Fitzgerald, D. P. (1990). Adolescent attachment, identity, and adjustment to college: Implications for the continuity of adaptation hypothesis. *Journal of Counseling and Development, 68*(5).

Lartec, J. K., & Espique, F. P. (2012). Communication strategies of teachers educating students who are legally blind in the general education setting. *Insight: Research and Practice in Visual Impairment and Blindness, 5*(2), 70-82.

Lazar, J., & Jaeger, P. (2011). Reducing barriers to online access for people with disabilities. *Issues in Science and Technology, 27*(2), 69-82.

Leander, S. (2012, August 21). Blind student presents 3-D tactile images to national microscopy conference. *Arizona State University*. Retrieved from https://asunews.asu.edu/20120821_stem_3dproject

Ledbetter, M. L. S. (Ed.). (1992). Exercises in cell biology for the undergraduate laboratory: A project of the American Society for Cell Biology Education Committee, 1992. *American Society for Cell Biology*. Retrieved from http://www.ascb.org/newsfiles/exercises_cell_bio.pdf

Leddy, M. H. (2010). Technology to advance high school and undergraduate students with disabilities in science, technology, engineering, and mathematics. *Journal of Special Education Technology, 25*(3), 3-8.

Lee, B. A. (2014). Students with disabilities: Opportunities and challenges for colleges and universities. *Change: The Magazine of Higher Learning, 46*(1), 40-45.

Leuchovius, D. (2015). ADA Q&A...The ADA, Section 504 & postsecondary education. *Pacer Center Action Information Sheets: Champions for Children with Disabilities*. Retrieved 7/18/15 from http://www.pacer.org/publications/adaqa/504.asp

Luckie, D. B., Rivkin, A. M., Aubry, J. R., Marengo, B. J., Creech, L. R., & Sweeder, R. D. (2013). Verbal final exam in introductory biology yields gains in student content knowledge and longitudinal performance. *CBE - Life Sciences Education, 12*, 515-529.

Mansoor, A., Ahmed, W. M., Samarapungavan, A., Cirillo, J., Schwarte, D., Robinson, J. P., & Duerstock, B. S. (2010). AccessScope project: Accessible light microscope for users with upper limb mobility or visual impairments. *Disability and Rehabilitation: Assistive Technology, 5*(2), 143-152. doi: 10.3109/17483100903387630

Marson, S. M., Harrington, C. F., & Walls, A. (2012). Teaching introductory statistics to blind students. *Teaching Statistics Trust, 35*(1), 21-25.

Mastropieri, M. A., & Scruggs, T. E. (1992). Science for students with disabilities. *Review of Educational Research*, *62*(4), 377-411.

Mathewson, J. H. (2005). The visual core of science: Definition and applications to education. *International Journal of Science Education*, *27*(5), 529-548. doi: 10.1080/09500690500060417.

Mayo, P. M. (2007). Critical theory. In G. M. Bodner & M. Orgill (Eds.), *Theoretical frameworks for research in chemistry/science education* (pp. 243-261). Upper Saddle River, NJ: Pearson Education, Inc.

Mazrui, J. (2012, August 30). FCC holds 2-day workshop to advance accessible technology development. *Official FCC Blog*. Retrieved 7/26/15 from https://www.fcc.gov/blog/fcc-holds-2-day-workshop-advance-accessible-technology-development

Mertens, D. M. (2007). Transformative considerations: Inclusion and social justice. *American Journal of Evaluation*, *28*(1), 86-90. doi: 10.1177/1098214006298058

Metz, A. M. (2008). Teaching statistics in biology: Using inquiry-based learning to strengthen understanding of statistical analysis in biology laboratory courses. *CBE—Life Sciences Education, 7*, 317-326.

Meyer, A. H. (2008). *The attitudes of college students without disabilities toward college students with disabilities with respect to the academic accommodation process* (Doctoral dissertation). Retrieved from ProQuest Central. (3324190)

Mezirow, J. (1991). *Transformative dimensions of adult learning.* San Francisco, CA: Jossey-Bass Inc.

Mezirow, J. (1997). Transformative learning: Theory to practice. *New Directions For Adult And Continuing Education, 74*, 5-12.

Miecznikowski, J. R., Guberman-Pfeffer, M. J., Butrick, E. E., Colangelo, J. A., & Donaruma, C. E. (2015). Adapting advanced inorganic chemistry lecture and laboratory instruction for a legally blind student. *Journal of Chemical Education. ASAP*. doi: 10.1021/ed500489c

Miller, J. S., & Naples, V. L. (2002). Forensic entomology for the laboratory-based biology classroom. *The American Biology Teacher, 64*(2), 136-142.

Milligan, N. V. (2010). Effects of training about academic accommodations on perceptions and intentions of health science faculty. *Journal of Allied Health, 39*(1), 54-61.

Miner, D. L., Nieman, R., Swanson, A. B., & Woods, M. (Eds.). (2001). Teaching chemistry to students with disabilities: A manual for high schools, colleges, and graduate programs (4th ed.). *The American Chemical Society Committee on Chemists With Disabilities, The American Chemical Society*.

Minogue, J., & Jones, M. G. (2006). Haptics in education: Exploring an untapped sensory modality. *Review of Educational Research, 76*(3), 317-348.

Model Request. (n.d.). *librarylyna*. Retrieved 7/18/15 from http://www.librarylyna.com/

Moon, N. W., Todd, R. L., Morton, D. L., & Ivey, E. (2012). *Accommodating students with disabilities in science, technology, engineering, and mathematics (STEM): Findings from research and practice for middle grades through university education*. Atlanta, GA: SciTrain: Science and Math for All sponsored by the National Science Foundation under Award No. 0622885.

Myers, K. A., Wood, J. N., & Pousson M. (2008). Universal instructional design and professional development for public school teachers. In J. L. Higbee & E. Goff (Eds.), *Pedagogy and student services for institutional transformation: Implementing universal design in higher education* (pp. 349-363). Minneapolis, MN: Regents of the University of Minnesota.

National Science Board, National Science Foundation. (2010, May 5). *Preparing the next generation of STEM innovators: Identifying and developing our nation's human capital*. Retrieved November 19, 2015 from https://www.nsf.gov/nsb/publications/2010/nsb1033.pdf

National Science Foundation, National Center for Science and Engineering Statistics. (2015). *Women, minorities, and persons with disabilities in science and engineering: 2015. Special Report NSF 15-311. Arlington, VA*. Retrieved from http://www.nsf.gov/statistics/2015/nsf15311/digest/nsf15311-digest.pdf

Neuroscience Comes Alive in the Lab. (2010). *Howard Hughes Medical Institute*. Retrieved from http://www.hhmi.org/news/neuroscience-comes-alive-lab

Nielsen, L. (2011, September 5). 25 incredible assistive technologies. *Lisa Nielsen: The Innovative Educator*. Retrieved from http://theinnovativeeducator.blogspot.com/2011/09/25-incredible-assistive-technologies.html

Open Learning and Educational Support. (n.d.). Introduction to Universal Instructional Design (UID) at the University of Guelph. *Teaching Support Services*. Retrieved 7/18/15 from http://opened.uoguelph.ca/en/students/resources/uid-workbook-ftf.pdf

Overview. (2016). DO-IT: Disabilities, Opportunities, Internetworking, and Technology. *DO-IT, University of Washington*. Retrieved from http://www.washington.edu/doit/about/overview

Ozturk, M. A., & Debalak, C. (2005). Setting realistically high academic standards and expectations. *Essays in Education, 15*. Retrieved from https://www.researchgate.net/publication/251304339_Setting_Realistically_High_Academic_Standards_and_Expectations

Palmer, J., & Caputo, A. (2006). The universal instructional design implementation guide. *University of Guelph*. Retrieved from https://www.uoguelph.ca/tss/uid/uid-implementation-guide-v6.pdf

Pant, M. (2014). Blind student sues Miami University: Junior claims Miami violating federal law, which school denies. *Dayton Daily News*. Retrieved 1/18/2014 from http://www.daytondailynews.com/news/news/blind-student-sues-miami-university/ncmR6/

Parry, M. (2010, November 12). Penn State accused of discriminating against blind students. *The Chronicle of Higher Education*. Retrieved 1/18/2014 from http://chronicle.com/blogs/wiredcampus/penn-state-accused-of-discriminating-against-blind-students/28154

Patton, M. Q. (2002). *Qualitative research & evaluation methods* (3rd ed.). Thousand Oaks, CA: Sage Publications.

Pence, L. E., Workman, H. J., & Riecke, P. (2003). Effective laboratory experiences for students with disabilities: The role of a student laboratory assistant. *Journal of Chemical Education, 80*(3), 295-298.

People With a Disability Less Likely to Have Completed a Bachelor's Degree. (2015, July 20). *Bureau of Labor Statistics*. Retrieved from http://www.bls.gov/opub/ted/2015/people-with-a-disability-less-likely-to-have-completed-a-bachelors-degree.htm

Peytchev, A., & Hill, C. A. (2008). Experiments in mobile web survey design. *Section on Survey Research Methods - 2008 AAPOR. RTI International, NC.* Retrieved from http://www.amstat.org/sections/srms/proceedings/y2008/files/peytchev.pdf

Pham, D. Q.-D., Higgs, D. C., Statham, A., & Schleiter, M. K. (2008). Implementation and assessment of a molecular biology and bioinformatics undergraduate degree program. *Biochemistry and Molecular Biology Education, 36*(2), 106-115. doi: 10.1002/bmb.20155

Pliner, S. M., & Johnson, J. R. (2004). Historical, theoretical, and foundational principles of universal instructional design in higher education. *Equity & Excellence in Education, 37*, 105-113. doi: 10.1080/10665680490453913

Policy And Procedures Manual - Chapter 3 - Academic Affairs. (2016). *Oklahoma State Regents for Higher Education*. Retrieved from http://www.okhighered.org/state-system/policy-procedures/2016/Chapter%203-%20February%202016.pdf

Power, C., & Jürgensen, H. (2010). Accessible presentation of information for people with visual disabilities. *Universal Access in the Information Society, 9*(2), 97-119. doi: 10.1007/s10209-009-0164-1

Prerequisites, Corequisites and Recommended Preparation. (n.d.). *College of San Mateo*. Retrieved from http://collegeofsanmateo.edu/prerequisites/faqs.asp

Profile of Undergraduate Students: 2007-08. (2010, September). *U.S. Department of Education, NCES 2010-205*. Retrieved from http://nces.ed.gov/pubs2010/2010205.pdf

Profile of Undergraduate Students: 2011-12. (2014, October). *U.S. Department of Education, NCES 2015-167.* Retrieved from http://nces.ed.gov/pubs2015/2015167.pdf

Protecting Students With Disabilities. (2013). *U.S. Department of Education.* Retrieved from http://www2.ed.gov/about/offices/list/ocr/504faq.html

Radwin, D., Wine, J., Siegel, P., & Bryan, M. (2013). 2011-12 National postsecondary student aid study (NPSAS:12): Student financial aid estimates for 2011-12 (NCES 2013-165). *Institute of Education Sciences, U.S. Department of Education. Washington, DC: National Center for Education Statistics*. Retrieved from http://nces.ed.gov/pubs2013/2013165.pdf

Raue, K., & Lewis, L. (2011). Students with disabilities at degree-granting postsecondary institutions (NCES 2011-018). *U.S. Department of Education, National Center for Education Statistics*. Washington, DC: U.S. Government Printing Office.

Reasonable Accommodations Explained. (2016). *American Psychological Association*. Retrieved from http://www.apa.org/pi/disability/dart/toolkit-three.aspx

Reed, M., & Curtis, K. (2011). High school teachers' perspectives on supporting students with visual impairments toward higher education: Access, barriers, and success. *Journal of Visual Impairment & Blindness, 105*(9), 548-559.

Reed, M., & Curtis, K. (2012). Experiences of students with visual impairments in Canadian higher education. *Journal of Visual Impairment & Blindness, 106*(7), 414-425.

Reinschmiedt, H. J., Sprong, M. E., Dallas, B., Buono, F. D., & Upton, T. D. (2013). Post secondary students with disabilities receiving accommodations: A survey of satisfaction & subjective well-being. *Journal of Rehabilitation, 79*(3), 3-10.

Renninger, K. A., & Bachrach, J. E. (2015). Studying triggers for interest and engagement using observational methods. *Educational Psychologist, 50*(1), 58-69. doi: 10.1080/00461520.2014.999920

Research in Disabilities Education (RDE). (n.d.). *National Science Foundation*. Retrieved from https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5482

Richardson, J. T. E. (2009). The academic attainment of students with disabilities in UK higher education. *Studies in Higher Education, 34*(2), 123-137. doi: 10.1080/03075070802596996

Roberts, C. M. (2010). *The dissertation journey: A practical and comprehensive guide to planning, writing, and defending your dissertation* (2nd ed.). Thousand Oaks, CA: Corwin.

Role of Laboratory and Field Instruction in Biology Education. (2005). *National Association of Biology Teachers*. Retrieved from https://www.nabt.org/websites/institution/index.php?p=95

Ronsheim, M. L., Pregnall, A. M., Schwarz, J., Schlessman, M. A., & Raley-Susman, K. M. (2009). Teaching outside the can: A new approach to introductory biology. *Bioscene, 35*(1), 12-22.

Ross-Gordon, J. M. (2011). Research on adult learners: Supporting the needs of a student population that is no longer nontraditional. *Peer Review, 13*(1). Retrieved from https://www.aacu.org/publications-research/periodicals/research-adult-learners-supporting-needs-student-population-no

Rossman, J. (2014, August 30). Livescribe 3 smartpen takes note-taking up a level. *The Dallas Morning News*. Retrieved 7/18/15 from http://www.dallasnews.com/business/technology/headlines/20140830-livescribe-3-smart-pen-takes-note-taking-up-a-level.ece

Rule, A. (2011). Tactile earth and space science materials for students with visual impairments: Contours, craters, asteroids, and features of mars. *Journal of Geoscience Education, 59*(4), 205-218.

Ryan, G. W., & Bernard, H. R. (2003). Techniques to identify themes. *Field Methods, 15*(1), 85-109. doi: 10.1177/1525822X02239569

Sadler, D. R. (2009). Grade integrity and the representation of academic achievement. *Studies in Higher Education, 34*(7), 807-826. doi: 10.1080/03075070802706553

Sahyun, S. C. (2000). *A comparison of auditory and visual graphs for use in physics and mathematics*. (Doctoral dissertation). Retrieved from http://facstaff.uww.edu/sahyuns/phd/index.html

Sample Size calculator. (2012). *Creative Research Systems*. Retrieved from http://www.surveysystem.com/sscalc.htm

Scientific Inquiry. (2004). *National Science Teachers Association*. Retrieved from http://www.nsta.org/about/positions/inquiry.aspx

Scott, R. (2009). *Undergraduate educational experiences: The academic success of college students with blindness and visual impairments* (Doctoral dissertation). Retrieved from ProQuest dissertations & theses A&I. (3395269)

Screen Reader User Survey #6 Results. (2015, July). *WebAIM*. Retrieved from http://webaim.org/projects/screenreadersurvey6/

Scruggs, T. E., & Mastropieri, M. A. (2007). Science learning in special education: The case for constructed versus instructed learning. *Exceptionality*, *15*(2), 57-74. doi: 10.1080/09362830701294144

Section IV - Laboratory Biosafety Level Criteria of Biosafety in Microbiological and Biomedical Laboratories (BMBL) 5th Edition. (2015). *Centers for Disease Control and Prevention / Office of Safety, Health, and Environment*. Retrieved 6/22/15 from http://www.cdc.gov/biosafety/publications/bmbl5/index.htm

Section 300.8 Child with a Disability. (n.d.). *U.S. Department of Education*. Retrieved from http://idea.ed.gov/explore/view/p/,root,regs,300,A,300%252E8,

Sharpe, M. N., Johnson, D. R., Izzo, M., & Murray, A. (2005). An analysis of instructional accommodations and assistive technologies used by postsecondary graduates with disabilities. *Journal of Vocational Rehabilitation, 22*, 3-11.

Shields, C. (2010). Transformative leadership: Working for equity in diverse contexts. *Educational Administration Quarterly, 46*(4), 558-589. doi: 10.1177/001316

Silver, P., Bourke, A., & Strehorn, K. C. (1998). Universal instructional design in higher education: An approach for inclusion. *Equity & Excellence in Education, 31*(2), 47-51. doi: 10.1080/1066568980310206

Silverstone, B., Lang, M. A., Rosenthal, B. (Eds.). (2000). *The lighthouse handbook on vision impairment and vision rehabilitation* (Vols. 1-2). New York: Oxford University Press.

Sinatra, G. M., Heddy, B. C., & Lombardi, D. (2015). The challenges of defining and measuring student engagement in science. *Educational Psychologist, 50*(1), 1-13. doi: 10.1080/00461520.2014.1002924

Smith, D. W., & Amato, S. (2012). Synthesis of available accommodations for students with visual impairments on standardized assessments. *Journal of Visual Impairment & Blindness, 106*(5), 299-304.

Sniatecki, J. L., Perry, H. B., & Snell, L. H. (2015). Faculty attitudes and knowledge regarding college students with disabilities. *Journal of Postsecondary Education and Disability, 28*(3), 259-275.

Solovieva, T. I., & Bock, J. M. (2014). Monitoring for accessibility and university websites: Meeting the needs of people with disabilities. *Journal of Postsecondary Education and Disability, 27*(2), 113-127.

Spring, K. R., & Davidson, M. W. (2015). Fundamentals of digital imaging. *Nikon, Microscopy: The Source for Microscopy Education*. Retrieved from 7/17/15 https://microscopyu.com/articles/digitalimaging/digitalintro.html

STEM Education Data. (2014). *National Science Foundation*. Retrieved from http://www.nsf.gov/nsb/sei/edTool/explore.html

Stodden, R. A., Jones, M. A., & Chang, K. (2002). *Services, supports and accommodations for individuals with disabilities: An analysis across secondary education, postsecondary education, and employment*. Retrieved from http://www.ncset.hawaii.edu/publications/pdf/sercices_supports.pdf

Student Counseling Services. (2016). *Mississippi College*. Retrieved from https://www.mc.edu/offices/counseling/student-with-disabilities/

Student Guide to Transfer. (n.d.). *Maryland Higher Education Commission*. Retrieved from http://www.mhec.state.md.us/preparing/stuguide.asp#Maryland%27s

Students who are Blind or have a Visual Impairment. (2016). *Student Disability Services, Allegheny College*. Retrieved from http://sites.allegheny.edu/disabilityservices/students-who-are-blind-or-have-a-visual-impairment/

Sullivan, G., Miller, C., & Goad, C. (2016). Helping students with visual impairments: Resources, tools and technology to foster school success. *Accredited Schools Online.* Retrieved from www.accreditedschoolsonline.org/resources/helping-students-with-visual-impairments/

Summers, J. A., White, G. W., Zhang, E., & Gordon, J. M. (2014). Providing support to postsecondary students with disabilities to request accommodations: A framework for intervention. *Journal of Postsecondary Education and Disability, 27*(3), 245-260.

Sumner, T. (2014, March 6). Computer program allows the blind to 'see' with sound. *Science Magazine*. Retrieved from http://news.sciencemag.org/biology/2014/03/computer-program-allows-blind-see-sound

Supalo, C. A. (2010). *Teaching chemistry and other sciences to blind and low-vision students through hands-on learning experiences in high school science laboratories* (Doctoral dissertation). Retrieved from ProQuest Dissertations and Theses. (3442959)

Supalo, C. A. (2012). The next generation laboratory interface for students with blindness or low vision in the science laboratory. *Journal of Science Education for Students with Disabilities, 16*(1), 34-39. doi: 10.14448/jsesd.05.0004

Supalo, C. A. (2013). A historical perspective on the revolution of science education for students who are blind or visually impaired in the United States. *Journal of Science Education for Students with Disabilities, 17*(1), 1-4.

Supalo, C. A., Isaacson, M. D., & Lombardi, M. V. (2014). Making hands-on science learning accessible for students who are blind or have low vision. *Journal of Chemical Education, 91*, 195-199. doi: 10.1021/ed3000765

Supalo, C. A., Mallouk, T. E., Amorosi, C., Rankel, L., Wohlers, H. D., Roth, A., & Greenberg, A. (2007). Talking tools to assist students who are blind in laboratory courses. *Journal of Science Education for Students with Disabilities, 12*(1), 27-32. doi: 10.14448/jsesd.01.0003

Supalo, C. A., Wohlers, H. D., & Humphrey, J. R. (2011). Students with blindness explore chemistry at "Camp Can Do." *Journal of Science Education for Students with Disabilities, W15*(1), 1-9. doi: 10.14448/jsesd.04.0001

Supalo, C. A., Wohlers, H. D., & McEnnis, K. (2009). Using adaptive tools and techniques to teach a class of students who are blind or low-vision. *Journal of Chemical Education, 86*(5), 587-591.

SurveyMonkey and IRB Guidelines. (2015). *SurveyMonkey*. Retrieved from http://help.surveymonkey.com/articles/en_US/SurveyMonkeyArticleType/How-does-SurveyMonkey-adhere-to-IRB-guidelines

Suskie, L. (2010). Why are we assessing? Rethinking assessment's purposes. *Inside Higher Ed.* Retrieved from http://barnard.edu/sites/default/files/why-are-we-assessing-suskie-article.pdf

Swap, R. J., & Walter, J. A. (2015). An approach to engaging students in a large-enrollment, introductory STEM college course. *Journal of the Scholarship of Teaching and Learning, 15*(5), 1-21.

The Americans with Disabilities Act of 1990 and Revised ADA Regulations Implementing Title II and Title III. (n.d.). *ADA.gov, United States Department of Justice, Civil Rights Division*. Retrieved from http://www.ada.gov/2010_regs.htm

The Integral Role of Laboratory Investigations in Science Instruction. (2007). *National Science Teachers Association*. Retrieved from http://www.nsta.org/about/positions/laboratory.aspx

The Talking Color Detector. (2016). *MaxiAids.com*. Retrieved from http://www.maxiaids.com/the-talking-color-detector

Torres, C. A. (2008). Paulo Friere, education and transformative social justice learning. In *Actas IV Encontro do Forum Internacional Paulo Freire*. Proto, Setembro 2004.

Trautmann, N. M., Richard, T., Krasny, M. E., Cushing, P., Hyson, S., Northrup, R., . . . Poseluzny, B. (1996). *Cornell Composting: Composting in Schools*. Retrieved from http://compost.css.cornell.edu/plantgrowth.html

Tsinidou, M., Gerogiannis, V., & Fitsilis, P. (2010). Evaluation of the factors that determine quality in higher education: An empirical study. *Quality Assurance in Education, 18*(3), 227-244. doi: 10.1108/09684881011058669

Understanding Prerequisites and Corequisites. (2015). *Santa Barbara City College*. Retrieved from http://www.sbcc.edu/prerequisitepolicy/Understandingpreandcoreqs.php

Van Gerven, C. (2015). 3D printing tactile graphics 101. *National Federation of the Blind*. Retrieved 7/7/15 from https://nfb.org/blog/atblog/tactile-graphics-101

Vanderheiden, G. C. (1996, May 6). Universal design: What it is and what it isn't. *Trace R&D Center, University of Wisconsin-Madison*. Retrieved 7/17/15 from http://trace.wisc.edu/docs/whats_ud/whats_ud.htm

Vermeij, G. J. (n.d.). To sea with a blind scientist. *National Federation of the Blind*. Retrieved from https://nfb.org/images/nfb/publications/books/kernel1/kern0610.htm

Visual Disabilities. (2013, August 28). *WebAIM: Web accessibility in mind*. Retrieved from http://webaim.org/articles/visual/

Visual Impairments. (2016). *Science for Students with Disabilities. National Science Teachers Association*. Retrieved from http://www.nsta.org/disabilities/visual.aspx

Vittoria, P., Strollo, M. R., Brock, S., & Romano, A. (2014, March 10-12). Surveys as praxis: A pilot study on transformative learning assessment with the laboratory experience of the theatre of the oppressed. *Proceedings of INTED2014 Conference 10th-12th March 2014, Valencia Spain*. 6147-6157.

Vollmer, A. C. (2012, July 26). Seeing biology through the eyes of visually-impaired students. Odds & Ends, Teachers Corner: Pedagogical Issues. *American Society for Microbiology*.

Retrieved 11/14/2014 from http://schaechter.asmblog.org/schaechter/2012/07/seeing-biology-through-the-eyes-of-visually-impaired-students.html

Wang, V. (2015, February 24). Students in wheelchairs find campus inaccessible. *Yale News*. Retrieved from http://yaledailynews.com/blog/2015/02/24/wheelchair-accessibility-leaves-much-to-be-desired/

Washington State School for the Blind. (2012, August 17). *Science techniques for the blind: Learn how to safely conduct and analyze experiments* [Video file]. Retrieved from https://www.youtube.com/watch?list=PLF126DB019FC5C859&v=Ok-2l2myqzw

Webb, K. W., Patterson, K. B., Syverud, S. M., & Seabrooks-Blackmore, J. J. (2008). Evidenced based practices that promote transition to postsecondary education: Listening to a decade of expert voices. *Exceptionality: A Special Education Journal*, *16*, 192-206. doi: 10.1080/09362830802412182

Wedler, H. B., Boyes, L., Davis, R. L., Flynn, D., Franz, A., Hamann, C. S., … Wang, S. C. (2014). Nobody can see atoms: Science camps highlighting approaches for making chemistry accessible to blind and visually impaired students. *Journal of Chemical Education, 91*(2), 188–194. doi: 10.1021/ed300600p

Wedler, H. B., Cohen, S. R., Davis, R. L., Harrison, J. G., Siebert, M. R., Willenbring, D., . . . Tantillo, D. J. (2012). Applied computational chemistry for the blind and visually impaired. *Journal of Chemical Education, 89*(11), 1400-1404. doi: 10.1021/ed3000364

Wegwert, J. C. (2012). Grading and student learning: Ideas for practice. *Childhood Education, 88*(6), 413-414.

Wentz, B., Jaeger, P. T., & Lazar, J. (2011, October 19). Retrofitting accessibility: The legal inequality of after-the-fact online access for persons with disabilities in the United States.

First Monday, 16(11). Retrieved July 16, 2014 from http://journals.uic.edu/ojs/index.php/fm/article/view/3666/3077

We're Proud to Provide Section 508-Compliant Surveys. (2015). *SurveyMonkey*. Retrieved from https://www.surveymonkey.com/mp/508-website-accessibility/

Wild, T., & Allen, A. (2009). Policy analysis of science-based best practices for students with visual impairments. *Journal of Visual Impairment & Blindness, 103*(2), 113-117.

Wilson, M, & Scalise, K. (2006). Assessment to improve learning in higher education: The BEAR assessment system. *Higher Education*, *52*, 635-663. doi: 10.1007/s10734-004-7263-y

Winograd, M. D., & Rankel, L. A. (2007). Making science fair: Making science instruction and labs accessible for students who are blind or visually impaired. *RE: view*, *39*(3), 122-127.

Womble, M. D., & Walker, G. R. (2001). Teaching biology to the visually impaired: Accommodating students' special needs. *Journal of College Science Teaching, 30*(6), 394-396.

Wu, H.-K., Krajcik, J. S., & Soloway, E. (2001). Promoting understanding of chemical representations: Students' use of a visualization tool in the classroom. *Journal of Research in Science Teaching, 38*(7), 821-842.

APPENDIX A. STUDENT SURVEY

Online Survey for Students with BVI

Italics indicate information that will not be visible on the questionnaire. Page numbers indicate the information and/or questions that will appear at one time on the screen.

Consent for Participation in Research

Page 1

Project Title: Evaluating College Biology Laboratory Accommodations for Students with Blindness and Visual Impairments (BVI)

I am a doctoral student in the educational leadership program at the University of New England. My project involves studying the effectiveness of specific accommodations, such as tactile models and audible equipment, provided for students with blindness and visual impairments (BVI) in the college biology laboratory. Results of this study should provide important information about specific accommodations that will benefit future students with BVI in the college biology laboratory.

Please read the following information.

Your participation in this study is voluntary. To participate in this study, you must have self-disclosed to the Disability Support Services (DSS) office (or equivalent) of the institution at which you took the college biology course, and your disability must have been classified by the DSS office as a visual impairment. You must be at least 18 years of age. The biology course must have included a laboratory portion that met face-to-face. The course may have been taken at a two-year or a four-year institution of higher education, but must have been taken between 2010 and 2015. You must have earned a C or better in the course.

It is important to know the perceptions of students with BVI who have successfully completed a college biology course and the perceptions of the college biology instructors teaching students with BVI. Data for my research is being collected entirely through anonymous, online surveys. There is one survey for students with BVI and another for college biology instructors who have taught students with BVI. I hope to gather the perceptions of 100 students and 100 instructors.

The questions on this survey will ask you about your perceptions of the specific laboratory accommodations, such as tactile models and audible equipment, that were provided for you in a college biology course. You can respond to many of the questions by choosing a response from a list of choices, but some of the questions ask you to write about your experience. I would be especially appreciative if you would take the time to answer those questions. There are a few background questions at the beginning of the survey that you will be required to answer, because they provide information about your visual impairment and ensure you are eligible to participate in the study. However, you can skip or choose not to answer any of the other questions on the survey. The survey should take approximately 15-20 minutes of your time to complete. If you so choose, you will be given the opportunity to withdraw from the study after completing the survey.

The only known risk in participating in this study is that your identity could be revealed. It is not possible to guarantee your anonymity, but every effort will be taken to make sure that any information you provide will remain anonymous. SSL encryption is enabled so you will see "https:" in the URL. IP addresses will not be available to me, so I will not be able to trace your location. To maintain your anonymity, all data from this survey will be stored on a flash drive kept in a locked safe in my office, not a computer hard drive. Since the survey is designed to be anonymous, please do not include in your answers any information that may individually identify you, your classmates, your instructor, or the institution at which you took the biology course. Any information that you accidentally include will be removed. No identifying information will be included in any publications resulting from this study.

The Institutional Review Board (IRB) for the Protection of Human Subjects at the University of New England has reviewed the use of human subjects in this research. The IRB is responsible for protecting the rights and welfare of people involved in research.

I am the researcher conducting this study. For questions or more information concerning this research you may contact me, Barbara Heard, MS, MT(ASCP), at bheard@une.edu, or my faculty mentor, Brianna Parsons, Ed.D, at (207) 299-3627 or bparsons4@une.edu. If you have any questions or concerns about your rights as a research subject, you may call Olgun Guvench, M.D. Ph.D., Chair of the UNE Institutional Review Board, at (207) 221-4171 or irb@une.edu.

Because this study is for a student research project, your consent is necessary. You may print and keep a copy of this consent form. *The survey will include a Disqualification Page. Students answering "No" to particular questions (as indicated) would be directed to that page and not permitted to take the survey.*

1) By clicking Yes, I indicate that I understand the above description of the research and the risks and benefits associated with my participation as a research subject. I understand that by proceeding with this survey I agree to take part in this research and do so voluntarily. *There will be a button marked with the choice, Yes. Individuals choosing this option will proceed to page 2 of the survey.*
2) By clicking No, I indicate that I choose not to participate in this study. *There will be a button marked with the choice, No. Individuals choosing this option will be directed to*

the Disqualification Page.

Page 2

Questions marked with an asterisk (*) require an answer. *Questions 3, 5, 6, and 9 will be marked with an asterisk.* The "Next" and "Prev" buttons at the bottom of each page allow you to move to the next page of the survey, or to return to the previous page.

3) Are you at least 18 years old? Choose Yes or No. *Students must answer this question to continue, and those answering No will be directed to the Disqualification Page.*
4) Please choose the option that best describes the nature of your visual impairment at the time you took the college biology course. Answer choices are from a scale recommended by Dandona and Dandona (2006, p. 5). There are 11 answer options for this question. *Options will be: "*Mild visual impairment; moderate visual impairment; severe blindness; very severe blindness; total blindness; unspecified visual impairment; severe, very severe, or total blindness in one eye; moderate visual impairment in one eye; mild visual impairment in one eye; and unspecified impairment in one eye*" (Dandona & Dandona, 2006, p. 5). Also, an option of "*Other*" will appear, with a comment box. Students must answer this question to continue.*
5) Was your visual impairment confirmed by the Disability Support Services office (or equivalent) at the institution at which you took the college biology course? Choose Yes or No. *Students must answer this question to continue. Those answering No will be directed to the Disqualification Page.*
6) Did you take the college biology course sometime between 2010 and 2015? Choose Yes or No. *Students must answer this question to continue. Those answering No will be directed to the Disqualification Page.*

7) Please indicate whether you took the college biology course at a two-year or a four-year institution. Choices will include 2-year or 4-year. *Students must answer this question to continue.*

8) Please indicate the course name and course number of the college biology course you took. If you do not remember the exact name and number, try to describe the course by indicating the level and type of biology course, such as "100-level non-majors biology," 200-level majors biology," or "300-level microbiology." *Students must answer this question to continue.*

9) Was the laboratory portion of the course taken face-to-face or online? *Options for each will be offered. Students must answer this question to continue, and those answering "online" will be directed to the Disqualification Page.*

10) Did you earn a C or better in the course? Choose Yes or No. *Students must answer this question to continue. Data will be collected from those answering No, but will not be included in the study.*

The following reference appears at the bottom of the page:

References

Dandona, L., & Dandona, R. (2006). Revision of visual impairment definitions in the international statistical classification of diseases. BMC Medicine, 4:7. doi:10.1186/1741-7015-4-7

Page 3

The Likert scale on this page will be: Strongly agree, Agree, Neutral, Disagree, Strongly disagree, I choose not to answer this question.

"Active participation" means that you worked with the equipment and/or materials and helped to perform the experiments and/or use the equipment.

General accommodations can include extended time on tests, using screen readers, or having a note taker. Any questions asking about specific accommodations are not asking about those general accommodations. Accommodations specific to the biology laboratory refer only to those provided for you in addition to general accommodations. They would include modifications to equipment or exercises such as Braille-labeled beakers, tactile images, audible equipment, or projections of microscopic images.

Please indicate your level of agreement or disagreement with the following statements.

11) I was able to actively participate in all laboratory activities without any accommodations specific to the biology laboratory, such as tactile images or audible devices.
12) Specific accommodations, such as tactile images or audible devices, were necessary for me to actively participate in one or more laboratory activities.

Please read questions 12 and 13 before answering either question.

13) With specific accommodations, such as tactile images or audible devices, I was able to actively participate in all of the laboratory activities.
14) With specific accommodations, such as tactile images or audible devices, I was able to actively participate in most of the laboratory activities.
15) Even with specific accommodations, such as tactile images or audible devices, I was able to actively participate in only one or two of the laboratory activities.
16) Even with specific accommodations, I was not able to actively participate in any of the laboratory activities.
17) An aide, assistant, or other non-student of the class helped me with all exercises in the laboratory.

18) An aide, assistant, or other non-student of the class helped me with some of the exercises in the laboratory.

19) Please describe accommodations specific to the biology laboratory that were provided for you.

20) Please describe accommodations specific to the biology laboratory that were particularly helpful.

21) Please describe accommodations specific to the biology laboratory that were provided to you, but were not helpful.

22) Please describe activities in which you could not participate at all or in which you had difficulty participating, even with specific accommodations.

Page 4

The Likert scale for questions 23-27 will be: Strongly agree, Agree, Neutral, Disagree, Strongly disagree, I choose not to answer this question.

The Likert scale for questions 28-35 will be: Strongly agree, Agree, Neutral, Disagree, Strongly disagree, Not applicable, I choose not to answer this question.

The term "group' is used in the questions below to indicate working with at least one other person to complete and interpret the laboratory exercises. Please indicate your level of agreement or disagreement with the following statements.

23) I felt safe in the laboratory.

24) I contributed to the group as we completed laboratory activities.

25) I contributed to my group's understanding as we discussed the results of laboratory activities.

26) I was interested in the laboratory activities.

27) I was curious about the results we would obtain in the laboratory exercises.

28) I successfully found images using the microscope.

29) I successfully interpreted images under the microscope.

30) I assisted in animal dissection.

31) I was able to safely use a Bunsen burner and/or hot plate.

"Accurately" means that what you interpreted, performed, or produced was correct, according to the instructor.

32) I accurately determined the results of tests requiring color interpretation.

33) I accurately constructed graphs.

34) I accurately interpreted graphs.

35) I was able to accurately pipette, pour, and measure liquids.

Page 5

The Likert scale for questions 36-41 will be: Strongly agree, Agree, Neutral, Disagree, Strongly disagree, I choose not to answer this question.

Please indicate your level of agreement or disagreement with the following statements.

36) I took notes and recorded data without assistance.

37) Having an aide, assistant, or other non-student of the class would have helped me to be more successful in the laboratory portion of the class.

38) My classmates treated me the same as everyone else in the class.

39) I learned the laboratory concepts as well as my classmates.

40) I learned the laboratory skills as well as my classmates.

41) I believe that I learned as much as sighted students who received the same grade in the class.

Page 6

42) Please tell me about your experience in the college biology laboratory. Please do not include any identifying information about you, your instructor, classmates, or the institution at which you took the biology course. *This question includes a comment box.*

Page 7

You have completed the survey. Thank you so much for your time and for sharing your stories!

Please check only one of the boxes below. Click "Submit my survey responses" to complete the survey and record your answers. Click "Delete my survey responses" to withdraw from the study. Then, click the "Done" button to exit the survey.

Thanks again. I sure appreciate that you donated your valuable time to my study!

43) Yes, I want to submit my survey responses. "Submit my survey responses" *will be the option*.

44) No, I prefer to withdraw from the study at this time. I understand that by checking the box, my answers will be deleted. "Delete my survey responses" *will be the option*. *Those checking this box will be directed to the Disqualification Page.*

APPENDIX B. INSTRUCTOR SURVEY

Online Survey for Instructors

Italics indicate information that will not be visible on the questionnaire. Page numbers indicate the questions that will appear at one time on the screen.

Consent for Participation in Research

Page 1

Project Title: Evaluating College Biology Laboratory Accommodations for Students with Blindness and Visual Impairments (BVI)

I am a doctoral student in the educational leadership program at the University of New England. My project involves studying the effectiveness of specific accommodations, such as tactile models and audible equipment, provided for students with blindness and visual impairments (BVI) in the college biology laboratory. Results of this study should provide important information about specific accommodations that will benefit future students with BVI in the college biology laboratory.

Please read the following information.

Your participation in this study is voluntary. To participate in this study, you must be a college biology instructor who taught a student or students with a disability designated by the Disability Support Services office (or equivalent) of your institution as a visual impairment. You may have taught the biology course at a two-year or a four-year institution of higher education, but the course must have been completed between 2010 and 2015. The course must also have included a laboratory component that met face-to-face, and the student must have earned a C or better in the course.

It is important to know the perceptions of students with BVI who have successfully completed a college biology course and the perceptions of the college biology instructors teaching students with BVI. Data for my research is being collected entirely through anonymous, online surveys. There is one survey for students with BVI and another for college biology instructors who have taught students with BVI. I hope to gather the perceptions of 100 students and 100 instructors.

The questions on this survey will ask you about your perceptions of the specific laboratory accommodations, such as tactile models and audible equipment, that were provided for the student with BVI in your college biology course. You can respond to many of the questions by choosing a response from a list of choices, but some of the questions ask you to write about your experience. I would be especially appreciative if you would take the time to answer those questions. There are a few background questions at the beginning of the survey that you will be required to answer, because they provide information about the student's visual impairment and ensure you are eligible to participate in the study. However, you can skip or choose not to answer any of the other questions on the survey. The survey should take approximately 20-25 minutes of your time to complete. If you so choose, you will be given the opportunity to withdraw from the study after completing the survey.

The only known risk in participating in this study is that your identity could be revealed. It is not possible to guarantee your anonymity, but every effort will be taken to ensure that any information you provide will remain anonymous. SSL encryption is enabled so you will see "https:" in the URL. IP addresses will not be available to me, so I will not be able to trace your location. To maintain your anonymity, all data from this survey will be stored on a flash drive kept in a locked safe in my office, not a computer hard drive. Since the survey is designed to be anonymous, please do not include in your answers any information that may individually identify you, any students in the class, or the institution at which you teach. Any information that you accidentally include will be removed. No identifying information will be included in any publications resulting from this study.

The Institutional Review Board (IRB) for the Protection of Human Subjects at the University of New England has reviewed the use of human subjects in this research. The IRB is responsible for protecting the rights and welfare of people involved in research.

I am the researcher conducting this study. For questions or more information concerning this research you may contact me, Barbara Heard, MS, MT(ASCP), at bheard@une.edu, or my faculty mentor, Brianna Parsons, Ed.D, at (207) 299-3627 or bparsons4@une.edu. If you have any questions or concerns about your rights as a research subject, you may call Olgun Guvench, M.D. Ph.D., Chair of the UNE Institutional Review Board, at (207) 221-4171 or irb@une.edu.

Because this study is for a student research project, your consent is necessary. You may print and keep a copy of this consent form. *The survey will include a Disqualification Page. Instructors answering "No" to particular questions (as indicated) would be directed to that page and not permitted to take the survey.*

1) By clicking Yes, I indicate that I understand the above description of the research and the risks and benefits associated with my participation as a research subject. I understand that by proceeding with this survey I agree to take part in this research and do so voluntarily. *There will be a button marked with the choice, Yes. Individuals choosing this option will proceed to page 2 of the survey.*
2) By clicking No, I indicate that I choose not to participate in this study. *There will be a button marked with the choice, No. Individuals choosing this option will be directed to*

the Disqualification Page.

Page 2

Questions marked with an asterisk (*) require an answer. The "Next" and "Prev" buttons at the bottom of each page allow you to move to the next page of the survey, or to return to the previous page.

BVI stands for blindness and visual impairments.

3) Please choose the option that best describes the nature of the visual impairment of the student at the time he or she took the college biology course. Answer the question to the best of your ability given the information provided to you by the disabled students services office (or equivalent) of your institution. Answer choices are from a scale recommended by Dandona and Dandona (2006, p. 5). There are 12 answer options for this question. *Answer options include:* Mild visual impairment; moderate visual impairment; severe blindness; very severe blindness; total blindness; unspecified visual impairment; severe, very severe, or total blindness in one eye; moderate visual impairment in one eye; mild visual impairment in one eye; unspecified impairment in one eye; I do not know the nature of the student's visual impairment. *Also, an option of "Other" will appear, with a comment box. Instructors are required to answer this question.*

4) Was the student's visual impairment confirmed by the Disability Support Services office (or equivalent) at the institution at which you taught the college biology course? Choose Yes or No. *Instructors are required to answer this question. Those answering No will be directed to the Disqualification Page.*

5) Please indicate the course name and course number of the college biology course you taught in which the student with BVI was enrolled, such as "General Biology I - BIOL109." *Instructors are required to answer this question.*

6) Did you teach the laboratory portion of the college biology course to the student with BVI sometime between 2010 and 2015? Choose Yes or No. *Instructors are required to answer this question. Those answering No will be directed to the Disqualification Page.*

7) Was the laboratory portion of the course taken in a face-to-face format? Choose Yes or No. *Instructors are required to answer this question. Those answering No will be directed to the Disqualification Page.*

8) Did the student complete the class with a C or better? Choose Yes or No. *Instructors are required to answer this question. Data will be collected from those answering No, but will not be included in the study*

9) Did you have prior experience teaching the laboratory component of a college biology course to a student with BVI prior to teaching this student? Choose Yes or No.

10) Approximately what percentage of the final course grade does the laboratory component of the class routinely comprise in your classes?

11) Approximately what percentage of a student's laboratory grade is normally derived from routine assessments in your classes, such as quizzes, lab practicals, and lab reports?

12) Approximately what percentage of the laboratory grade routinely represents the student's ability to demonstrate skills proficiency, such as microscopy or animal dissection?

13) Can students receive a passing grade in the course if they fail the laboratory component of the course? Choose Yes or No.

14) Did you teach the student at a 2-year or a 4-year institution? Choose 2-year or 4-year.

The following reference will appear at the bottom of the page:

References

Dandona, L., & Dandona, R. (2006). Revision of visual impairment definitions in the international statistical classification of diseases. BMC Medicine, 4:7. doi:10.1186/1741-7015-4-7

Page 3

The following questions pertain only to the student with BVI in the laboratory portion of your course.

15) Was the percentage of the laboratory grade normally derived from routine assessments modified for the student in your class? Choose Yes or No.

16) Was the percentage of the laboratory grade normally derived from demonstration of skills proficiency modified for the student in your class? Choose Yes or No.

17) Approximately what percentage of the laboratory grade, if any, routinely represents a student's active participation in the laboratory exercises?

18) Was the percentage of the laboratory grade representing the student's active participation in the laboratory exercises modified for the student in your class? Choose Yes or No.

19) Approximately what percentage of the laboratory grade, if any, represents a student's contribution to group understanding of the experiments and results? *A text box appears.*

20) Was the percentage of the laboratory grade representing the student's contribution to group understanding of the experiments and results modified for the student in your class? Choose Yes or No.

21) If you answered Yes to question #20, please describe how you modified the percentage of the laboratory grade for the student. If you answered No to question #20, please skip this question. *A text box appears.*

22) Does your class include at least one lab practical? If your answer is No, skip questions 23 and 24. *Choices are Yes or No. If respondents answer No, they will skip the next three questions and be directed to the next page.*

23) If you answered Yes to question 22, was the student able to complete the lab practical with the other students in the class? If you answered No to question #22, skip this question and go on to #25. *Choices are Yes or No. Those marking Yes will be directed to answer question #24. Those marking No will be directed to answer question #25.*

24) If you answered Yes to question #22, please describe any modifications to the practical or the grading of the practical for the student. If you answered No to question #22, skip this question and go on to question #25.

25) If you answered No to question #22, please describe how the student was assessed on the material covered in the lab practical. If you answered Yes to question #22, skip this question.

Page 4

The Likert scale for questions 25-27 will be: Strongly agree, Agree, Neutral, Disagree, Strongly disagree, I choose not to answer this question.

The following questions pertain only to the student with blindness or visual impairment.

Please indicate your level of agreement or disagreement with the following statements.

26) The student actively participated in laboratory activities without any accommodations specific to the biology laboratory, such as tactile images or audible devices.

27) Specific accommodations, such as tactile images or audible devices, were required for the student to actively participate in one or more of the laboratory activities.

28) Accommodations specific to the biology laboratory, such as tactile images or audible devices, were required for all laboratory activities to enable the student to actively participate in the laboratory exercises.
29) Please describe accommodations specific to the biology laboratory that were provided for the student.
30) Please describe accommodations specific to the biology laboratory that were particularly helpful to the student.
31) Please describe any accommodations specific to the biology laboratory that were provided, but not helpful, to the student.
32) Please describe activities in which the student could not participate at all, or in which the student had difficulty participating, even with accommodations.

Page 5

The Likert scale for questions 32-34 will be: Strongly agree, Agree, Neutral, Disagree, Strongly disagree, I choose not to answer this question.

The Likert scale for questions 35-44 will be: Strongly agree, Agree, Neutral, Disagree, Strongly disagree, Not applicable, I choose not to answer this question.

The following questions pertain only to the student with blindness or visual impairment.

Please indicate your level of agreement or disagreement with the following statements.

33) The student was safe in the laboratory.
34) The student appeared interested in the class.
35) The student appeared curious about experimental results.
36) The student contributed to the group as he or she completed laboratory activities.
37) The student contributed to the group's understanding as they discussed the results of

laboratory activities.

38) The student was able to successfully find images using the microscope.

39) The student was able to successfully interpret images under the microscope.

40) The student was able to accurately determine the results of tests requiring color interpretation.

41) The student assisted in animal dissection.

42) The student was able to safely use a Bunsen burner and/or hot plate.

43) The student was able to accurately construct graphs.

44) The student was able to accurately interpret graphs.

45) The student was able to accurately pipette, pour, and measure liquids.

Page 6

The Likert scale for questions 45-52 will be: Strongly agree, Agree, Neutral, Disagree, Strongly disagree, I choose not to answer this question.

The following questions pertain only to the student with blindness or visual impairment.

Please indicate your level of agreement or disagreement with the following statements.

46) The student was able to take notes and record data without assistance.

47) The student requested and was provided an aide, assistant, or other non-student of the class to help in the laboratory.

48) An aide, assistant, or other non-student of the class would have enabled the student to be more successful in the class.

49) The student was treated by classmates the same as everyone else in the class.

50) The student demonstrated knowledge of laboratory concepts at a level comparable to that of the sighted students in the class.

51) The student demonstrated laboratory skills at a level comparable to that of the sighted students in the class.

52) My perception is that the student learned as much as sighted students who received the same grade.

53) There were accommodations I wanted to offer the student but could not due to lack of time, lack of funds, or for other reasons. *A comment box of "*Please explain*" will be included for this question.*

Page 7

The Likert scale for questions 53-55 will be: Strongly agree, Agree, Neutral, Disagree, Strongly disagree, I choose not to answer this question

Please indicate your level of agreement or disagreement with the following statements.

54) Laboratory assessments should be altered, if necessary, so that students with blindness or visual impairment can successfully pass the laboratory portion of the course.

55) Even with specific accommodations for the biology laboratory, I had to make alterations to laboratory assessments for the student with blindness or visual impairment. However, the altered assessments enabled equivalent assessment of laboratory concepts as compared to the assessments I gave sighted students.

56) Even with specific accommodations for the biology laboratory, I had to make alterations to laboratory assessments for the student with blindness or visual impairment. However, the altered assessments enabled equivalent assessment of laboratory skills as compared to the assessments I gave sighted students.

57) What types of alterations did you make to assessments of laboratory concepts?

58) What types of alterations did you make to assessments of laboratory skills?

Page 8

59) Please tell me about your experience with a student with blindness or visual impairment in the college biology laboratory. Please do not include any identifying information about you, any of the students in the class, or the institution. *This question includes a comment box.*

Page 9

You have completed the survey. Thank you for your time and for sharing your stories!

Please check only one of the boxes below. Click "Submit my survey responses" to complete the survey and record your answers. Click "Delete my survey responses" to withdraw from the study.

Then click the Done button to exit the survey.

Thanks again. I sure appreciate that you donated your valuable time to my study!

60) Yes, I want to submit my survey responses.

61) No, I prefer to withdraw from the study at this time. I understand that by checking the box, my answers will be deleted.

APPENDIX C. DSS OFFICE EMAIL

Email to DSS Offices

Dear (Name of individual in charge of the DSS office),

I am an assistant professor of biology at a community college in New Jersey. I am also a student in the doctor of education in educational leadership program at the University of New England (UNE). The community college where I teach is experiencing an increase in the number of students with disabilities, including those with blindness and visual impairments (BVI). As a result, more students with BVI are taking our biology courses. My dissertation research seeks to evaluate the effectiveness of specific accommodations, such as tactile models and auditory equipment, provided for students with BVI in the college biology laboratory. Results of this study should provide information that will inform best practices in providing accommodations for students with BVI in the college biology laboratory.

Both student and instructor perspectives are important to the validity of the study. The study will incorporate a mixed-methods approach to gather the perceptions of students with BVI who are at least 18 years of age, and who have completed a college biology course with a face-to-face laboratory component between the years 2010 and 2015. Instructors who have taught students with BVI in the college biology laboratory within those same parameters will also be included in the study. I will be contacting college biology faculty members separately.

The study consists of anonymous online surveys posted on SurveyMonkey® that include both closed- and open-ended questions. There are separate questionnaires for the students and the instructors. Student participation in this study is vital. Since the number of potential participants is small, I am reaching out to the Disability Support Services (DSS) offices (or equivalent) of many institutions of higher education. Should your office be willing to grant site permission, I request that the following email be sent to students at your institution who meet the study criteria. UNE is requesting site permission from DSS offices only; I do not need administrative permission. If you can provide site permission, or if you have any questions regarding this request, please email me at bheard@une.edu. Your assistance would be greatly appreciated.

If you have any questions or concerns regarding the survey, please email me at bheard@une.edu. Additional information is available on the study website at bheardu.net. Thank you for your consideration.

Sincerely,

Barbara R. Heard, MS, MT(ASCP)

Email to be sent to qualified student participants by the institution's DSS office

Dear Student,

You are receiving this email because you completed a college biology course between 2010 and 2015. The Disability Support Services office, or equivalent, where you took the biology course was asked to forward this information to you.

I am a student in the doctor of education in educational leadership program at the University of New England. I am doing a study to evaluate the effectiveness of specific accommodations, such as tactile models and auditory equipment, that were provided for students with blindness and visual impairments (BVI) in the college biology laboratory. Results of this study should benefit future students with BVI taking college biology courses that include a laboratory component.

Both student and instructor perspectives are important to the validity of the study. The study will gather the perceptions of instructors who have taught students with BVI and students with BVI who have completed a college biology course. Because instructor perceptions are important to the study, I will be contacting biology faculty at your institution with a similar request.

Participation in this study is completely voluntary, and you can stop at any time. The study will consist of the completion of an anonymous online survey taken on SurveyMonkey®. A screen reader should enable you to take the survey, if necessary. The survey should take approximately 15-20 minutes of your time to complete. Though it is not possible to guarantee anonymity, every effort will be taken to ensure that any information you provide will remain anonymous. No identifying information will be collected, including IP addresses.

Additional information about the study is available on the study website at bheardu.net. Your participation would be highly appreciated. If you would be willing to participate, please click on the following link: https://www.surveymonkey.com/r/accommodations-student. You are welcome to share the link with other qualified individuals. I would also appreciate it if you would refer any college biology instructors you know who have taught a student with BVI to the study website for information and the link to the instructor survey.

If you have any questions or concerns regarding this survey, please email me at bheard@une.edu.

Thank you for your consideration.

Sincerely,

Barbara R. Heard, MS, MT(ASCP)

APPENDIX D. BIOLOGY FACULTY EMAIL

Email to Biology Faculty

Dear Colleague,

I am an assistant professor of biology at a community college in New Jersey. I am also a doctoral candidate in the doctor of education in educational leadership program at the University of New England. The community college where I teach is experiencing an increase in the number of students with disabilities, including those with blindness and visual impairments (BVI). As a result, more students with BVI are taking our biology courses. My dissertation research seeks to evaluate the effectiveness of specific accommodations, such as tactile models and auditory equipment, provided for students with BVI in the college biology laboratory. Results of this study should inform best practices in providing accommodations for students with BVI in the college biology laboratory.

Both student and instructor perspectives are important to the validity of the study. The study will gather the perceptions of instructors who have taught students with BVI completing a face-to-face college biology laboratory between the years 2010 and 2015. Because student perceptions are also important to the study, I will be contacting the Disability Support Services office, or equivalent, at your institution with a request to forward study information to qualified students.

Instructor participation in this study is vital. Since the number of potential participants is small, I am reaching out to biology faculty members at many institutions of higher education. The study consists of completion of an anonymous online survey taken on SurveyMonkey®. This survey should take approximately 20-25 minutes of your time to complete. Though it is not possible to guarantee anonymity, every effort will be taken to ensure that any information you provide will remain anonymous. No identifying information will be collected, including IP addresses. Participation in this study is completely voluntary, and you can stop at any time.

Additional information about the study is available on the study website at bheardu.net. Your participation would be highly appreciated. If you would be willing to take the survey, please click on the following link: https://www.surveymonkey.com/r/accommodations-instructor. You are welcome to share the link with other qualified individuals. I would also appreciate it if you would refer any qualified students you know to the study website for information and the link to the student survey.

If you have any questions or concerns regarding this request, please email me at bheard@une.edu.

Thank you for your consideration.

Sincerely,

Barbara R. Heard, MS, MT(ASCP)

APPENDIX E. ORGANIZATIONS EMAIL

Email to Organizations

To Whom It May Concern,

I am an assistant professor of biology at a community college in New Jersey. I am also a doctoral candidate in the doctor of education in educational leadership program at the University of New England (UNE). My dissertation topic seeks to evaluate the effectiveness of specific accommodations, such as tactile models and auditory equipment, provided for students with blindness and visual impairments (BVI) in the college biology laboratory. Results of this study should provide information that will inform best practices in providing accommodations for students with BVI in the college biology laboratory.

Both student and instructor perspectives are important to the study. The study will gather the perceptions of students with BVI who are at least 18 years of age, and who have completed a college biology course with a face-to-face laboratory component between the years 2010 and 2015. Instructors who have taught students with BVI in the college biology laboratory within those same parameters will also be included in the study.

The study consists of anonymous online surveys posted on SurveyMonkey® that include both closed- and open-ended questions. There are separate questionnaires for the students and the instructors. Student participation in this study is vital. Since the number of potential participants is small, I am reaching out to national organizations for help. If your organization would be willing, would you please inform any eligible students and instructors about the study and provide the link to the study website, bheardu.net? Your assistance would be greatly appreciated.

If you have any questions or concerns regarding this survey, please email me at bheard@une.edu.

Thank you in advance for your consideration.

Sincerely,

Barbara R. Heard, MS, MT(ASCP)

Email to be sent to qualified student participants by National Organizations

Dear Student,

You are receiving this email because you completed a college biology course between 2010 and 2015.

I am a student in the doctor of education in educational leadership program at the University of New England. I am doing a study to evaluate the effectiveness of specific accommodations, such as tactile models and auditory equipment, that were provided for students with blindness and visual impairments (BVI) in the college biology laboratory. Results of this study should benefit future students with BVI taking college biology courses that include a laboratory component.

Participation in this study is completely voluntary, and you can stop at any time. The study will consist of the completion of an anonymous online survey taken on SurveyMonkey®. A screen reader should enable you to take the survey, if necessary. The survey should take approximately 15-20 minutes of your time to complete. Though it is not possible to guarantee anonymity, every effort will be taken to ensure that any information you provide will remain anonymous. No identifying information will be collected, including IP addresses.

Your participation would be highly appreciated. If you would be willing to participate, please click on the following link: https://www.surveymonkey.com/r/accommodations-student. You are welcome to share the link with other qualified individuals.

If you have any questions or concerns regarding this survey, please email me at mailto:bheard@une.edu.

Thank you for your consideration.

Sincerely,

Barbara R. Heard, MS, MT(ASCP)