Academic Quality Using Bloom's Taxonomy in Biology:

A Quantitative Correlational Study

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Abstract

The area of interest considered for the study was the overall academic achievement in biology lecture and laboratory courses using Bloom's Taxonomy. The problem of the study is the lack of higher-order thinking skills leading to a learning gap in many universities and colleges. The purpose of the quantitative correlational study was to determine if there is a statistically significant relationship between the biology lecture examination question answers (correct or incorrect), a dichotomous variable, based on Bloom's Taxonomy, and the matching laboratory assessment grade, a continuous variable, received by 51 students in a community college in northern New Jersey. The framework for this study was created by combining descriptive theory, meta-theory, and Bloom's Taxonomy. The key research questions included the relationship between lecture assessments and laboratory assessment grades of students in General Biology I. Archival data and a Point Biserial Correlation was used for data analysis. The key results include two significant relationships and one non-significant relationship between the lecture assessment questions and the laboratory assessment grades. The main conclusion portrays how the knowledge/comprehension question has no relationship with the laboratory assessment grade and the application/analysis and synthesis/evaluation questions have a relationship with the laboratory assessment grades. Instructional faculty can benefit from the study and implications include improving the academic outcomes of students at the basic and advanced levels of Bloom's Taxonomy.

Keywords: Bloom's taxonomy, quantitative correlation, point-biserial, lecture assessment, laboratory-grade, community college

Dedication

I am dedicating my dissertation to my son Mukund and daughter Tanu for putting up with my busy schedule and academic efforts for almost 5 years. They supported me all the way through with a lot of encouragement and enthusiasm. They would always make me think about the end goal. At the same time, my kids are proud of me for undertaking this venture and securing a Doctorate. I cannot thank them enough. I also thank my parents, especially my mother Mrs. Radha for encouraging me to apply to this Doctorate program, my father Dr. Subramanian, spouse Mr. Ramakrishnan, family members, and friends for their support.

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Chapter 1: Introduction

Learning is attained through effort, repetition, and perseverance by students and teachers within the context of Bloom's Taxonomy (Bibi et al., 2020). Bloom's Taxonomy was developed in the 1950s by the American educational psychologist Benjamin Bloom who fostered a common objective towards learning (Adams, 2015). The taxonomy of educational objectives is a framework for developing the learning curve of students based on instruction and the effect of affect (Nelson et al., 2020). Overall, the area of interest for the research study involved the observation of academic achievement in lecture and laboratory courses of General Biology using Bloom's Taxonomy of Educational Objectives at a community college in northern New Jersey. Research has been conducted in this area for promoting students to use higher-level thinking skills (Erdimez et al., 2017). The topic is warranted primarily because of the presence of laboratories in the biological sciences. Some educators have assessed critical thinking in the classrooms using Bloom's taxonomy for an introductory biology course (Boslaugh, 2019).

The potential benefits of further study include the usage of Bloom's Taxonomy matrix to reach higher-level learning objectives (Spence, 2019). Critical thinking and problem-solving skills are beneficial to develop in areas like the biological sciences (Revati & Meera, 2017). Foundational knowledge is important for categorizing educational goals (Msaedeh, 2019). Bloom's Taxonomy gives educators a baseline to explain whether the teaching standards meet the criteria of lower-level and higher-level thinking. Taxonomy is the hierarchy of processes ranging from simple to complex and there are six levels of expertise starting from knowledge, comprehension, application, analysis, synthesis, and evaluation (Adams, 2015). The proposed research was to see how students can relate to Bloom's Taxonomy in General Biology courses.

The study took place in a community college in northern New Jersey and the study explored how Bloom's Taxonomy of educational objectives could affect the learning process in students (Boslaugh, 2019).

Bloom's Taxonomy is a valid way to classify levels of learning (Adams, 2015). By adopting a behavioral science approach, managerialism is a way of managing schools and is based on Bloom's Taxonomy (Ormell, 2019). Bloom's Taxonomy portrays what a student should do, having reached each of the six levels of Bloom's Taxonomy including knowledge, comprehension, application, analysis, synthesis, and evaluation (see Appendix A). The Taxonomy was based on applying the principles of behavioral science to the work of schools.

Instructors could use Bloom's Taxonomy to ensure students engage with higher-level objectives (Spence, 2019). The taxonomy should be used as a tool for educators by including numerous learning objectives including remembering, understanding, applying, analyzing, synthesizing, and evaluating (Adams, 2015). The application of Bloom's Taxonomy by teachers includes the creation of an environment where the students could realize the mistakes on the path to mastery of a subject (Gershon, 2018).

Bloom's Taxonomy is a practical tool for teachers because teaching, learning, and assessments could be divided up into processes, ordering, and systematics (Gershon, 2018). The application and analysis of Bloom's Taxonomy in the classroom enhance the teaching and learning process (Spence, 2019). An introduction, background of the problem, statement of the problem, the purpose of the study, the significance of the study, research questions, hypotheses, theoretical framework, the definition of terms, assumptions, scope and delimitations, limitations, and a summary are included in the chapter.

Background of the Problem

The quantitative correlational study was based on Bloom's Taxonomy, a theoretical framework by Benjamin Bloom used to classify and organize higher education learning objectives (Bloom, 1956). Six hierarchical categories are in the cognitive domain, as classified by Bloom, including remember, understand, apply, analyze, evaluate, and create (Gershon, 2018). The cognitive taxonomy evolved over time and Anderson et al. (2001) proposed an order including remembering, understanding, applying, analyzing, evaluating, and synthesizing. Krathwohl (2002) revised the Bloom's Taxonomy framework to a Revised Bloom's Taxonomy.

Research literature related to the quantitative correlational study include the major findings of Bloom's Taxonomy and academic improvement, Bloom's Taxonomy and cognitive levels, Bloom's Taxonomy in an introductory scripture course, and applying Bloom's Taxonomy in framing multiple-choice questions (Singh et al., 2016). The research implies the students are being tested on lower levels of Bloom's Taxonomy and every effort needs to be made to include higher level application and synthesis questions in the testing curriculum (Gershon, 2018). Bloom's Taxonomy and outcomes in the curriculum, Revised Bloom's Taxonomy, Revised Bloom's Taxonomy and alignment, flipped classroom and Bloom's Taxonomy, Bloom's Taxonomy Histology Tool, Blooming Biology Tool, and the Blooming Anatomy Tool are other topics included in the study (Crowe et al., 2017). Bloom's Taxonomy is a progressive sequence of educational objectives used for lesson planning, assessment, and measurement of learning outcomes by educators (Ramirez, 2017). The Blooming Biology Tool was used to determine the cognitive skills level assessed in the newly developed first-year introductory biological concepts of health course (Murrant et al., 2015). More topics include outcome-based education through

Bloom’s Taxonomy, language assessment through Bloom’s Taxonomy, role of comprehension on performance at higher levels of Bloom’s Taxonomy, and engineering faculty, using Bloom’s Taxonomy (Kumar et al., 2019). The research implies students were being tested on lower levels of Bloom’s Taxonomy and every effort needs to be made to include higher-level application and synthesis questions in the testing curriculum (Gershon, 2018).

Bloom’s Taxonomy lacked the fulfillment of its objectives in various parts of the world, and a gap comprising the lack of higher-order cognitive skills in higher education in community colleges could be addressed through research (Adams, 2015). A gap remains in the literature, as to the assessment of the various educational objectives in general biology laboratory and lecture courses using Bloom’s Taxonomy in community colleges (Crowe et al., 2017). The background of the problem was to identify the effects of Bloom’s Taxonomy including the six levels of learning objectives to improve academic achievement (Bloom, 1956). The six levels are knowledge, comprehension, application, analysis, synthesis, and evaluation (Gershon, 2018).

The importance of the problem lies in the observation of the application of Bloom’s Taxonomy in general biology lecture and laboratory courses at a community college (Bibi et al., 2020). The extent of the problem was in various lecture and laboratory sequences in biology courses and to what level the six educational objectives were being applied. Biology examinations only promote low-level learning including the regurgitation of facts (Spence, 2019). Lower objectives of Bloom’s Taxonomy are being tested rather than the higher levels of synthesis and evaluation (Cullinane & Liston, 2016). People impacted by the problem could be the students taking the biology lecture and laboratory courses and the extent of the understanding of the subject.

Statement of the Problem

The problem explored in this study was the lack of higher-order thinking skills consisting of analyzing, evaluating, and creating levels of Bloom's Taxonomy, which need to be improved at all levels of education (Bozdemir et al., 2019; Köksal & Ulum, 2018; Singh et al., 2016). Target population is defined as the population who shall participate in a study and refers to the entire group of individuals to whom researchers are interested in generalizing the conclusions (Dahabreh et al., 2020). A target population included 112 students who had taken General Biology I from 2016 to 2017 at a community college in northern New Jersey, seeking an associate degree in the sciences (Becker & Vargas, 2018). Students from General Biology I were selected for the quantitative correlational study. The grades received by students were used for analysis.

What is known about the quantitative correlational study is how the students are being tested only on the lower levels of Bloom's Taxonomy (Revati & Meera, 2017). Every effort needs to be made to include higher-level application and synthesis questions in the testing curriculum (Singh et al., 2016). According to Cullinane and Liston (2016), high-stakes assessments including terminal exams result in a narrowed curriculum where students learn only by rote. Current biology examinations promote low-level learning and do not prepare students for the working world (Neiro & Johansson, 2020). Many of the curricula focus on remembering, understanding, and applying levels in the cognitive area, and factual and conceptual knowledge dimensions in the knowledge area (Bozdemir et al., 2019). Analysis of student writing using Bloom's Taxonomy in a general science course revealed how descriptions and questions posed by the instructors demonstrate lower-order thinking skills (Gitari & Gerrard, 2017).

Implementation of an online biology course was successful in engaging students to get involved with family and friends for the assignments and made science accessible to the greater community (Gonzalez, 2016). Students could complete questions based on the cognitive level of Bloom's Taxonomy with a good percentage in terms of remembering and understanding categories when compared to the analyzing and evaluating categories (Arlianty et al., 2018).

What is not known about the quantitative correlational study, based on Bloom's Taxonomy, is how a shift from terminal exams to a mixed approach could benefit the students (Cullinane & Liston, 2016). Gitari and Gerrard (2017) portrayed a need for the science course instructors to figure a higher-order thinking discourse for students to improve the construction of scientific ideas. To attain institution-specific goals, core concepts need to be enhanced to achieve the core competencies (Gonzalez, 2016). The specific research problem was clarified based on the fact of collecting data from examinations based on Bloom's Taxonomy (Gershon, 2018). The research problem is current, relevant, and important because the higher-order thinking skills consisting of analyzing, evaluating, and creating levels need to be improved at all levels of education (Arlianty et al., 2018). Bloom's Taxonomy lacked in the fulfillment of the objectives in various parts of the world and portrays a gap, needed to be filled to an extent by conducting the quantitative correlational study at a community college in northern New Jersey (Kressler & Kressler, 2020). A gap remains in the literature as to the assessment of biology lecture and laboratory courses using Bloom's Taxonomy in community colleges (Lysne & Miller, 2015).

Purpose of the Study

The purpose of the quantitative correlational study was to determine if there is a statistically significant relationship between the biology lecture examination question answers (correct or incorrect), a dichotomous variable, based on Bloom's Taxonomy, and the matching laboratory assessment grade, a continuous variable, received by 51 students in a community college in northern New Jersey. The current study used archived data and students who took both the lecture and laboratory classes were selected to match the grades. The researcher selected a relevant lecture assessment question based upon a valuable skill students should learn rooted in Bloom's taxonomy types and used a point bi-serial correlation to determine if there is a relationship between the laboratory assessment grade and the lecture class. The dichotomous variable was the lecture question answer with two categories of correct versus incorrect. The continuous variable was the matching laboratory assessment grade. A quantitative correlational study could help to establish the extent to how categories of application, analysis, synthesis, and evaluation versus knowledge and comprehension components of the Bloom's Taxonomy framework are utilized to test freshman students (Gershon, 2018).

The study is necessary to determine if all parts of the framework of Bloom's Taxonomy are being used to test students or only one or two or three educational objectives are being used (Spence, 2019). Failure to follow all the educational objectives of Bloom's Taxonomy to test students would happen if a thorough study is not properly conducted in this area (Ramirez, 2017). The proposed study may contribute to the knowledge base by providing ways to improve the educational standards of students. The geographical location of this study was northern New Jersey, and the target population was a community college.

For the quantitative correlational study, the accessible population or the total sample was 51 students from 3 semesters in 2016-2017. The sample size was determined based on the number of students enrolled in the past semesters of 2016 and 2017. Using Slovin's formula to calculate an appropriate a priori sample size from a population at a 90% confidence interval, the required adequate sample size for the study was only 38 students for a target population of 112 students. The study included 51 students and was more than sufficient based on the calculations of Slovin's formula. Slovin's formula was used to determine sample size from a population (Arizal & Agus, 2019). The purpose of the study was aligned to the problem, as community colleges offering associate degrees every year are striving and working to meet the learning outcomes at higher levels of Bloom's Taxonomy (Sharpe, 2019).

The rationale for the research was to determine if there was a relationship between the educational objectives of Bloom's Taxonomy in the lecture examination questions and if the student had the answer correct or incorrect, versus the matching laboratory grades received by students in General Biology laboratory assessments. Quantitative research maintains the assumption of an empiricist paradigm stating concepts originate in experience (Creswell & Gutterman, 2019). The research methodology was quantitative with a correlational design for the researcher to analyze the data of students' performance (Creswell & Creswell, 2018). Performance was measured by recording the grades received by students in the examinations.

The two variables used in the quantitative correlational study were a dichotomous variable and a continuous variable (Creswell & Creswell, 2018). The dichotomous variable in the quantitative correlational study was if specific lecture exam questions based on Bloom's Taxonomy of educational objectives for General Biology I and the two categories were correct *vs* incorrect answers. The continuous variable was the matching laboratory assessment grades of students. Six categories of Bloom's Taxonomy of Educational Objectives include knowledge, comprehension, application, analysis, synthesis, and evaluation (Gershon, 2018). An entire set of the listed categories of Bloom's Taxonomy were used in the examination questions.

Correlational research includes variables to covary or co-relate with each other in different abilities (Haythornthwaite, 2018). Changes in one variable are reflected with changes in the other (Hoy & Adams, 2016). The variables correlate because as one variable deviates from the mean in one direction, the other variable deviates from the mean in the same direction (Creswell & Creswell, 2018).

The quantitative correlational design was suitable to test the hypotheses because of a simple association between two variables, comprising the lecture question answers (correct *vs* incorrect) based on Bloom's Taxonomy and the matching laboratory assessment grades received by students (Hoy & Adams, 2016). Level of data, used for the quantitative correlational study, is the interval variable, where the difference between two values is meaningful (Ali & Bhaskar, 2016). The interval variable is the continuous variable and is the matching laboratory assessment grade received by students. The lecture exam question and the answer with two categories of correct *versus* incorrect is the dichotomous variable and is the nominal data measurement level (Laerd Statistics, 2017).

The quantitative correlational study examined what relationship Bloom's Taxonomy had on the curriculum of biology. The problem and the purpose were related because both aspects were trying to improve the academic standards of students by ensuring the implementation of various levels of Bloom's Taxonomy (Spence, 2019). The research methodology provided the necessary answers to the research questions because quantitative data were gathered and analyzed to determine whether there was any correlation between Bloom's Taxonomy in a lecture class and academic application in the laboratory class of community college students in northern New Jersey (Sharpe, 2019).

Significance of the Study

The study can help educators advance the knowledge about the problem the students are facing in understanding, applying, and evaluating the concepts in general biology courses (Spence, 2019). Bloom’s Taxonomy should be used to identify cognitive weaknesses in students of engineering and the sciences, especially in biology (Crowe et al., 2017). The taxonomy could be used by professionals training others to write learning objectives describing the skills and abilities desired in the learners to master and demonstrate (Adams, 2015). Bloom’s Taxonomy leads to deeper learning and transfer of knowledge and skills to a greater variety of tasks and contexts, calling for higher levels of cognitive skills (Kressler & Kressler, 2020). Bloom’s Taxonomy provides a framework for certainty and communicability in ascertaining student learning (Bertucio, 2017).

The study will be shared with the teaching community including the community college where the research was performed to improve the curriculum and instruction of the teaching faculty (Sharpe, 2019). This study may contribute to the knowledge base by providing ways to improve the educational outcomes of students. The geographical location of the study is northern New Jersey, and the target population is a community college. The research methodology provides the necessary answers to the research questions because quantitative data will be gathered and analyzed to determine whether there is any correlation or a relationship between assessments based on Bloom’s Taxonomy in the form of lecture questions and answers (correct *vs* incorrect) and the matching laboratory assessments in terms of grades of community college students in northern New Jersey (Adams, 2015). Understanding the relationship between these variables and how one is related to the other should be important to develop successful curricula to improve the academic acuity of students and to reduce the existing academic gaps in community colleges in northern New Jersey. A relationship between these variables could provide some evidence promoting application and use of knowledge, based on Bloom's Taxonomy, for useful skills in biology.

Implications for positive social change include improvement in lecture and laboratory curricula and the style of teaching in community colleges (Lysne & Miller, 2015). Bloom's Taxonomy provides a framework for stability and communication in promoting student learning (Bertucio, 2017). The quantitative correlational study may help provide curriculum planning and have a real impact on the level of daily experience in the classroom. Bloom's Taxonomy could provide university examiners and college professors with clearer educational aims and a universal language for collaboration (Spence, 2019). The study may help educators to encourage higher-order thought in students by building from lower-level cognitive skills (Bibi et al., 2020). This study could improve learning outcomes for students because of specific lessons or as a whole course.

Bloom's Taxonomy has set standards to improve the process of cognition when students are involved in activities at all six levels of Bloom's Taxonomy (Crompton et al., 2019). Dependable insights should be shared by instructors with the study and Bloom's Taxonomy makes expertise in the education field accessible to all, regardless of the background, and acts as a standardizer (Bertucio, 2017). The quantitative correlational study might undergird the development of applications for open and distance learners based on the relationship of the performance of students and Bloom's Taxonomy, and writing a curriculum based on the learning outcomes (Ekren & Keskin, 2016).

Research Questions

The research questions addressed the relationship between the lecture exam questions with two categories of correct *vs* incorrect based on Bloom's Taxonomy of Educational Objectives and the matching laboratory assessment grades in the General Biology I course. Both lecture and laboratory courses were used for quantitative correlational study and student lecture question answers were matched to their appropriate laboratory grade. In addition, the Point-Biserial Correlation test was used to analyze the research questions (Creswell & Creswell, 2018). For Research Question 1, the dichotomous variable is the lecture assessment question, using Bloom's knowledge and comprehension levels with two categories of correct *vs* incorrect. The continuous variable is the grades received by students in the matching General Biology I laboratory assessments. For Research Question 2, the dichotomous variable is the lecture assessment question with the same two categories of correct *vs* incorrect, based on application and analysis category, and the continuous variable is the grades received by students in General Biology I in the matching laboratory assessments. For Research Question 3, the dichotomous variable is the lecture assessment question based on synthesis and evaluation using the same two categories of correct *vs* incorrect and the continuous variable is the matching grades received by students in General Biology I laboratory assessments. To achieve the purpose of the quantitative correlational study, the research questions are as follows.

Research Question 1: Is there a significant relationship between the lecture assessment Bloom's Taxonomy question for knowledge and comprehension answer (correct *vs* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey?

Research Question 2: Is there a significant relationship between the lecture assessment Bloom's Taxonomy question for application and analysis answer (correct *vs* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey?

Research Question 3: Is there a significant relationship between the lecture assessment Bloom's Taxonomy question for synthesis and evaluation answer (correct *vs* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey?

Hypotheses

The hypotheses included a null and an alternate hypothesis for all the research questions. Alternate hypotheses are H1, H2, and H3, and the null hypotheses are $H1_0$, $H2_0$, and $H3_0$. The hypotheses for the quantitative correlational study are as follows.

$H1_0$: No significant correlation exists between the lecture assessment Bloom's Taxonomy question for knowledge and comprehension answer (correct *vs* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey.

$H1_a$: A significant correlation exists between the lecture assessment Bloom's Taxonomy question for knowledge and comprehension answer (correct *vs* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey.

$H2_0$: No significant correlation exists between the lecture assessment Bloom's Taxonomy question for application and analysis answer (correct *vs* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey.

$H2_a$: A significant correlation exists between the lecture assessment Bloom's Taxonomy question for application and analysis answer (correct *vs* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey.

$H3_0$: No significant correlation exists between the lecture assessment Bloom's Taxonomy question for synthesis and evaluation answer (correct *vs* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey.

$H3_a$: A significant correlation exists between the lecture assessment Bloom's Taxonomy question for synthesis and evaluation answer (correct *vs* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey.

Theoretical Framework

The theoretical framework was used to guide the research in an organized fashion because there were various levels of educational objectives that were tested in the courses. Descriptive and meta-theory blend in to create the framework of Bloom's Taxonomy, first introduced in 1956 by Benjamin Bloom (Bloom, 1956). Application of the dimensions of the descriptive theory and the dimensions of the meta-theory support the purpose of the study by providing the classification of various educational objectives the professors could use to set goals for the students and are related to the research questions in the study (Watkins, 2020). The first version of Bloom's Taxonomy included six levels of learning: (a) knowledge, (b) comprehension, (c) application, (d) analysis, (e) synthesis, and (f) evaluation (Adams, 2015). Bloom's Taxonomy is effective in creating educational models and promotes a cognitive learning process stimulating more extensive forms of thinking like deeper analysis and evaluation of procedures (Gershon, 2018). The six elements from the cognitive dimensions based on Bloom's Taxonomy include verbs, such as remembering, understanding, applying, analyzing, evaluating, and creating (Nelson et al., 2020).

Descriptive theory aligns with the study of academics because there are some propositions that attempt to describe and explain the world and relates to the research questions in the study (Watkins, 2020). Sebastien (2016) portrayed descriptive theory, as applied to advocating for the implementation of a set of propositions, attempting to describe something and is accepted by the scientonomy community. Scientonomy is a discipline that uncovers the mechanism of scientific change (Patton, 2019). The origin of the descriptive theory is from the Theory of Scientific Change, encompassing the set of all methods and theories accepted at a given time by a scientific community (Barseghyan, 2015). Descriptive research is used to generate and test descriptive theories and is known as exploratory research (Collazos et al., 2019).

All fields of research share some meta-theory, irrespective of whether explicit or correct (Apolskii et al., 2019). Metacognitive knowledge involves thinking about one's thought processes and Bloom's taxonomy is an effective tool for a unique kind of thinking (Gershon, 2018). Understanding the dimensions of meta-theory to support student engagement in the classroom could help motivate and improve student grades in the study (Haslam et al., 2017). Meta means above and goes one step beyond the usual procedural and factual knowledge (Konstabel, 2019). Meta-theory is relevant to the study concerning the academic improvement in the biological sciences because developmental biology shall continue to increasingly influence research and theory in cognitive development (Katsumi, & Grüninger, 2018). Evolutionary theory, under the biological sciences, is on the way to becoming a metatheory for cognitive development and developmental psychology (Bjorklund, 2018).

Definitions of Terms

Definitions are provided for the dichotomous and continuous variables of the quantitative correlational study. Additional terms used in the study having ambiguous or multiple meanings are included. The meaning of the framework and theories discussed in the study are listed.

Bloom's Taxonomy of Educational Objectives: The taxonomy has retained obeisance for decades and is the framework for certainty and communicability in emphasizing student learning (Bertucio, 2017). The assessments following Bloom's Taxonomy of Educational Objectives should include questions based on knowledge, comprehension, application, analysis, synthesis, and evaluation. Bloom's Taxonomy is the common language to exchange learning and assessment methods.

Descriptive Theory: Descriptive theory aligns with the study of academics because there are some propositions attempting to describe and explain the world and relating to the research questions in the study (Watkins, 2020).

Laboratory grades: Laboratory grades is the continuous variable for the study and are the grades received by students following the General Biology I laboratory assessment in the community college (Sharpe, 2019). The laboratory assessment grade for each student will be matched with the lecture assessment question answers, the dichotomous variable.

Lecture assessment questions answers: Dichotomous variable. Assessments are examinations following the Educational Objectives of Bloom's Taxonomy in General Biology I lecture. (Bibi et al., 2020). The variable has two categories of correct versus incorrect and the answers to the lecture questions shall be matched to the laboratory grade for all students.

Meta-theory: Meta means above and goes one step beyond the usual procedural and factual knowledge (Konstabel, 2019). Meta-theory is relevant to the study concerning the academic improvement in the biological sciences since developmental biology could continue to increasingly influence research and theory in cognitive development (Katsumi, & Grüninger, 2018).

Assumptions

The assumptions of the study included a relationship between Bloom's Taxonomy and student learning, and courses created in 2016 were like the current courses. The students from 2016 were like the current students in 2022 concerning age and background. As this study was designed, there was an assumption of having a relationship between lecture and laboratory examinations based on Bloom's Taxonomy levels and student grades. The assumptions of the point biserial correlational design include having a continuous variable, a dichotomous variable, paired variables, absence of outliers, homogeneity of variances, and normal distribution (Laerd Statistics, 2017). The quantitative correlational study design does have a continuous variable, the matching laboratory grade of students, and the dichotomous variable, the lecture assessment question answers (correct *vs* incorrect), and the variables are paired. Absence of outliers, homogeneity of variances, and normal distribution relates to the nature of the data and were tested using the Statistical Package of the Social Sciences (Bala, 2016). Convenience sampling, also known as availability sampling, was used in the quantitative correlational study, where the selection of participants was based on ready availability (Quatember, 2019). An assumption where the sample was comparable to a random sample from the same population was made when inferential statistics were applied to convenience samples (Frey, 2018).

The quantitative correlational study supported the assumption of lecture and laboratory examinations having questions at all the six levels of Bloom’s Taxonomy (Crompton et al., 2019). The six levels include knowledge, comprehension, application, analysis, synthesis, and evaluation (Gershon, 2018). Because the college reduced the levels to three categories of knowledge and comprehension, application and analysis, and synthesis and evaluation, it is assumed that Bloom’s Taxonomy was applied correctly in the assessments for both lecture and laboratory. Testing students at all the levels of Bloom’s Taxonomy should enhance student cognitive engagement (Spence, 2019). Instructors should include activities that promote high levels of cognitive processing and have started to include such activities in the curriculum. The assumption is, low *versus* high-level thinking opportunities are enhanced in science, mathematics, and social studies. Students learn within the context of Bloom’s Taxonomy by adapting to the questioning techniques of instructors (Bibi et al., 2020). The questions are normally on the knowledge and comprehension types more than the synthesis and evaluation types (Kressler & Kressler, 2020).

The study was based on the grades of the students available in a specific area of the website of the community college, available to the instructors. Grades of students were also emailed by the assessment assistant at the college. The assumption of question selection at the six levels of Bloom's Taxonomy for the laboratory assessment is necessary because the laboratory examinations were made by the instructor and not extracted from the test bank (Campbell et al., 2018). Assumption was necessary because there is no printed proof of the instructor questions in a test bank, but the topic covered in the laboratory was related to lecture. The instructor has the professional ability to categorize the laboratory examination questions based on the levels of Bloom's Taxonomy. The categorization occurred based on knowledge/comprehension, application/analysis, and synthesis/evaluation levels.

Scope and Delimitations

The quantitative correlational study focuses on one community college in northern New Jersey (Sharpe, 2019). This sample consisted of 51 students taking lectures and laboratory courses in General Biology I, who each have the lecture and matching laboratory class taught by the same instructor. The number of students to be examined does not let the study make the same conclusion for all other majors besides the sciences (Creswell & Creswell, 2018). The study is restricted to one community college, being a delimitation to speak about diversity and the influence on teaching methods, examinations, and grades of other community colleges in the state of New Jersey. A lack of the standardized use of the Bloom's Taxonomy of Educational Objectives for majors without laboratories other than the sciences to test students is another delimitation of the research design to be universally applicable (Agarwal, 2019).

Coverage of the quantitative correlational study was over a period of 2016-2017 for an in-depth analysis, although archival data from 2014-2019 were accessible, but not used. The study consisted of archival data because current semesters and grades cannot be used, as the students could be subject to bias (Richardson et al., 2016). The study comprised one course, General Biology I, and no other courses such as General Biology II, College Biology I and II, Anatomy and Physiology, or Microbiology. General Biology I was used as more archival data were available for this course than other courses. Another delimitation was not able to cover all the lecture assessment questions based on Bloom’s Taxonomy for the laboratory grades in the quantitative correlational study. Relevant assessment questions from the lecture were selected based upon the importance of the questions and Bloom’s Taxonomy question type.

Limitations

One of the important limitations of the quantitative correlational study is the use of three test questions to establish a relationship between lecture assessments and laboratory grades. The three test questions belonging to each of the Bloom’s categories were selected, as only the laboratory grades covering those topics were available from the archival data. The study could be stronger if additional questions were used. Moreover, the laboratory assessments were shorter compared to lecture assessments. More questions from each of the categories could have been selected from the lecture assessments, but an equivalent number of questions covering the respective Bloom’s categories in the laboratory assessments would have been difficult to find. The natural limitations inherent in the research design to measure the performance of students based on the six levels of Bloom’s Taxonomy included the taxonomy and the way to classify levels of learning (Spence, 2019). The six levels of Bloom’s Taxonomy are compared to six-trick appliers, six-trick analysts, and six-trick synthesizers (Ormell, 2019). Correlational research is non-experimental research and is not an experimental research method having more support and validity (Seeram, 2019). Bertucio (2017) described the limitations of Bloom’s Taxonomy in terms of the failure of the taxonomy to nurture the whole person and by merely preparing students just for the job market. The limitations to convenience sampling used in the quantitative correlational study included sampling error and undercoverage (Frey, 2018).

Sampling error is where the sampling method provides a sample whose characteristics differ from the population of interest and under coverage includes certain individuals in the population of interest being excluded by the sampling method (Williamson, 2018). The research factors included using archival data for the laboratory grades of students, comprising the continuous variable. The disadvantages of archival data include the data not being up-to-date and not conforming to the recent changes and conditions. Suppression of statistics is another issue associated with small populations or data pools (Overholser, 2019). One of the other disadvantages of using archival data includes data collection and the accuracy of the methods (Deller, 2019). Although less ideal, the reliability of the quantitative correlational study could be enhanced by using archival data, since the current study could predict consistency between current research and previous data (Creswell & Creswell, 2018). The limitations to the correlational design include not being able to conclude the causal relationships among the measured variables, misuse of correlations, not being able to identify causal relationships, and not being able to provide certain conclusive information (Rezigalla, 2020). The threats to the internal validity of the quantitative correlational study include testing, instrumentation, and experimenter bias (Hoy & Adams, 2016). Threats to testing in the quantitative correlational study were minimized by having a longer time interval between administrations of the tests (Lee et al., 2019). Instrumentation includes instrument changes between tests affecting the scores on the outcome and was minimized by using the same instrument for all tests (Creswell &

Gutterman, 2019). Experimenter bias refers to an experimenter behaving differently with different groups in a study. The type of bias could influence impact the results of the study and can be eliminated through blinding (Richardson et al., 2016).

Threats to external validity could include the interaction of selection of participants and treatment, the interaction of setting and treatment, and interaction of history of past results and treatment (Creswell & Creswell, 2018). The quantitative correlational study was affected by the interaction of selection and treatment because of the narrow characteristics of participants in the study. This threat was minimized by restricting claims about groups where the results cannot be generalized (Verenna et al., 2018). The quantitative correlational study was affected by external validity since the study was restricted to one educational institution (Cor, 2016). This threat was minimized by conducting additional studies in new settings to see if the same results occurred as in the initial setting (Costa et al., 2016).

Chapter Summary

The purpose of the quantitative correlational study was to determine if there is a statistically significant relationship between the biology lecture examination question answers (correct or incorrect), a dichotomous variable, based on Bloom's Taxonomy, and the matching laboratory assessment grade, a continuous variable, received by 51 students in a community college in northern New Jersey. A quantitative correlational study may help to establish the extent to how categories of application, analysis, synthesis, and evaluation versus knowledge and comprehension components of the Bloom's Taxonomy framework are utilized to test freshman students (Gershon, 2018). The measurement was accomplished by analyzing the grades received by students in laboratory assessments in General Biology I for a 1-year period, 2016-2017, although archival data from 2014-2019 were available for the study. A general problem addressed when using Bloom's Taxonomy in teaching was the lack of coverage of all the six major categories, including knowledge, comprehension, application, analysis, synthesis, and evaluation (Kuzu et al., 2019).

Chapter 1 introduced the background and statement of the problem and the purpose of the study. The significance of the study was discussed, and the research questions and hypotheses were listed. A theoretical framework was identified in Chapter 1 and the definition of terms, assumptions, scope, delimitations, and limitations of the study were provided.

The next chapter is Chapter 2, providing a discussion of the literature review related to the quantitative correlational study. The major topics discussed include theory and framework for the study, the descriptive and metatheories, and Bloom's Taxonomy of Educational Objectives. Chapter 2 describes the application of Bloom's Taxonomy of Educational Objectives in various fields of education.

Chapter 2: Literature Review

Bloom's Taxonomy was developed by the American educational psychologist Benjamin Bloom who fostered a common objective towards learning (Bloom, 1956). The taxonomy of educational objectives is a framework for developing the learning curve of students based on instruction (Gershon, 2018). The problem explored in this study was the lack of higher-order thinking skills consisting of analyzing, evaluating, and creating levels of Bloom's Taxonomy, which need to be improved at all levels of education. A general concern when using Bloom's Taxonomy in teaching is the lack of coverage of all the six major categories, including knowledge, comprehension, application, analysis, synthesis, and evaluation (Kuzu et al., 2019). The specific issue when using Bloom's Taxonomy is to gauge the application of the six categories in student assessments by demonstrating if a relationship between assessments and student performance exists or not (Crowe et al., 2017). The purpose of the quantitative correlational study was to determine if there is a statistically significant relationship between the biology lecture examination question answers (correct or incorrect), a dichotomous variable, based on Bloom's Taxonomy, and the matching laboratory assessment grade, a continuous variable, received by 51 students in a community college in northern New Jersey.

Literature establishes the relevance of the research by implying the way students are being tested on lower levels of Bloom's Taxonomy and every effort needs to be made to include higher-level application and synthesis questions in the testing curriculum (Singh et al., 2016). Many of the curricula focus on remembering, understanding, and applying levels in the cognitive area and factual and conceptual knowledge dimensions in the knowledge area (Bozdemir et al., 2019). Researchers have shown no higher-level thinking questions are being used in various universities (Köksal & Ulum, 2018).

Bloom's Taxonomy is lacking in fulfilling its objectives in various parts of the world and a gap, the lack of higher-order cognitive skills in higher education in community colleges should be addressed through research (Adams, 2015). The major sections of the chapter include the literature search strategy, the theoretical framework, research literature review, and the summary and conclusions. The research literature review includes topics such as the Bloom's Taxonomy and academic improvement, Bloom's Taxonomy and cognitive levels, Bloom's Taxonomy in an introductory scripture course, and applying Bloom's Taxonomy in framing multiple-choice questions. Bloom's Taxonomy and outcomes in the curriculum, revised Bloom's Taxonomy, revised Bloom's Taxonomy and alignment, flipped classroom and Bloom's Taxonomy, Bloom's Taxonomy Histology Tool, and Blooming Biology Tool are included in the literature review. Blooming Anatomy Tool, Outcome Based Education through Bloom's Taxonomy, language assessment through Bloom's Taxonomy, and role of comprehension on performance at higher levels of Bloom's Taxonomy are more topics discussed in the review. The literature review includes examination questions in an engineering faculty using Bloom's Taxonomy, using Bloom's Taxonomy matrix to reach higher-level learning objectives, analysis of student science writing using Bloom's Taxonomy, Bloom's Taxonomy in online classroom discussions, and higher-order cognitive skills. This review helps to fill the gaps in the literature and explains contrary literature (Agarwal, 2019).

Literature Search Strategy

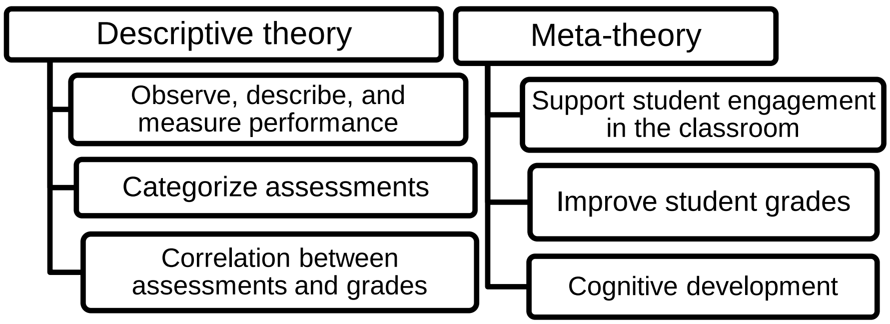
The literature search focused on two major goals: (a) Bloom's Taxonomy and (b) identifying the effect of Bloom's Taxonomy on academics (Adams, 2015). An electronic search was conducted using the library databases of the American College of Education and Google Scholar and Google. Education Resources Information Center (ERIC) and Education Source are two of the databases used from the American College of Education library. Electronic copies of peer-reviewed articles were generated from these databases. ProQuest was another database that was used in the search. The following keywords and phrases were used in the literature search: *Bloom's Taxonomy, Revised Bloom's Taxonomy, Bloom's Taxonomy and Biology, college education, academic performance, Bloom's Taxonomy and Chemistry, Bloom's Taxonomy and the objectives of education, analysis, understanding, cognition, higher education, Bloom's Taxonomy and Mathematics, undergraduate Biology, learning strategy, contrary literature to Bloom's Taxonomy, and teaching.*

Theoretical Framework

Descriptive and meta-theory blend in to create the framework of Bloom's Taxonomy first introduced in 1956 by Benjamin Bloom (Bloom, 1956). Application of the dimensions of the descriptive theory and the dimensions of the meta-theory support the purpose of the study by providing the classification of various educational objectives, enabling the professors to set goals for the students (Watkins, 2020). The first version of Bloom's Taxonomy included six levels of learning: (a) knowledge, (b) comprehension, (c) application, (d) analysis, (e) synthesis, and (f) evaluation (Adams, 2015). Bloom's Taxonomy is effective in creating educational models and promotes a cognitive learning process, stimulating more extensive forms of thinking like a deeper analysis and evaluation of procedures (Gershon, 2018). The six elements form the cognitive dimensions based on Bloom's Taxonomy include verbs like remembering, understanding, applying, analyzing, evaluating, and creating (Nelson et al., 2020). Figure 1 provides a visual representation of how the descriptive and meta-theories relate to Bloom's Taxonomy and improving the academic performance of community college students.

Figure 1

Relationship of the Descriptive and Meta Theories with Bloom's Taxonomy



Descriptive Theory

Descriptive theory aligns with the study of academics because there are some propositions that attempt to describe and explain the world (Watkins, 2020). Sebastien (2016) portrayed descriptive theory could be applied to advocate for the implementation of a set of propositions, attempting to describe something and is accepted by the scientonomy community. Scientonomy is a discipline that uncovers the mechanism of scientific change (Patton, 2019). The origin of the descriptive theory is from the Theory of Scientific Change (TSC) and encompasses the set of all methods and theories accepted at a given time by a scientific community (Barseghyan, 2015). Descriptive research is used to generate and test descriptive theories and is known as exploratory research (Collazos et al., 2019).

One of the major theoretical propositions is to apply descriptive theory to make effective decisions (Sebastien, 2016). In the case of academics, descriptive theory should include the inductive and deductive processes used in learning science (Barseghyan, 2015). Descriptive theories explain how learning occurs and predicts learning results (Watkins, 2020). A formal descriptive theory of software-based creative practice is of cognition with the aim of informing the development of analysis (Collazos et al., 2019).

As the descriptive theory blends in to create the framework of Bloom's Taxonomy, a descriptive theory of awareness for the purpose of supporting groupware development is generated, as well as the taxonomy including awareness information (Collazos et al., 2019). Awareness information improves the collaborative experience of individuals (Sebastien, 2016). When descriptive theory is applied to academics, the dimensions of the theory could provide the classification of various educational objectives (Watkins, 2020). When an empirical method involves observation of a phenomenon in the natural setting, descriptive studies are employed (Barseghyan, 2015).

The quantitative correlational study relates to the observation of the performance of students on assessments based on Bloom's Taxonomy. The research questions relate to descriptive theory because the purpose of the descriptive theory was to predict the relationship and effectiveness of the variables of teaching (Collazos et al., 2019). Descriptive theories are the most basic type of theory and classify specific dimensions of individuals, groups, or situations by summarizing the commonalities found in discrete observations (Watkins, 2020). The two categories of descriptive theory are naming and classification (Sebastien, 2016). Classification theories are commonly known as taxonomies and state if the characteristics of a given phenomena are structurally interrelated and more prevalent (Chiu et al., 2019).

Meta-Theory

All fields of research share some meta-theory, meaning a theory whose subject matter is itself a theory (Apolskii et al., 2019). Understanding the dimensions of meta-theory to support student engagement in the classroom could help motivate and improve student grades (Haslam et al., 2017). Meta means above and goes one step beyond the usual procedural and factual knowledge (Konstabel, 2019). Meta-theory is relevant to the study concerning the academic improvement in the biological sciences since developmental biology could continue to increasingly influence research and theory in cognitive development (Katsumi & Grüninger, 2018). Evolution, under the biological sciences is on the way to becoming a metatheory for cognitive development and developmental psychology (Bjorklund, 2018).

A metatheory for cognitive development could influence Bloom’s Taxonomy as the taxonomy involves various levels of learning like knowledge, comprehension, application, analysis, synthesis, and evaluation. As there is an increasing emphasis of biology in cognitive development, the likely candidate for a metatheory of cognitive development would be the evolutionary theory. Evolution is change over time and the theory about evolutionary theory states students get smarter with time because of the acquisition of more advanced cognitive skills and accomplishments (Bjorklund, 2018).

Research Literature Review

The research literature review is a discussion of Bloom’s Taxonomy and academic improvement (Adams, 2015). Revised Bloom’s Taxonomy and alignment between curriculum objectives are portrayed (Sonmez, 2019). Tools like the Blooming Biology Tool and the Bloom’s Taxonomy Histology Tool are explained in the review (Morton & Colbert-Getz, 2017).

Bloom's Taxonomy and Academic Improvement

Bloom's Taxonomy is a progressive sequence of educational objectives used for lesson planning, assessment, and measurement of learning outcomes by educators (Ramirez, 2017). Six categories of objectives are ordered hierarchically from the simplest to the most advanced in Bloom's Taxonomy (Adams, 2015). Knowledge, comprehension, application, analysis, synthesis, and evaluation are the levels where knowledge is the lowest level of cognition and evaluation is the highest (Gershon, 2018).

Knowledge is concerned with recall of information, discovery, observation, listing, locating, naming, memory, and knowing (Gershon, 2018). Comprehension is about understanding, translating, summarizing, demonstrating, and discussing (Sonmez, 2019). Application is concerned with using and applying knowledge, using problem-solving methods, manipulating, designing, and experimenting (Adams, 2015). Analysis involves identifying and analyzing patterns, organization of ideas, and recognizing trends (Ramirez, 2017). Synthesis involves using old concepts to create new ideas, design and invention, composing, imagining, inferring, modifying, predicting, and combining (Spence, 2019). Evaluation includes assessing theories, comparison of ideas, evaluating outcomes, solving, judging, recommending, and rating (Gitari & Gerrard, 2017).

The instructional process is slowed down by Bloom's Taxonomy, giving ample time for students to digest information at each step of learning (Spence, 2019). For structuring and sequencing, a progressively difficult learning process, Bloom's Taxonomy could be extremely helpful (Gitari & Gerrard, 2017). Bloom's Taxonomy helps educators attain clarity in setting direction and for designing the teaching process (Gummineni, 2020). Not all students should synthesize and evaluate to the same extent (Gershon, 2018). The challenge inherent in Bloom's Taxonomy is open to all students and the challenge is met and experienced in different ways (Adams, 2015). Bloom's Taxonomy provides an excellent framework for teaching, learning, and assessment (Bertucio, 2017).

College professors and university examiners wanted clear educational aims and a universal language like Bloom's Taxonomy for collaboration (Adams, 2015). Bertucio (2017) portrayed Bloom's Taxonomy to create a common language and establish a system where knowledge of student learning would become common or shared. To observe and measure knowledge, and to align instruction, Bloom's Taxonomy was used, besides portraying explicit behavioral criteria, allowing any teacher, a novice, or a veteran to participate in the success of instruction (Spence, 2019). Gershon (2018) implied Bloom's Taxonomy was used to create and share dependable insights and expertise with teachers regardless of the social background or position within a school. Bloom's Taxonomy is accessible and communicable and is indispensable even for policymakers to create a greater need for an objective framework (Gummineni, 2020).

Carmichael et al., (2016) used Bloom's Taxonomy to develop new exam questions to increase undergraduate underrepresented minority (URM) student success through assessment driven interventions. In case of mathematics comparatively, the framework of Revised Bloom's Taxonomy (RBT) (Anderson et al., 2001), when used, provides a method that could be used to teach, learn, or assess mathematics at a secondary or an undergraduate level (Radmehr & Drake, 2018). Bloom's Taxonomy, with its six levels in the cognitive domain, was used to classify the multiple-choice questions (MCQs) from Ayurveda Postgraduate Entrance Examinations

(PGEEs) conducted in different universities in India (Singh et al., 2016). The examinations did not have any questions based on synthesis and evaluation required for higher level thinking (Adams, 2015). Three levels of Bloom's Taxonomy including remembering, understanding, and applying shall be used in case-studies, where small infusions of action learning may show the progress of students (Carloye, 2017).

Bloom's Taxonomy should be used to identify cognitive weaknesses in students of engineering and the sciences, especially in biology (Crowe et al., 2017). To prepare engineers for future jobs in the industry, various universities, education regulators, and teachers are involved in many discussions (Gummineni, 2020). Bloom's Taxonomy is a popular approach to describe three areas of learning, including the cognitive, affective, and psychomotor domains (Kumar et al., 2017). Cognitive domain concerns the recognition of information, skills, and concepts for the development of knowledge and abilities, the affective domain deals with emotional growth and feelings, and the psychomotor domain tends to the development of physical skills (Adams, 2015). Kumar et al. (2017) traced the performance of students by utilizing Bloom's Taxonomy and the test questions were arranged by the noteworthy Bloom's Taxonomy levels.

Bloom's Taxonomy and Cognitive Levels

In a peer-reviewed study, Bloom's Taxonomy was used to evaluate the cognitive levels of the questions in the tenth-grade high school English textbooks in Israel (Assaly & Smadi, 2015). The instrument used to categorize the cognitive levels was a checklist based on Bloom's Taxonomy (Gershon, 2018). To rank the cognitive levels of the questions, a statistical test called the chi-square goodness of fit test (Creswell & Creswell, 2018) was used.

Results indicated 52% of the questions emphasized the comprehension level, and the knowledge and application level had a frequency of 6% and 3.7% respectively (Assaly & Smadi, 2015). Authors of a textbook should be aware of the different cognitive levels for each grade and present questions to students enabling thinking and participation (Gershon, 2018). For any subject, the teachers should evaluate a textbook and check if the goals of the curriculum are properly met (Tarman & Kuran, 2015). According to Sonmez (2019), besides the textbook, gender and the number of languages spoken by students affect the second level of Bloom's Taxonomy, the comprehension skills.

Bloom's Taxonomy was used to examine the cognitive level of questions in the recently revised social studies textbooks by teachers (Tarman & Kuran, 2015). Teachers opined the questions in the textbooks were not distributed in a balanced way based on Bloom's Taxonomy (Gershon, 2018). Descriptive analysis was used to assess the open-ended questions, multiple-choice questions, and prep questions (Creswell & Creswell, 2018). Teachers agreed to the fact of the prep questions and multiple-choice questions being at a far lower cognitive level than the students (Adams, 2015). Higher-level thinking skills including analysis, synthesis, and evaluation were found in the open-ended questions (Spence, 2019). The distribution of questions was not balanced in accordance with Bloom's Taxonomy since there are more low-level thinking questions and the textbooks are still inadequate (Sonmez, 2019).

Bloom's Taxonomy was used as a theoretical framework to review mobile learning and student cognition from pre-kindergarten through twelfth grade and for categorizing the student level of cognitive activities (Crompton et al., 2019). To broaden the learning environment for students, mobile learning including tablets, computer notebooks, or mobile phones are being used (Zhang et al., 2019). The students were found to be immersed in all six levels of Bloom's Taxonomy (Gershon, 2018).

Sixty percent of researchers who are developing good cognitive activities for online learning include and 40% are developing activities minimizing the cognitive skills of students (Crompton et al., 2019). Mobile learning is being integrated into science, mathematics, social studies, and art (Zhang et al., 2019). Community colleges use mobile learning for assignments created for biology courses (Gershon, 2018).

Bloom's Taxonomy in an Introductory Scripture Course

Bloom's Taxonomy helps to categorize and sequence learning, and many courses in higher education rely on the hierarchical organization of Bloom's Taxonomy (Adams, 2015). The six levels in Bloom's Taxonomy include knowledge, comprehension, application, analysis, synthesis, and evaluation and the introductory courses in scripture emphasize remembering content and background as a basis of applying the sacred text to life (Gershon, 2018). No statistically significant correlation was found between the remember task on a comprehensive exam in a New Testament survey course and an application task in an assignment (Bruehler, 2018). Students struggled with the interpretation portion of the application assignment and introductory scripture courses should be better organized around the central integrating practice of interpretation (Spence, 2019). An independent-samples *t*-test was conducted to compare the application assignment scores for the adult and traditional students and a significant difference was found, as traditional college students under age 25 scored higher than the adult students over age twenty-five (Creswell & Creswell, 2018).

Outcome Based Education (OBE) Through Bloom's Taxonomy

Bloom’s Taxonomy is a valuable methodology for learning outcome assessments in outcome-based education (Adams, 2015). To make engineering graduates more competent, an outcome-based education is increasingly important, enabling graduates to be effective in hands-on activities (Kumar et al., 2019). Bloom’s Taxonomy is valuable and portrays the zone of learning in the cognitive, affective, and psychomotor areas (Kumar et al., 2017). Universities, guidance controllers, and educators are working towards an ideal approach for future jobs and livelihood in the field of engineering (Gummineni, 2020). Bloom’s Taxonomy helps to investigate the course outcomes (COs), and the centrality in the evaluation of program outcomes (POs) and program educational objectives (PEOs) (Gershon, 2018).

Language Assessment Through Bloom’s Taxonomy

To measure higher- and lower-level cognitive skills, various assessments or examinations are used based on Benjamin Bloom’s Taxonomy of educational objectives (Ramirez, 2017). A descriptive content analysis was performed to investigate if the exam questions of General English courses were based both on higher and lower order thinking levels (Köksal, & Ulum, 2018). Educators should work towards incorporating higher-level cognitive skills when writing the exam papers (Adams, 2015). Exam questions need to be categorized in terms of four language skills including reading, writing, speaking, and listening based on Bloom’s Taxonomy of Educational Objectives pedagogical tool (Nelson et al., 2020). Teachers should incorporate Bloom’s Taxonomy into the overall teaching process (Gershon, 2018). Knowledge and comprehension levels of Bloom’s Taxonomy are the lower cognitive levels, and were observed in the examined questions, according to the researchers (Spence, 2019).

Applying Bloom’s Taxonomy in Framing Multiple-Choice Questions

By applying Bloom's Taxonomy (BT) in framing multiple-choice questions (MCQs), formative assessment (FA) was improved in first year medical students in India (Kadiyala et al., 2017). Bloom's Taxonomy describes the developmental progression for knowledge in formative assessments driving deeper learning (Gershon, 2018). Students were subjected to multiple-choice question tests at the end of series of lectures, and the multiple-choice questions were framed on Bloom's Taxonomy levels of cognition including knowledge, comprehension, application, analysis, synthesis, and evaluation (Adams, 2015). Pearson's correlation coefficient and a paired *t*-test were used to show how the introduction of multiple-choice questions as a tool for formative assessment at the end of each lecture helped to reinforce learning in first year medical students (Creswell & Creswell, 2018).

Bloom's Taxonomy and Outcomes in the Curriculum

Analysis of physics questions for undergraduate placement examinations according to Bloom's Taxonomy and the outcomes in the curriculum were portrayed by Ayvaci et al. (2016). Physics questions asked in the undergraduate examinations were examined based on the outcomes in the secondary school physics and primary science lessons curriculum (Bhaw & Kriek, 2020). Physics questions were analyzed based on the revised Bloom's Taxonomy in the second stage (Sonmez, 2019).

Data were collected in the form of tables and frequency values (Creswell & Creswell, 2018). Although all candidates who were taking the undergraduate placement examination were required to know the physics from multiple grades, some of the questions in the exam should only be solved by students who took elective physics courses in high school (Bhaw & Kriek, 2020). Radmehr and Drake (2018) examined an assessment-based model for exploring the solving of mathematical problems utilizing revised Bloom’s Taxonomy and facets of metacognition (Krathwohl, 2002). Ayvaci et al. (2016) could use the revised Bloom’s Taxonomy to target broader student thinking in high school physics to improve the undergraduate placement examination performance.

Revised Bloom’s Taxonomy

Revised Bloom’s Taxonomy (RBT) is a revision of the famous Bloom’s Taxonomy and consists of the accumulation of the knowledge and cognitive process dimensions (Bloom, 1956). Four types of knowledge are in the knowledge dimension, including factual, conceptual, procedural, and metacognitive (Adams, 2015). The cognitive processes dimension includes remember, understand, apply, analyze, evaluate, and create (Krathwohl, 2002). The curricula of life studies focused on remembering, understanding, and applying levels in the cognitive dimension (Bozdemir et al., 2019). Science curricula did not focus on the metacognitive knowledge and achievements in the analyzing, evaluating, and creating levels of the taxonomy (Gershon, 2018). The greatest number of achievements were in the conceptual knowledge dimension, including classifications and principles (Spence, 2019).

Revised Bloom’s Taxonomy was used in the laboratory of management for the process of learning (Krathwohl, 2002). The revised Bloom’s Taxonomy contributed to generating interest and improved the process of learning in the laboratory of management (Souza et al., 2020). Various activities were generated in the laboratory of management using the revised Bloom’s Taxonomy (Nelson et al., 2020).

Various companies participated and primary data were collected in the laboratory of management through the completion of forms of decision-making (Gummineni, 2020).

Interviews were conducted with students of participating companies (Creswell & Creswell, 2018). Results indicated students created innovative projects to compete among themselves and active participation during the development of activities in the laboratory of management (Souza et al., 2020).

The reading comprehension skill according to the revised Bloom's Taxonomy could change depending on the cognitive processes (Sonmez, 2019). In physics undergraduate placement examinations, most of the questions were from remembering and comprehension and none of the questions were from evaluation and creation representing high level cognitive steps (Ayvaci et al., 2016). No higher-level thinking questions were used leading to academic improvement (Köksal & Ulum, 2018). The educational taxonomy should induce the memories of students to store, retrieve, and use the intended material effectively (Darwazeh, 2017).

Darwazeh (2017) proposed a new revision of the revised Bloom's Taxonomy to promote the thinking skills of students enhancing the performance levels. The new revision incorporates more mental processes and is intended to be used in broader and comprehensive frames by teachers, supervisors, and educators (Köksal & Ulum, 2018). Traditional or nontraditional learning systems, intending to promote student thinking and skills, should use the new revision to the revised Bloom's Taxonomy (Krathwohl, 2002).

The revised Bloom's Taxonomy (Sonmez, 2019) was used to analyze and explore the similarities and differences among curriculum standards. Larger proportions of the curricula had lower levels of cognitive processes than the higher levels, and conceptual knowledge represented the largest proportion of the curricula (Bing & Yitong, 2019). Recommendations for changes, which need to be brought about in terms of science curricula, are critical (Darwazeh, 2017).

Erdoğan (2017) described the nature of questions about language lessons in terms of the revised Bloom's Taxonomy. Fourth grade students from different schools and the teachers were asked to prepare questions and then the questions were revised based on the revised Bloom's Taxonomy (Sonmez, 2019). The cognitive levels were determined, and the teachers were interviewed to determine the opinions about the questioning skills in lessons and the questioning skills of students (Darwazeh, 2017). Results indicated the questioning skills of teachers and students were at a lower cognitive level (Gershon, 2018). Teachers should improvise the style of teaching and include enough and necessary work to improve the questioning skills of students for better grades (Köksal & Ulum, 2018).

İlhan and Gezeri (2017) compared the reliability of the structure of observed learning outcomes (SOLO) taxonomy and the revised Bloom's Taxonomy to analyze the cognitive levels of assessment questions. Experts used the generalizability theory, describing the statistical framework for designing and conceptualizing reliable observations (Atilgan, 2019). The structure of the observed learning outcomes taxonomy was found to have a higher variance percentage on the assessment questions than the revised Bloom's Taxonomy (Elazzabi & Kacar, 2020).

Structure of observed learning outcomes taxonomy was found to be more reliable than the revised Bloom's Taxonomy was in the determination of the cognitive level of assessment questions in social studies and science textbooks (İlhan & Gezeri, 2017). The structure of observed learning outcomes taxonomy has clear and intelligible levels based on the opinions of teachers (Atilgan, 2019). Objectivity of the structure of observed learning outcomes taxonomy is high (Elazzabi & Kacar, 2020).

Revised Bloom's Taxonomy and facets of metacognition were used in an assessment-based model for exploring the solving of mathematical problems (Radmehr & Drake, 2018). The methods were used to review the assessment of mathematics and to help develop questions targeting broader student thinking (Gershon, 2018). Revised Bloom's Taxonomy and metacognition were used to design questions to address the different cognitive processes and knowledge types (DeMara et al., 2019). Metacognition is the self-awareness of thought processes, cognition about cognition, and knowing about knowing (Katsumi & Grüninger, 2018). These frameworks enable a broader student thinking and constructive cognitive processes (DeMara et al., 2019).

Examination of the Reading Comprehension Skills

Sonmez (2019) used an independent group *t*-test to examine the effect of the gender factor and being monolingual or bilingual on the reading comprehension skills of secondary school age children. The comprehension skills of bilingual children were lower compared to the monolingual children in cognitive skills including analysis, evaluation, and creation (Gershon, 2018). A significant correlation was found between the categories of understanding, applying, analyzing, and creating, but for remembering and evaluating categories (Adams, 2015). A Pearson significance correlation was used for the research and low rates indicated a low significant correlation (Creswell & Creswell, 2018). Because the students did not comprehend correctly, the significance correlation between the cognitive categories occurs in lower rates (Sonmez, 2019). Many countries in Asia, including China and Taiwan, emphasize the memory of factual and conceptual knowledge, and Hongkong emphasizes understanding, in the junior high school science curriculum (Bing & Yitong, 2019). Gender and language skills were not considered in the Asian countries during evaluation, based on Revised Bloom's Taxonomy (Bloom, 1956).

Revised Bloom's Taxonomy and Chemistry Textbooks

Textbooks are a major source of information and play a prominent role in science teaching and learning (Enero & Akangbe, 2015). Textbooks are a means of information for planning and classroom practice (Gershon, 2018). The revised Bloom's Taxonomy was used to classify and analyze end-of chapter questions from three senior chemistry textbooks (Sonmez, 2019). There was a significant difference in the number of questions categorized under evaluation and creation at a higher level of cognition when compared with the lower levels of cognitive processes (Gierasch et al., 2015). There were no metacognitive questions, and the highest number of questions were from understand and analyze categories (Katsumi & Grüninger, 2018).

Revised Bloom's Taxonomy and Alignment Between Curriculum Objectives

Alignment between the objectives of the curriculum of a course and the questions in the national assessment exam for any subject should be in alignment (Cullinane & Liston, 2016). There needs to be an alignment between the objectives and the assessment (Nelson et al., 2020). More than half of the objectives were at the apply level and half of the objectives were intended for applying procedural knowledge in an eighth grade English curriculum (Kozikoglu, 2018). Metacognitive knowledge was not included, and the descriptive study was based on the Revised Bloom's Taxonomy (Katsumi & Grüninger, 2018). The Statistical Package of the Social Sciences, SPSS-18 program, was used to calculate the frequencies and percentages of the distribution of the exam questions based on Revised Bloom's Taxonomy (Sonmez, 2019). The

English course questions were designed at the lower order thinking skills levels, the remember and understand levels (Gershon, 2018).

Biology Examinations

According to qualitative historical research by Cullinane and Liston (2016), examinations in Ireland did not measure student achievement in terms of cognitive thinking skills, reducing academic quality. Biology examination papers were reviewed based on Bloom's Taxonomy (Adams, 2015). Examinations did not promote higher-order thinking skills (Gershon, 2018). The biology examination questions were based on the lower levels of the taxonomy, such as remember, suggesting students could rely on rote learning (Spence, 2019). Current biology examinations promote low-level learning demanding a regurgitation of facts rather than understanding of topics (Kumar et al., 2017). The literature review examined a trend required from terminal exams to a mixed approach, including hands-on testing for the working world (Gierasch et al., 2015).

Flipped Classroom (FC), Lecture Classroom (LC) and Bloom's Taxonomy

The chosen research design in the paper by Morton and Colbert-Getz (2017) is a quantitative research design and the flipped classroom proved to be a better solution to improve student-centered learning at the University of Utah School of Medicine. Multiple choice questions were part of a final examination between two classes of first year medical students (Gierasch et al., 2015). Questions were categorized based on the knowledge level of Bloom's Taxonomy called low cognition and the application or analysis level called high cognition (Adams, 2015).

Student performance was measured using Mann Whitney tests and flipped classroom students performed better than lecture classroom students on analyzing items of high cognition, based on Bloom's Taxonomy (Hoy & Adams, 2016). No difference in performance was seen between flipped classroom and lecture classroom students in terms of knowledge and application (Morton & Colbert-Getz, 2017). The same scenario should not be applicable in later entry learners, as many are disadvantaged with respect to science education (Gitari & Gerrard, 2017). The course instructors are required to engage the later entry learners with higher-order thinking discourses in the science course (Gierasch et al., 2015).

Bloom's Taxonomy Histology Tool (BTHT)

Another tool required to reach the Bloom's Taxonomy pyramid is Bloom's Taxonomy Histology Tool, based on a science course called histology, defined as the study of tissues (Campbell et al., 2018). To build a subject-specific scoring tool for histology multiple-choice questions (MCQs), Bloom's Taxonomy was adopted (Morton & Colbert-Getz, 2017). The researchers were working on a graduate level histology course and used the Bloom's Taxonomy Histology Tool to analyze teacher and student-generated quiz and examination questions (Zaidi et al., 2017). A positive correlation was seen between the Bloom's Taxonomy Histology Tool levels for teacher-generated multiple-choice questions and the responses of students, suggesting higher level Bloom's Taxonomy questions differentiate well between higher and lower performing students (Adams, 2015). No significant correlation existed when examining the Bloom's Taxonomy Histology Tool scores for multiple-choice questions, written by students *versus* the teacher generated multiple-choice questions (Creswell & Creswell, 2018).

The ability to answer histology multiple choice questions was dependent on a different skillset than the aptitude to construct higher-level Bloom's Taxonomy questions (Zaidi et al., 2017). When compared with the Blooming Biology Tool (BBT) meant to help educators write questions at higher levels of Bloom's Taxonomy, the Bloom's Taxonomy Histology Tool was used to differentiate between higher and lower performing students (Crowe et al., 2017). Both the tools are used in the field of science (Gierasch et al., 2015).

Blooming Biology Tool (BBT)

Bloom's Taxonomy should be used to enhance student learning in biology, study skills, and metacognition (Adams, 2015). The Blooming Biology Tool was designed to address research problems and questions including ways to help science faculty to better align the assessments with the teaching activities to help students (Crowe et al., 2017). Blooming Biology Tool is an assessment tool based on Bloom's Taxonomy (Gershon, 2018). The assessment tool could be used to guide and enhance teaching and student learning in a discipline-specific manner in postsecondary education (Spence, 2019). Many of the science questions from college life science exams and standardized tests were ranked using the Blooming Biology Tool (Gierasch et al., 2015).

Blooming Biology Tool is used to design questions at higher cognitive skills levels and in writing study questions at higher levels of Bloom's Taxonomy (Crowe et al., 2017). Another tool called the Blooming Anatomy Tool is specific to the anatomical sciences (Thompson & O'Loughlin, 2015). When both the tools are compared, the Blooming Anatomy Tool served more as a rubric to frame the multiple-choice questions in anatomy and the Blooming Biology

Tool was used by educators to write higher level Bloom's Taxonomy questions in biology (Gershon, 2018).

The Blooming Biology Tool was used to determine the cognitive skills level assessed in the newly developed first year introductory biological concepts of health course (Murrant et al., 2015). The new multi-sectional biological concepts of health course could replace Biology I and Biology II (Campbell et al., 2018). Using the Blooming Biology Tool is an evidence-based approach, demonstrating the Blooming profiles for all components of each course (Crowe et al., 2017). The independent variable was the questions based on the six levels of Bloom's Taxonomy and the dependent variable was the weighted average of the examinations in all the three courses including Biology I, Biology II, and the new Biological Concepts of Health course. Results indicate a deeper level of cognition, oral communication, and independent learning skills in large first year-classes achieved by the new course (Spence, 2019).

Blooming Anatomy Tool (BAT)

In the anatomical sciences, the study of internal structures of organisms, a tool called the Blooming Anatomy Tool was developed as a discipline-specific rubric for utilizing Bloom's Taxonomy in the design and evaluation of assessments (Thompson & O'Loughlin, 2015). To assess the cognitive level associated with course assignments and examination questions, Bloom's Taxonomy is a common resource (Gershon, 2018). In the anatomical sciences, Bloom's Taxonomy has received limited attention as an analytical tool and the Blooming Anatomy Tool was developed (Adams, 2015). The Blooming Anatomy Tool rubric provides discipline-specific guidelines to Blooming anatomy multiple-choice questions (Gierasch et al., 2015). A traditional

Bloom's Learning Objectives (BLO) and the Blooming Anatomy Tool rubrics were used to Bloom a series of anatomy multiple-choice questions (Bloom, 1956).

Role of Comprehension on Performance at Higher Levels of Bloom's Taxonomy

In findings from assessments of healthcare professional students, the first four levels of Bloom's Taxonomy included knowledge, comprehension, application, and analysis and were used to create quiz questions (Verenna et al., 2018). Computer-based tutorials were presented to students on gastrointestinal (GI) histology and physiology in an integrated fashion and separately (Campbell et al., 2018). The validity of Bloom's cumulative hierarchy and the effectiveness of an integrated curriculum were assessed by analyzing student responses to the quiz questions (Gershon, 2018).

No statistically significant differences were found between quiz scores from students who received the integrated curriculum *versus* the students who received the separate tutorials (Verenna et al., 2018). Scores on the lower levels of Bloom's Taxonomy predicted scores on the higher levels and were analyzed through multiple regression analyses in a quantitative study (Gershon, 2018). Educators increased the number of comprehension level questions in course assessments to evaluate the lower order cognitive skills and to predict the success of students on higher-order cognitive skill questions of Bloom's Taxonomy (Spence, 2019).

Examination Questions in an Engineering Faculty Using Bloom's Taxonomy

Bloom's Taxonomy was used to critically evaluate examination questions in an engineering faculty using the classical Bloom's Taxonomy (Ogunwolu et al., 2018). The six levels in Bloom's Taxonomy include knowledge, comprehension, application, analysis, synthesis, and evaluation (Gershon, 2018). Statistical experiments were designed, and an analysis of variance (ANOVA) technique was used to test within and between treatment variations of the differences of means for the six levels of Bloom's Taxonomy (Creswell & Creswell, 2018). Significant differences in ratings of Bloom's Taxonomy for different courses were discovered and significant differences in course ratings at different Bloom's Taxonomy levels were observed (Spence, 2019). Significant differences were seen in group tests of hypotheses on mean ratings for the courses showing upper levels of Bloom's Taxonomy questions like synthesis and evaluation need to be incorporated to produce good engineers (Adams, 2015).

Higher Level Learning

Educators face challenges in teaching students higher-level course content in radiologic sciences (Campbell et al., 2018). Medical imaging techniques require students to apply, analyze, and evaluate various concepts (Adams, 2015). Bloom's Taxonomy addresses higher-level course objectives used by educators (Gierasch et al., 2015). Educators use Bloom's Taxonomy to write learning objectives and outcomes (Gershon, 2018). A Bloom's Taxonomy matrix is another strategy an instructor should employ to ensure students engage with higher-level objectives (Spence, 2019). Instructors could create a matrix and list the six classifications of the revised Bloom's Taxonomy objectives on the left including remember, understand, apply, analyze, evaluate, and create and enter the names of the courses in the top row on the right and describe the courses against every classification (Nelson et al., 2020).

Student Science

In community colleges, where there are adult learners taking general biology classes, scientific discourse needs to be prioritized (Campbell et al., 2018). Later entry learners, who were disadvantaged from receiving a science education, were enrolled in a general science course (Gitari & Gerrard, 2017). The problem descriptions portrayed only the remember and understand categories of Bloom's Taxonomy (Adams, 2015). The exploration questions demonstrated low order thinking skills by the later entry learners and signaled the need for the course instructor to scale up and teach higher-order thinking skills in the science course (Gershon, 2018). No trend or relationship exists among the data between the cognitive level of problem descriptions and matching exploration questions (Assaly & Smadi, 2015).

Online Classroom

With the advent of online courses in many fields including business, education, and the sciences for undergraduate and graduate majors, more research is warranted (Arasaratnam-Smith & Northcote, 2017). Incorporating Bloom's Taxonomy in online discussions increases higher-order thinking in students (Bloom, 1956). As the online discussions are continuous in a thread format with responses to other students and the faculty, the discussions tend to become more effective and meaningful (Thomas et al., 2019).

Community colleges employing online education in the form of hybrid courses for biology have discussions, following a rubric for grading (Adams, 2015). Higher education relies on online communication depending on the written words used for discussion and enhances social relationships through education (Gershon, 2018). In community college education, where many adult learners from different countries are present, online education would not require a refined face-to-face interaction with advanced communication skills (Arasaratnam-Smith & Northcote, 2017).

Higher-Order Cognitive Skills

Biologists used Bloom’s Taxonomy to write and review a set of higher-order cognition questions and to logically analyze the questions (Gershon, 2018). Question difficulty, the length of time required for students to address the questions, and the experience of students with such questions were considered by the biologists (Nelson et al., 2020). Some biologists demonstrated an assumption for questions to just have one answer and not multiple possible answers undermining the effectiveness of higher-order cognition questions (Lemons & Lemons, 2017). Biologists look for ways to measure difficulty when writing higher-order questions (Crowe et al., 2017). The assumption of biologists about the role of questions in student learning strongly influences the types of higher-order questions written (Adams, 2015). Practice builds up expertise for students enabling the students to solve a greater diversity of higher-order questions than without practice (Spence, 2019).

Contrary Literature

In terms of a counterargument, Bloom’s Taxonomy should not align with brain science because some levels of higher-order thinking do happen with no conscious thought at all (Spence, 2019). The question is, if students require fact knowledge analogous to Bloom’s Taxonomy, or if higher-order learning could be achieved directly by engaging in complex questioning and materials (Agarwal, 2019). Results indicated higher-order quizzes improved higher-order test performance and fact quizzes did not improve higher-order learning contrary to Bloom’s Taxonomy (Adams, 2015). The students did not need fact knowledge before higher-order learning and higher-order learning increases most from higher-order retrieval practice (Nelson et al., 2020). Higher-order retrieval practice includes no-stake quizzes with complex material, engaging students in bringing what is known (Gierasch et al., 2015). The contrary literature is applied to middle school and college students and in laboratory and K-12 settings (Carmichael et al., 2016).

Although called ineffectual, intellectual rambling, the consequences of teaching under a hierarchy of behavioral objectives are clear (Bertucio, 2017). Subjects that require contemplation, wonder, appreciation, or merely spending time with a study, should be dismissed as a waste of instructional time (Gierasch et al., 2015). Content and meaning are not given importance and are separated from cognitive work (Nelson et al., 2020). School is reduced to work, and students leave the classroom tired and uninspired (Kuzu et al., 2019). Bloom's Taxonomy engenders a subtle alienation and creates confinement in the ethos, pathos, and logos of a subject (Gershon, 2018). Reality in the classroom is reduced and there are declared days of learning for the sake of learning (Agarwal, 2019).

An approach to integrate upper levels of Bloom's Taxonomy is essential to produce good biologists and engineers, and to provide them with the right training (Ogunwolu et al., 2018). According to Bozdemir et al. (2019), science achievements in life studies course curricula need to be improved and recommendations are to be incorporated to revise the lesson plans. According to Thompson and O'Loughlin (2015), only the first four levels of Bloom's Taxonomy are tested in examinations using multiple-choice questions and the upper two levels including synthesis and evaluation cannot be tested. The Revised Bloom's Taxonomy was found to be effective as a teaching tool for developing reading comprehension skills and language teaching (Sonmez, 2019).

The science curricula need to be revised to improve critical thinking, creative thinking, and entrepreneurship. Life studies course curricula should incorporate key concepts forming the basis of science courses as part of the learning-teaching process and help students develop life skills useful in daily lives (Bozdemir, et al., 2019). Biological science courses should focus on meta-cognitive knowledge crucial for individuals to be responsible for learning (Radmehr & Drake, 2018).

Chapter Summary

The major topics discussed include theory and framework for the research, the descriptive and metatheories and Bloom's Taxonomy of Educational Objectives. The major findings include Bloom's Taxonomy and academic improvement, Bloom's Taxonomy and cognitive levels, Bloom's Taxonomy in an introductory scripture course, and applying Bloom's Taxonomy in framing multiple-choice questions. Bloom's Taxonomy and outcomes in the curriculum, Revised Bloom's Taxonomy, Revised Bloom's Taxonomy and alignment, flipped classroom (FC) and Bloom's Taxonomy, Bloom's Taxonomy Histology Tool (BTHT), Blooming Biology Tool (BBT), and the Blooming Anatomy Tool (BAT) are other findings. More findings include Outcome Based Education (OBE) through Bloom's Taxonomy, language assessment through Bloom's Taxonomy, role of comprehension on performance at higher levels of Bloom's Taxonomy, and engineering faculty using Bloom's Taxonomy. Bloom's Taxonomy matrix to reach higher-level learning objectives, analysis of student science writing using Bloom's Taxonomy, Bloom's Taxonomy and online classroom discussions, and higher-order cognitive skills are discussed. Much of the research implies the students are being tested on lower levels of Bloom's Taxonomy and every effort needs to be made to include higher-level application and synthesis questions in the testing curriculum (Gershon, 2018). According to

Adams (2015), the learning objectives in many training programs and curricula focus on the lower levels of Bloom's Taxonomy, including knowledge and comprehension.

Educators should consider the shortcomings in various professions, such as health professions, where increasing levels of skill and function are necessary. Bloom's taxonomy provides the encouragement needed by instructors to reflect learning objectives in behavioral terms and to consider what the learner could do because of the instruction (Gershon, 2018). Action verbs, remember, understand, apply, analyze, evaluate, and create, are required to write efficient learning objectives for educational institutions (Adams, 2015).

Bloom's Taxonomy is lacking in fulfilling the objectives in various parts of the world and portrays a gap, partially worked on, and filled to a small extent, by conducting a study at a community college in northern New Jersey. A gap remains in the literature as to the assessment of biology laboratory courses using Bloom's Taxonomy in county colleges. Bloom's Taxonomy could be used by professionals training others to write learning objectives that describe the skills and abilities desired in the learners to master and demonstrate (Adams, 2015). This taxonomy leads to deeper learning and transfer of knowledge and skills to a greater variety of tasks and contexts, calling for higher levels of cognitive skills. Bloom's Taxonomy provides a framework for certainty and communicability in ascertaining student learning (Bertucio, 2017). This taxonomy promotes the enlightenment ideal of education as intellectual work.

The following chapter, Chapter 3, provides a quantitative correlational methodology associated with the study and discusses the possibility of a correlation between the biology examinations based on the Bloom's Taxonomy of educational objectives and laboratory assessment grades at a community college in northern New Jersey (Bloom, 1956). Also discussed are the hypotheses framed for the quantitative correlational study, including the null and alternate hypotheses (Creswell & Creswell, 2018). A rationale of the quantitative correlational study and research procedures including the population, sample, recruitment, participation, instrumentation, data collection, and data presentation is discussed. Chapter 3 includes description of the data collection process, data analysis, reliability, and validity of the study along with ethical procedures.

Chapter 3: Methodology

Bloom's Taxonomy of Educational Objectives is one of the most widely used methods of organizing levels of expertise in teaching, including teachers and college professors (Bloom, 1956). Bloom's Taxonomy is used to reach higher-level learning objectives (Spence, 2019). The taxonomy of educational objectives is a framework for developing the learning curve of students based on classroom instruction (Sonmez, 2019). Educational objectives for the knowledge-based goals include various levels of expertise like knowledge, comprehension, application, analysis, synthesis, and evaluation (Spence, 2019).

The problem explored in this study was the lack of higher-order thinking skills consisting of analyzing, evaluating, and creating levels of Bloom's Taxonomy, which need to be improved at all levels of education. A concern when using Bloom's Taxonomy in teaching was the lack of coverage of all the six major categories, including knowledge, comprehension, application, analysis, synthesis, and evaluation (Kuzu et al., 2019). An issue when using Bloom's Taxonomy is to gauge the application of the six categories in student assessments by demonstrating if a relationship between assessments and student performance exists or not (Crowe et al., 2017). The purpose of the quantitative correlational study was to determine if there is a statistically significant relationship between the biology lecture examination question answers (correct or incorrect), a dichotomous variable, based on Bloom's Taxonomy, and the matching laboratory assessment grade, a continuous variable, received by 51 students in a community college in northern New Jersey. A quantitative correlational study could help to establish the extent of categories of application, analysis, synthesis, and evaluation versus knowledge and comprehension components of Bloom's Taxonomy framework utilized to test freshman students (Gershon, 2018).

The research questions addressed the relationship between the lecture assessment questions (correct *vs* incorrect) based on Bloom's Taxonomy of Educational Objectives and the matching laboratory assessment grades in the General Biology I course. Both lecture and laboratory were used for the quantitative correlational study. To achieve the purpose of the quantitative correlational study, the research questions are as follows.

Research Question 1: Is there a significant relationship between the lecture assessment Bloom's Taxonomy question for knowledge and comprehension answer (correct *vs* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey?

Research Question 2: Is there a significant relationship between the lecture assessment Bloom's Taxonomy question for application and analysis answer (correct *vs* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey?

Research Question 3: Is there a significant relationship between the lecture assessment Bloom's Taxonomy question for synthesis and evaluation answer (correct *vs* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey?

Hypotheses

The hypotheses include a null and an alternate hypothesis for all research questions. Alternate hypotheses were $H1_a$, $H2_a$, and $H3_a$, and the null hypotheses were $H1_0$, $H2_0$, and $H3_0$. The hypotheses for the quantitative correlational study were as follows:

$H1_0$: No significant correlation exists between the lecture assessment Bloom's Taxonomy question for knowledge and comprehension answer (correct *vs* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey.

$H1_a$: A significant correlation exists between the lecture assessment Bloom's Taxonomy question for knowledge and comprehension answer (correct *vs* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey.

$H2_0$: No significant correlation exists between the lecture assessment Bloom's Taxonomy question for application and analysis answer (correct *vs* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey.

$H2_a$: A significant correlation exists between the lecture assessment Bloom's Taxonomy question for application and analysis answer (correct *vs* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey.

$H3_0$: No significant correlation exists between the lecture assessment Bloom's Taxonomy question for synthesis and evaluation answer (correct *vs* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey.

$H3_a$: A significant correlation exists between the lecture assessment Bloom's Taxonomy question for synthesis and evaluation answer (correct *vs* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey.

Chapter 3 details the research methods and design used in the quantitative correlational study. A rationale of the quantitative correlational study and research procedures, including the population, sample, recruitment, participation, instrumentation, data collection, and data presentation are discussed. The chapter includes description of the data collection process, data analysis, reliability, and validity of the study along with ethical procedures.

Research Methodology, Design, and Rationale

According to Creswell and Gutterman (2019), quantitative research maintains the assumption of an empiricist paradigm stating concepts originate in experience. For the proposed study, the research method shall be quantitative with a correlational design to analyze the data of students' performance (Creswell & Creswell, 2018). Measuring performance could be achieved through recording the grades received by students in the examinations. Bloom's Taxonomy should help measure the perception of students and provide a partial performance analysis (DeMedeiros et al., 2019).

Methodology

Quantitative research is concerned with the development and testing of hypotheses and generation of models and theories explaining behavior (Hoy & Adams, 2016). The quantitative correlational study shall be used to determine if a relationship exists between student grades and examination questions based on Bloom's Taxonomy of Educational Objectives (see Appendix B). Correlational research is a non-experimental research method utilized to establish a statistical relationship between two variables (Seeram, 2019). Correlational designs use variables like the categorical and continuous variables (Pirlott & MacKinnon, 2016).

Design

A categorical variable is known as a discrete variable and can include a category like the dichotomous variable, while the continuous variable is a quantitative variable (Creswell & Gutterman, 2019). The categorical variable in the quantitative correlational study are the lecture exam questions based on Bloom's Taxonomy of Educational Objectives for General Biology I with two categories of correct *vs* incorrect (see Appendix C). The continuous variable is the matching laboratory assessment grades of students varying based on the differences in questions built on Bloom's Taxonomy categories. Six categories of Bloom's Taxonomy of Educational Objectives include knowledge, comprehension, application, analysis, synthesis, and evaluation (Gershon, 2018). The lecture assessment questions shall be based on Bloom's Taxonomy categories.

Correlational research includes variables covarying or correlating with each other in different abilities (Haythornthwaite, 2018). Changes in one variable are reflected with changes in the other (Hoy & Adams, 2016). In a point biserial correlation, there is one continuous and one dichotomous variable and the correlation is used to measure the strength and direction of association between the variables (Creswell & Creswell, 2018).

Rationale

The quantitative correlational design is suitable to test the hypotheses because of a simple association between two variables, the lecture question answers (correct *vs* incorrect) based on Bloom's Taxonomy and the matching laboratory assessment grades received by students (Hoy & Adams, 2016). The time and resource constraints in choosing the quantitative correlational design incorporates archival observation in the form of tests given to students every semester in the community college (Pryor, 2018). In the quantitative correlational study, the categorical variable should not be manipulated because of the use of archived data, leading to the use of a non-experimental design.

Role of the Researcher

The quantitative correlational study did not involve any personal relationship between the researcher and the participants, who were students. Only the archival grades of the participants who already graduated from the college were used in the study. A professional relationship existed between the participants and the researcher working as an instructor. The professional relationship in the work environment was not subject to ethical problems because archival data were explored for the study, *ex post facto.* I had no personal interaction with the students. No conflicts existed, as the participants were not part of the work environment any longer. The reliability was not undermined since the scores were already recorded on Moodle, the College platform and was used for the study. Validity was not undermined because testing of students was already performed, and archival data were used for the study.

Research Procedures

A quantitative correlational research design for the study was used to observe the relationship between Bloom’s Taxonomy of Educational Objectives and student performance in a General Biology I course. The section describes the research related activities to fulfill the objectives of the quantitative correlational study. Included in the section is the description of population, sample selection, instrumentation, and data collection.

Population and Sample Selection

Target population is defined as the population, participating in a study and refers to the entire group of individuals researchers are interested in generalizing the conclusions (Dahabreh et al., 2020). A target population included 112 students who had taken General Biology I in 2016 and 2017 at the community college in northern New Jersey seeking an associate degree in the sciences (Becker & Vargas, 2018). Students from the General Biology I course were selected for the quantitative correlational study. The grades received by students in 2016-2017 recorded on the college software were used for analysis. Only the data sets considered to be archival data were used for the study.

A sample is a small set of cases, selected for research from a large pool and will generalize to a population (Creswell & Creswell, 2018; Hoy & Adams, 2016). Measures of central tendencies and indicators of variability are estimated from the sample (Quatember, 2019). One measure of central tendency, the mean, could be used for the quantitative correlational study by taking the grades of students from the examinations. Measures of variability like the range, variance, and standard deviation were calculated from the datasets of the community college. The effect of examinations based on Bloom's Taxonomy were measured by the grades the students secure.

For the quantitative correlational study, the sample population or the total sample was 51 students from three semesters. The sample size was determined based on the number of students enrolled in the past semesters. Using Slovin's formula to calculate an appropriate sample size from a population at a 90% confidence interval, the sample size was 38 students for a population of 112 students in the quantitative correlational study. Slovin's formula is used to determine sample size from a population (Arizal & Agus, 2019).

The characteristics required for prospective samples to be included in the quantitative correlational study are the inclusion criteria (Columbus, 2019). Characteristics, disqualifying prospective samples from inclusion in the quantitative correlational study are the exclusion criteria (García-Peña et al., 2018). Factors constituting the inclusion and exclusion criteria are age, sex, race, and ethnicity (Zimmerman et al., 2015). The inclusion criteria for sample selection in the study are the primary requirement of being a student and taking the general biology course. Grades of students in the class were used to void the reason for exclusion criteria.

Participants were from one community college in northern New Jersey where the quantitative correlational study was conducted. Students had taken both the Biology I lecture class and the matching laboratory classes taught by the same instructor. The consent to perform the quantitative correlational study and use of the students' performance data was obtained from the community college (see Appendix D). The sampling strategy used for the quantitative correlational study was convenience sampling, where the selection of participants was based on the ready availability (Quatember, 2019). Convenience sampling is a form of non-probability sampling that does not require an exhaustive list of the study population (Frey, 2018). Certain biases, such as sampling error and undercoverage, meaning the exclusion of certain individuals from the population of interest by the sampling method, were observed (Williamson, 2018).

Instrumentation

The quantitative correlational study used archival data and examined the relationship between the lecture assessment questions (categorical variable with two categories of correct *vs* incorrect) based on Bloom's Taxonomy of Educational Objectives and the academic achievement of students based on matching laboratory assessment grades (continuous variable).

The quantitative correlational study was contingent on the Blooming Biology Tool (see Appendix E), developed by Crowe et al. (2017) as an assessment tool based on Bloom's Taxonomy to assist science faculty in assessments of students' performance. A request letter to use the archival data was emailed to the college (see Appendix F). Raw data was obtained from the Moodle platform and the college assessment assistant (see Appendix G). A certification to protect human research participants was completed (see Appendix H).

A permission letter and the granted approval to use the Blooming Biology Tool are shown in Appendices I and J. Archival data is a type of instrumentation used in the quantitative correlational study. Archival data of student grades from 2016 and 2017 of the community college were used for the quantitative correlational study.

The archival data were the recordings by the instructor who was trained to use the grade reporting software. The data has a second observer, the community college assessment assistant, who checks the grades to ensure validity. Multiple years of assessment data from 2016 and 2017 were used to aid in reliability.

General examples of biology assessment questions based on the knowledge and comprehension category were to classify and describe macromolecules like carbohydrates, fats, proteins, and nucleic acids. A question used in the lecture assessment, belonging to the knowledge and comprehension category, is to comprehend the classes of biological molecules consisting of both small molecules and macromolecular polymers (see Appendix C). The reason for selecting this question was to make students understand the categories of large macromolecules used for various tests in the laboratory sessions. Carbohydrates could comprise both small molecules and large macromolecular polymers, fats do not form polymers, whereas proteins and nucleic acids do form polymers (Campbell et al., 2018).

Application and analysis category does require to predict, for example, the amount of acetic acid in grams required to make 10 liters of a 0.1 molar aqueous solution of acetic acid (see Appendix C). The question was selected in the lecture assessment as the students should know various conversion factors to solve the problem. The analysis used here was applied in the laboratory assessments to use conversion factors and make a solution. Analysis and application category should require students to interpret data, graphs, and figures.

Synthesis and evaluation category does require the development of a hypothesis and designing of an experiment (Gershon, 2018). Evaluation category required participants to critique an experimental design or a research proposal (Crowe et al., 2017). The synthesis and evaluation question used in the lecture assessment includes critical thinking where the absorption of light by an organism called *Halobacterium* is questioned, by comparing it to the action spectrum of green plants (see Appendix C). A question was selected in the lecture assessment, as students are required to know the wavelengths of light absorbed and transmitted by plants and other organisms. The synthesis category here is to understand the absorption of light and will be used in the Spectrophotometry laboratory. Spectrophotometry is where absorbance of a sample solution would increase as concentration of the sample increases (Barry et al., 2020). Spectrophotometry is a quantitative analysis to measure the amount of light absorbed by a substance in solution and is extensively used in biology laboratories (Pereira & Hosker, 2019).

Validity and Reliability

Validity is the degree a measurement or a conclusion is well-founded to and applies to the real world (Creswell & Gutterman, 2019). Inter-rater reliability, or inter-rater agreement, is the degree of agreement among raters and a score of how much homogeneity exists in the ratings given by the judges (Patten, 2017). Murrant et al. (2015) used the Blooming Biology Tool to determine the cognitive skills level in a large, first-year, introductory, multisectional Biological Concepts Health course. According to Murrant et al. (2015), the inter-rater agreement was 86% for the Bloom's level in the entire Biological Concepts of Health course.

Bloom's level for a Biology I course demonstrated an inter-rater agreement of 79.4% (Murrant et al., 2015). The agreement was based on four out of six raters accepting the Bloom level of each question. The level of agreement between raters is called inter-rater reliability (Creswell & Gutterman, 2019). Inter-rater reliability is 1, or 100%, if all the raters *agree*, and is 0, or 0%, if the raters *disagree* (Carpente & Gattino, 2018). The inter-rater reliability above 75% is acceptable for most fields (Jeevannavar et al., 2018).

Archival data were used by the instructor for the quantitative correlational study from where the grades were extracted. The archival data were recorded by the instructor teaching the General Biology I course using Moodle, a learning management system and the system includes a gradebook where grades from multiple years can be stored. Moodle is a reliable platform to run an online or an in-person course as discussions, assignments, and grades can be recorded (Feng, 2018). The college assessment assistant was the second observer of the data who checked the grades to ensure validity. Data from multiple years includes 2016 and 2017 and were used to aid in reliability.

Tool Description

Blooming Biology Tool helps students enhance study skills and metacognition (Crowe et al., 2017). Furthermore, metacognition is understanding of the self-thought processes and higher-order thinking skills (Haeruddin et al., 2020). In addition, metacognition is an awareness of the learning process and predicts life-long learning trends (Demir & Doğanay, 2019). Also, an assessment tool could be used to guide and enhance teaching and learning (O’Neill et al., 2010). Besides, active learning assignments increase student learning skills (Dyer & Elsenpeter, 2018). Moreover, the tests to be taken by students for the quantitative correlational study were based on the Blooming Biology Tool (Crowe et al., 2017). The sample of questions used to test students based on the Blooming Biology Tool in General Biology I examinations are provided in Appendix C, and questions include knowledge/comprehension, application/analysis, and synthesis/evaluation categories

The level of data used for the quantitative correlational study was the interval variable, where the difference between two values is meaningful, and a categorical variable has two categories (correct *vs* incorrect). A variable has one of four different levels of measurements, including nominal, ordinal, interval, or ratio (Hoy & Adams, 2016). The interval level of measurement classifies and orders the measurements and specifies the distances between each interval on the scale as being equivalent along the scale from a low interval to a high interval (Creswell & Gutterman, 2018). The interval level of measurement in the quantitative correlational study indicates the interval between the laboratory assessment scores of students. The categorical variable used is the dichotomous variable, also called a nominal variable and has two categories, 0 for an incorrect answer and 1 for a correct answer to a question in an assessment.

Blooming Biology Tool has six categories for testing students (Murrant et al., 2015). Categories include knowledge, comprehension, application, analysis, synthesis, and evaluation

(Crowe et al., 2017). Knowledge, comprehension, and application categories are used to test lower order cognitive skills (Thompson & O'Loughlin, 2015). The analysis, synthesis, and evaluation categories are utilized to test higher-order cognitive skills (Gershon, 2018) (see Appendix E).

Archival Data

Information existing in files is referred to as archival data and is stored for reference or as an internal record (Rivard, 2019). Archival data is a result of evaluations, and sources of archival data could include schools, colleges, universities, and public records (Creswell & Creswell, 2018). The examination of archival data was required to obtain the information to express the categorical and the continuous variable for the quantitative correlational study.

Archival data of examination grades was extracted using a college password-protected Moodle platform. Moodle is a learning platform, and is a single, secure, and an integrated platform for educators to create personalized learning environments (Feng, 2018). Consent to use the data was secured from the Dean of the community college (see Appendix D).

Archival students' performance data used for the quantitative correlational study was collected in the previous years and could be accessed through the college generated username and password. Archival data should be stored on electronic devices with double password protection (Wu et al., 2019). The advantage of using archival data is to save time and money and allow the possibility of considering the effects of the study over time (Overholser, 2019). Small organizations including community colleges with limited resources could conduct thorough evaluation studies with archival data (Sutherland, 2019). One main advantage of archival data is its cost and time effectiveness, since the data is accessible from the respective website and no changes should be implemented to the data (Kumar, 2019).

The disadvantages of archival data include the data not being up-to-date and not conforming to the recent changes and conditions. Suppression of statistics is another issue associated with small populations or data pools (Overholser, 2019). Suppression could occur when a single causal variable is related to an outcome variable through two mediator variables (Zhang et al., 2019). Archival data enables evaluating a program in retrospect after the program has been completed (Creswell & Creswell, 2018). Archival research does not include laboratory experiments, serving as a powerful tool for social psychology research (Heng et al., 2018). One of the main disadvantages of using archival data includes data collection and accuracy of the methods (Deller, 2019). The reliability of the quantitative correlational study was enhanced by using archival data, as the current study predicts consistency between current research and previous data.

Data Collection

The quantitative correlational study required the collection of data using the Moodle platform of the community college. The permission was granted by the Interim Executive Dean of the College (see Appendix D) upon request (see Appendix F). Moodle could be accessed by the faculty of the college through the staff tab on the community college website. The grades were collected through the Moodle gradebook and the grades were also emailed by the assessment assistant at the community college. At times, the grades were also downloaded onto a flash drive to store information. The lecture assessment answers to the questions based on Bloom’s Taxonomy were collected from student answers of the lecture examinations from 2016 and 2017 through the assessment assistant of the community college. The past laboratory assessment grades from 2016 and 2017 were collected from Moodle and the assessment assistant of the community college (Crowe et al., 2017).

The course used for the quantitative correlational study was General Biology I, including the lecture and the matching laboratory component with both classes taught by the same instructor (Murrant et al., 2015). The assessment grade for the laboratory component of the course was collected using Moodle and the data were set up in the Statistical Package for the Social Sciences for analysis. In addition, the Statistical Package for the Social Sciences (SPSS) is a software package used for interactive statistical analysis (Kusumah, 2018). Besides, a Point-Biserial Correlation was calculated using the collected data (Hoy & Adams, 2016). The Point-Biserial Correlation is used to measure the strength and direction of the association that exists between one continuous variable and one dichotomous variable (Creswell & Creswell, 2018). If there is a perfect positive association in the study, then the Point-Biserial Correlation Coefficient is +1. The correlation coefficient is -1 if there is a perfect negative association, and 0 indicates no association (Creswell & Gutterman, 2019).

Data Preparation

A first step in data preparation was to gather data for the quantitative correlational study and archival data from the community college was used for the purpose. Grades of students who had completed General Biology I from three semesters were used. The three semesters from where data were gathered are spring 2016, fall 2016, and spring 2017. The second step was to discover and assess data and the data for analysis were prepared in the form of a table containing examination grades. Three data sets in total were used and entered in the Statistical Package of the Social Sciences software. Separate datasets for the three categories are knowledge/comprehension, application/analysis, and synthesis/evaluation. Each of the data sets had three columns, including one column for the participants, one column for the dichotomous variable, and the final column for the matching laboratory assessment score (see Appendix G).

The first data set included the dichotomous variable being either 0 or 1 for an incorrect or correct answer for the Bloom's Taxonomy knowledge/comprehension lecture assessment question and the laboratory assessment grade of 51 students was used as a continuous variable. The second data set included the dichotomous variable, where either 0 or 1 was used for an *incorrect* or *correct* answer for the Bloom's Taxonomy application/analysis lecture assessment question and the laboratory assessment grade of 51 students was used as a continuous variable. The third data set included the dichotomous variable where either 0 or 1 was for an *incorrect* or *correct* answer for the Bloom's Taxonomy synthesis/evaluation lecture assessment question and the laboratory assessment grade of 51 students was used as a continuous variable.

A third step was to cleanse and validate the data. Extraneous data and outliers were removed from the data sets. Tables were constructed using Microsoft Word and the data were entered into the tables manually after conforming the data to a standardized pattern. Tables were used primarily to organize the data and the missing values were screened manually for a significant analysis of results. A Point-Biserial Correlation Coefficient was established between the lecture assessment question answers (correct *vs* incorrect), the categorical variable and the matching laboratory assessment grade, the continuous variable (Creswell & Creswell, 2018). The final step was to store the data in the form of Microsoft Excel sheets and to use the Statistical Package of Social Sciences software for further processing and analysis.

Data Analysis

The study selected a relevant lecture assessment question based upon a valuable skill students should learn rooted in Bloom's Taxonomy types and used a Point Bi-serial correlation to determine if there was a relationship with the laboratory assessment grade matching the lecture class. The point-biserial correlation has six assumptions including having a continuous variable, a dichotomous variable, two paired variables, not having significant outliers, homogeneity of variances, and an assumption of normality (Laerd, 2017). Moreover, the data of the quantitative correlational study meet the first three assumptions. First, the continuous variable is the matching laboratory assessment grade. Second, the dichotomous variable is the lecture question answer with two categories of correct versus incorrect. Third, both the continuous and the dichotomous variables are paired for every student. In addition, the last three assumptions were tested using the Statistical Package for the Social Sciences.

The fourth assumption of having outliers or not was detected by creating boxplots of the data using the Statistical Package for the Social Sciences. The fifth assumption of homogeneity of variances was tested using Levene's test of equality of variances using the Statistical Package for the Social Sciences (Laerd Statistics, 2017). Final and the sixth assumption of normality for statistical significance was tested using the Shapiro-Wilk test for normality using the Statistical Package for the Social Sciences.

The purpose of the data analyses was to determine the relationship between the laboratory grades received by students and the lecture assessment questions based on the Blooming Biology Tool for the General Biology I course. Data was presented based on the lecture examinations having questions at the six levels of the Blooming Biology Tool (categorical variable) and the laboratory grades received by students (continuous variable). A relationship between the Blooming Biology Tool and the research questions were established in the quantitative correlational study (see Appendix B).

The Point-Biserial Correlation Coefficient ranges from -1 to +1, where a -1.0 indicates a perfect negative association, a + 1.0 indicates a perfect positive association, and a 0.0 indicates no association to show no statistical relationship between the two variables. The quantitative correlational study tested for a relationship between the knowledge/comprehension, application/analysis, and synthesis/evaluation categories of lecture assessments and the matching laboratory grades of students. If a significant relationship was found between the lecture assessment question answers (correct *vs* incorrect) and the laboratory grade, the null hypotheses were rejected and if a significant correlation was not found, then the null hypotheses were accepted.

The Point-Biserial Correlation, a correlational statistical test, was used to analyze the data to answer the research questions and test the hypotheses (Hoy & Adams, 2016). Point-Biserial Correlation Coefficient denoted as r_{pb}, is a measure of the strength of the association between two variables (Onoshima et al., 2019). The Point-Biserial Correlation Coefficient was used to determine the relationship between the research hypotheses in the quantitative correlational study (Laerd Statistics, 2017). A correlation coefficient was calculated based on the students' laboratory grades (continuous variable) and the lecture assessment questions (categorical variable). A relationship was seen by using graphs to demonstrate a positive, negative, or no association between the two variables.

The most current version of the Statistical Package of Social Sciences software was used to allow for the comparison of data between two different numbers (Bala, 2016). Correlation between the lecture assessment questions following Bloom's Taxonomy of Educational Objectives and laboratory grades was analyzed. The relationship between the lecture assessment questions following the Bloom's Taxonomy of Educational Objectives including knowledge/comprehension, application/analysis, and synthesis/evaluation and the laboratory grades received in the General Biology I course was analyzed.

Reliability and Validity

Reliability and validity are two terms for research to attain believability drawn from conclusions (Kukul & Karatas, 2019). Reliability measures repeatability, consistency, or accuracy over a period (Creswell & Gutterman, 2019). Validity refers to a test or procedure measuring what it is supposed to compute (Fallon, 2016). The Blooming Biology Tool used in the Biological Concepts of Health course had an inter-rater reliability of 86%, defined as the degree of agreement between raters (Murrant et al., 2015). The inter-rater reliability of 86% assesses the degree of agreement between two or more raters in the appraisals. The Blooming Biology Tool used in the correlational study has an agreement of 86% between raters increasing the reliability of the instrument and the study.

Archival data of examination grades for the quantitative correlational study were extracted using a college password-protected Moodle platform. Moodle is a learning platform and is a single, secure, and integrated platform for educators to create personalized learning environments and includes a gradebook (Feng, 2018). The archival data was the recording by the instructor who was trained to use the grade reporting software. The data has a second observer, the community college assessment assistant, who checks the grades to ensure validity. Multiple years of data from 2016 and 2017 were used to aid in reliability. According to a study on Moodle Learning Management System, the reliability coefficient calculated by Cronbach's alpha was 0.94, and an exploratory factor analysis was performed to show the validity of the structure (Yildiz et al., 2018).

Reliability

Threats to reliability include factors causing errors, and the inconsistency in a measurement could arise from such errors (Chiu et al., 2019). The sources of error could include researcher error, environmental changes, and participant changes (Creswell & Creswell, 2018). Inconsistency in measurement arises from such errors (Hammer et al., 2018).

Researcher error is an error and should be prevented by exercising caution when attempting to record scores and conducting measurements in the quantitative research study (Hoglund et al., 2019). Errors from environmental changes including the testing environment shall be minimized by recording the measurements from all individuals under identical conditions (Creswell & Gutterman, 2019). Participant changes include the attitude of study participants to the examinations and can change based on circumstances. Pressure from academics would matter for lack of sleep and focus by students (Berthelon et al., 2019). Hunger and tiredness could lead to a lower mental performance and may be minimized by rest before an examination (Kane & Clark, 2016).

Validity

Validity is to what degree a measurement, or a conclusion is well-founded to and applies to the real world. Two types of validity exist. Internal and external validity determine if the results of a study are trustworthy and meaningful (Creswell & Creswell, 2018).

Internal Validity

Internal validity is the extent a study establishes a trustworthy cause-and-effect relationship between a treatment and outcome (Creswell & Gutterman, 2019). The limitations to the correlational design include not being able to draw conclusions about the causal relationships among the measured variables, not being able to identify causal relationships, not being able to provide certain conclusive information, and misuse of correlations (Rezigalla, 2020). Internal validity in the quantitative correlational study is comprised of the examinations based on Bloom’s Taxonomy of Educational Objectives and the grades received by students. The threats to internal validity of the quantitative correlational study included testing, instrumentation, and experimenter bias (Hoy & Adams, 2016).

Testing is when participants become familiar with the outcome measure and remember responses for later testing (Johnson et al., 2019). The threats to testing were minimized by having a longer time interval between administrations of the tests (Lee et al., 2019). Instrumentation includes instrument changes between tests impacting the scores on the outcome and were minimized by using the same instrument for all tests (Creswell & Gutterman, 2019). Tests for the quantitative correlational study are based on the Blooming Biology tool. The tool cannot be changed for the study in every test and the questions asked in the tests are based on the Blooming Biology Tool.

Experimenter bias refers to an experimenter behaving in a different way with different groups in a study. Bias of this type could affect the results of the study and may be eliminated through blinding (Richardson et al., 2016). Blinding refers to participants and testers being unaware of what intervention is being received to avoid bias in a study (Gill & Prasad, 2019). The quantitative correlational study included an intervention like Bloom's Taxonomy of Educational Objectives, but is not a scientific experiment, leading to no threats of internal validity (Streiner, 2016).

External Validity

External validity refers to the application of the outcome of a study to other settings (Creswell & Gutterman, 2019). External validity is threatened when a study does not consider the interactions of variables (Gethin et al., 2019). Threats to external validity could include the interaction of selection of participants and treatment, interaction of setting and treatment, and interaction of history of past results and treatment (Creswell & Creswell, 2018).

Quantitative correlational study was affected by the interaction of selection and treatment because of the narrow characteristics of participants in the study. The threat was minimized by restricting claims about groups to whom the results cannot be generalized (Verenna et al., 2018). The quantitative correlational study was affected by external validity because the study is restricted to one educational institution (Cor, 2016). The threat was minimized by conducting additional studies in new settings to see if the same results occur as in the initial setting (Costa et al., 2016).

The Blooming Biology Tool was used for the quantitative correlational study based on a good test-retest reliability and internal consistency overriding construct validity (Murrant et al., 2015). Construct validity is another type of validity and is a threat to research findings and is the quality of choices about the forms of variables, like the categorical and continuous variables (Mueller et al., 2018). Demand characteristics in a research setting include unstated demands, like the desire to cooperate and anxiety about evaluation, contributing to the threats of the construct validity of an experiment (Creswell & Gutterman, 2019).

Ethical Procedures

Research should be ethically practiced and evaluated (Fatien & Nizet, 2019). Validity and objectivity cannot be separated from ethical and practical implications (Zyphur & Pierides, 2017). Ethical considerations are important for the credibility and believability of a study and the results (Glenna et al., 2019). The arrangement and procedures required to protect human participants in the quantitative correlational study should include obtaining the Letter of Consent and approval from the community college administration (see Appendix D).

Ethics matters in scientific and academic research helps people understand clearly about professional expectations and to be aware of research misconduct, fabrication, and falsification (Creswell & Gutterman, 2019). Ethical concepts and processes and awareness of legal requirements for human subjects' protections and related ethical guidelines were completed for the quantitative correlational study (see Appendix H). The Collaborative Institutional Training Institute was responsible for awarding the certificate for Protecting Human Research Participants (Hadden et al., 2018).

Anticipating ethical issues in a study is normal as ethics could affect the professional and personal development of students (Creswell & Creswell, 2018). Protection of vulnerable groups and permission to use student data are key elements in avoiding ethical issues (Vakkuri et al., 2019). The permission to use the Blooming Biology Tool for the quantitative correlational study has been obtained through email (see Appendices I and J).

Archival data used in the quantitative correlational study were stored in a secure platform known as Moodle in a password protected community college website. Identifiable data of the participants cannot be revealed for the quantitative correlational study and identity of the students should not be collected, increasing the confidentiality of the quantitative correlational study (Creswell & Gutterman, 2019). The community college platform used for the quantitative correlational study, Moodle, is a secure platform dedicated to the faculty of the college. The platform was protected by a username and a password.

Collected information and data of the quantitative correlational study will be retained for 3 years after the study is completed. The reason is to prevent misconceptions about the data from other researchers. Student data is archived, and the community college could retain the data on the Moodle website for the faculty.

Chapter Summary

Bloom's Taxonomy of Educational Objectives classified the intellectual skills of most concern to educators into categories representing increasing complexity (Spence, 2019). The purpose of the quantitative correlational study was to determine if there is a statistically significant relationship between the biology lecture examination question answers (correct or incorrect), a dichotomous variable, based on Bloom's Taxonomy, and the matching laboratory assessment grade, a continuous variable, received by 51 students in a community college in northern New Jersey. The Blooming Biology Tool was used to frame the questions based on Bloom's Taxonomy of Educational Objectives (Adams, 2015).

Six categories of educational objectives including knowledge, comprehension, application, analysis, synthesis, and evaluation were tested using three research questions (Gershon, 2018). Framing of examination questions based on the Blooming Biology Tool and the answers to the questions was the categorical variable. The laboratory grades received by students measuring academic achievement was the continuous variable. The quantitative correlational study had access to archival data from 2014 to 2019.

An introduction, research design and rationale, and research procedures were included in Chapter 3. The quantitative correlational study utilized descriptive statistics and the Point-Biserial Correlation. The Point-Biserial Correlation was used to determine the strength of a linear relationship between one continuous variable and one dichotomous variable with two categories, 0 and 1 (Hoy & Adams, 2016). Chapter 3 is a description of the ethical procedures in detail and how the quantitative correlational study protects the confidentiality of the samples.

Data collection and data analysis and results are included in Chapter 4. Chapter 4 includes presentation of data, sample population, and the kind of statistics employed. The Chapter includes graphs and figures and reliability and validity concepts followed by the Chapter summary.

Chapter 4: Research Findings and Data Analysis Results

Learning is a biological function of human beings and memory helps with association of information (Gershon, 2018). Learning is attained through effort, repetition, and perseverance by students and teachers within the context of Bloom's Taxonomy (Bibi et al., 2020). Bloom's Taxonomy was developed in the 1950s by the American educational psychologist Benjamin Bloom who fostered a common objective towards learning (Chandio et al., 2021). Bloom's Taxonomy is the hierarchy of processes ranging from simple to complex and there are six levels of expertise starting from knowledge, comprehension, application, analysis, synthesis, and evaluation (Spence, 2019). The taxonomy of educational objectives is a framework of developing the learning curve of students based on instruction and the effect of affect (Nelson et al., 2020). The overall area of interest for the study involves the observation of academic achievement in lecture and laboratory courses of General Biology using Bloom's Taxonomy of Educational Objectives at a community college in northern New Jersey. Research has been conducted in this area for promoting students to use higher-level thinking skills (Erdimez et al., 2017).

The problem explored in this study was the lack of higher-order thinking skills consisting of analyzing, evaluating, and creating levels of Bloom's Taxonomy, which need to be improved at all levels of education. The purpose of the quantitative correlational study was to determine if there is a statistically significant relationship between the biology lecture examination question answers (correct or incorrect), a dichotomous variable, based on Bloom's Taxonomy, and the matching laboratory assessment grade, a continuous variable, received by 51 students in a community college in northern New Jersey. A quantitative correlational study could help to establish the extent of the categories of application, analysis, synthesis, and evaluation versus knowledge and comprehension components of the Bloom's Taxonomy framework being utilized to test community college students (Gershon, 2018).

Research Questions

The research questions address the relationship between Bloom's Taxonomy of Educational Objectives and the assessments or examinations in the General Biology I course. Both lecture and laboratory courses were used for the quantitative correlational study. A Point-Biserial Correlation test was used to analyze the research questions (Creswell & Creswell, 2018). Research Question 1, the categorical (dichotomous) variable is the lecture assessment question answers (correct *vs* incorrect) based on the knowledge/comprehension Bloom's level, and the continuous variable is the matching grades received by students in General Biology I laboratory examinations. For Research Question 2, the categorical (dichotomous) variable is the lecture assessment question answers (correct *vs* incorrect) based on the application/analysis Bloom's level, and the continuous variable is the matching grades received by students in General Biology I laboratory examinations. For Research Question 3, the categorical (dichotomous) variable is the lecture assessment question answers (correct *vs* incorrect) based on the synthesis/evaluation Bloom's level, and the continuous variable is the matching grades received by students in General Biology I laboratory examinations. To achieve the purpose of the quantitative correlational study, the research questions are as follows.

Research Question 1: Is there a significant relationship between the lecture assessment Bloom's Taxonomy question for knowledge and comprehension answer (correct *vs* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey?

Research Question 2: Is there a significant relationship between the lecture assessment Bloom's Taxonomy question for application and analysis answer (correct *vs* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey?

Research Question 3: Is there a significant relationship between the lecture assessment Bloom's Taxonomy question for synthesis and evaluation answer (correct *vs* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey?

Hypotheses

The hypotheses include a null and an alternate hypothesis for all the research questions. Alternate hypotheses are $H1_a$, $H2_a$, and $H3_a$ and the null hypotheses are $H1_0$, $H2_0$, and $H3_0$. The hypotheses for the quantitative correlational study are as follows.

$H1_0$: No significant relationship exists between the lecture assessment Bloom's Taxonomy question for knowledge and comprehension answer (correct *vs* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey.

$H1_a$: A significant relationship exists between the lecture assessment Bloom's Taxonomy question for knowledge and comprehension answer (correct *vs* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey.

$H2_0$: No significant relationship exists between the lecture assessment Bloom's

Taxonomy question for application and analysis answer (correct *vs* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey.

$H2_a$: A significant relationship exists between the lecture assessment Bloom's Taxonomy question for application and analysis answer (correct *vs* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey.

$H3_0$: No significant relationship exists between the lecture assessment Bloom's Taxonomy question for synthesis and evaluation answer (correct *vs* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey.

$H3_a$: A significant relationship exists between lecture assessment Bloom's Taxonomy question for synthesis and evaluation answer (correct *vs* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey.

Chapter 4 comprises the data collection procedures used in the study and the treatment or intervention, if applied. Data analysis, results, reliability, and validity are discussed in the chapter. Statistical analyses used for the quantitative correlational study are demonstrated using tables and graphs.

Data Collection

A quantitative correlational study required the collection of data using the Moodle platform of the community college in northern New Jersey. As a result, Moodle was accessed by the faculty of the college through the staff tab on the community college website. First, the past examination grades from 2016 and 2017 based on the Blooming Biology Tool were collected (Crowe et al., 2017). Second, data were collected based on lecture and laboratory examinations available on Moodle from the fall and spring semesters in 2016 and 2017. Next, the number of students for data collection was 51 including the fall and spring semesters. Also, there was no deviation from the data collection plan presented in Chapter 3 and it is the same archival data collection plan. Finally, the examination grades were based on each semester, usually 4 months, from where the grade points were collected.

The number of students used in the quantitative correlational study was 51 students and the grade data from the accessible assessments of the years 2016 and 2017 were used in the study. Additionally, the sample size was determined based on the number of students enrolled in the past semesters. Using Slovin's formula to calculate an appropriate sample size from a population of 112 students, at a 90% confidence interval, the sample size was 38 students in the quantitative correlational study. The total sample size was 51 students and was higher than the required sample size based on Slovin's formula (Arizal & Agus, 2019).

The course used for the quantitative correlational study was General Biology I, including lectures and laboratories (Crowe et al., 2017). First, the final examination grade for the laboratory component from the course was collected using Moodle. Second, data were transferred to the Statistical Package for the Social Sciences, a software package used for interactive statistical analysis (Kusumah, 2018). Third and finally, a Point-Biserial Correlation was calculated using the collected data (Hoy & Adams, 2016). The Point-Biserial Correlation was used to determine the strength of a linear relationship between one continuous variable and one nominal variable with two categories also called the dichotomous variable (Laerd Statistics, 2017).

The value of the point-biserial correlation coefficient can range from -1 to +1. The relationship is stronger as the values approach ±1 and are indicated by larger absolute values of the coefficient. No linear relationship exists between the two variables if the value of the coefficient is zero (Creswell & Gutterman, 2019).

Although there are six levels of Bloom's Taxonomy, including knowledge, comprehension, application, analysis, synthesis, and evaluation, the questions in the examinations covered, included two levels overlapped at a time like knowledge/comprehension, application/analysis, and synthesis/evaluation (Campbell et al., 2018). The students were still essentially tested on all the levels of Bloom's Taxonomy where two levels were blended into one question at one time. As a result, the three main overlapped categories of Bloom's Taxonomy questions used in the General Biology I course and used for the quantitative correlational study, are shown in Table 1. Overlapping levels include the knowledge/comprehension level, the application/analysis level, and the synthesis/evaluation level. The knowledge/comprehension level question in the examinations includes the recall of a pattern, structure, or setting, and the understanding of what is being communicated. The application/analysis level question in the examinations includes the use of abstractions in concrete situations and the breakdown of communication into constituent elements. Lastly, the synthesis/evaluation level question in the examinations includes the putting together of elements and judgements about the value of materials and methods.

Students used for the quantitative correlational study were enrolled in the years 2016 and

2017 at the community college, and the grades received by the 51 students in the laboratory assessments were recorded for each of Bloom's levels. Additionally, permission to use the data from Moodle was secured from the Dean of the community college (see Appendix D). Furthermore, the students were adults and hence parental consent was not required. To collect the grade points of students, the archival data from Moodle were used and statistical analyses were performed.

Table 1

Selection of Students

Year	Course	Bloom's taxonomy levels	Number of students (*N*)
2016–2017	General Biology I	Knowledge and comprehension	51
2016–2017	General Biology I	Application and analysis	51
2016–2017	General Biology I	Synthesis and evaluation	51

The students from General Biology I complete lecture and laboratory assessments during the semesters at the College. There could be multiple lectures and laboratory assessments every semester. For example, there could be the first assessment in lecture covering the first three chapters and the same topics will be covered practically in the first three laboratory classes. The lecture and laboratory assessments are interdependent as the concepts taught in lecture are applied practically in laboratories and the assessments reflect the same. The assessments were based on Bloom's Taxonomy of Educational Objectives and the questions were formatted based on the levels of Bloom's Taxonomy including knowledge/comprehension, application/analysis, and synthesis/evaluation.

Questions belonged to knowledge and comprehension, application and analysis, and synthesis and evaluation levels (see Appendix C). Categorical variables in the quantitative correlational study are the lecture assessment questions based on Bloom's Taxonomy with two categories of correct versus incorrect. The continuous variable is the matching laboratory assessment grades of students varying based on the differences in questions built on Bloom's Taxonomy categories. In addition, the topic tested in the lecture assessment and the answer (correct *vs* incorrect) was related to the matching grade in the respective laboratory assessments as the same topic tested in lecture is covered in the laboratory assessments.

Instrument

The quantitative correlational study used archival data to examine the relationship between the lecture assessment questions (categorical variable with two categories of *correct vs incorrect*) based on Bloom's Taxonomy of Educational Objectives and the academic achievement of students based on matching laboratory assessment grades (continuous variable). General examples of biology assessment questions based on the knowledge and comprehension category could be to classify and describe macromolecules like carbohydrates, fats, proteins, and nucleic acids. A question used in the lecture assessment belonging to the knowledge and comprehension category is to comprehend the classes of biological molecules consisting of both small molecules and macromolecular polymers. Application and analysis categories do require predicting, for example, the amount of acetic acid in grams required to make ten liters of a 0.1 molar aqueous solution of acetic acid. The question was selected in the lecture assessment as the students should know various conversion factors to solve the problem. The synthesis and evaluation question used in the lecture assessment includes critical thinking where the absorption of light by an organism called *Halobacterium* is questioned, by comparing it to the action spectrum of green plants (Appendix C).

Archival Data

A first step in data preparation was to gather data for the quantitative correlational study, and archival data from the community college were used for this purpose. Second, the grades of students who have completed General Biology I from three semesters were used and the three semesters from where data were gathered are spring 2016, fall 2016, and spring 2017. As a result, there were three data sets in total entered in the Statistical Package of the Social Sciences software. Third and finally, there were separate datasets for the three categories of knowledge/comprehension, application/analysis, and synthesis/evaluation. Each of the data sets had three columns, including one common column for the participants, one column for the dichotomous variable, and the final column for the matching laboratory assessment score (see Appendix G). There are 51 participants, and the dichotomous variable is either an incorrect answer or a correct answer in the lecture assessments based on Bloom's Taxonomy of Educational Objectives.

Data Analysis and Results

The purpose of the data analyses was to determine the relationship between the grades received by students and the examinations conducted based on the Blooming Biology Tool for General Biology I lecture and laboratory. Data is presented based on the correct versus the incorrect answers (categorical variable) for the lecture examination questions at all levels of the Blooming Biology Tool and the matching laboratory grades received by students (continuous variable). The levels included knowledge/comprehension, application/analysis, and synthesis/evaluation. The relationship between the Blooming Biology Tool and the research questions was established in the quantitative correlational study (see Appendix B). The lecture examinations had questions based on the Blooming Biology Tool having the knowledge/comprehension, application/analysis, and synthesis/evaluation questions. In the study, a correlation or a relationship was established between the lecture assessment questions and the laboratory grades received by the students. The research questions and hypotheses addressed the relationship between the lecture assessment questions based on the Blooming Biology tool and the laboratory grades and described if the relationship was significant or not.

Six statistical assumptions for the point-biserial correlation were used for the quantitative correlational study. First, the three assumptions relate to the study design and the next three assumptions are related to the nature of the data, tested using the Statistical Package for the Social Sciences. The first three assumptions are characterized by having a continuous variable, a dichotomous variable, and the pairing of the two variables. Next, the continuous variable is the matching laboratory grades received by students and the dichotomous variable is the incorrect versus the correct answers in the lecture assessments based on Bloom's Taxonomy of Educational Objectives. The next three assumptions include not having significant outliers as demonstrated in Figures 2, 3, and 4, homogeneity of variances assessed by the Levene's test for equality of variances, and the assumption of normality assessed by the Shapiro-Wilk's test. No violations to these assumptions exist and the results reveal one nonsignificant correlation, and two significant correlations using the data. Statistical analyses including Descriptive Statistics and the Point-Biserial Correlation were calculated using the Statistical Package for the Social Sciences, Version 27, a leading statistical software.

In the quantitative correlational study, box plots in Figures 2, 3, and 4 were solely used as one of the assumption testing methods just to check for the presence or absence of outliers for the Point-Biserial correlation. The whiskers on the top and bottom of every box represent the highest and the lowest grade received by the students. The boxes on the right-hand side represent the grade distribution for the correct answers given by students in the lecture assessments and the respective maximum and minimum score is portrayed by the top and bottom whiskers and the boxes on the left-hand side show the grade distribution for the students with the incorrect answers. Outliers could be data points showing an abnormal grade for a student, and none can be seen in Figures 2, 3, and 4.

Figure 2

Box Plot of Knowledge/Comprehension Question Answers

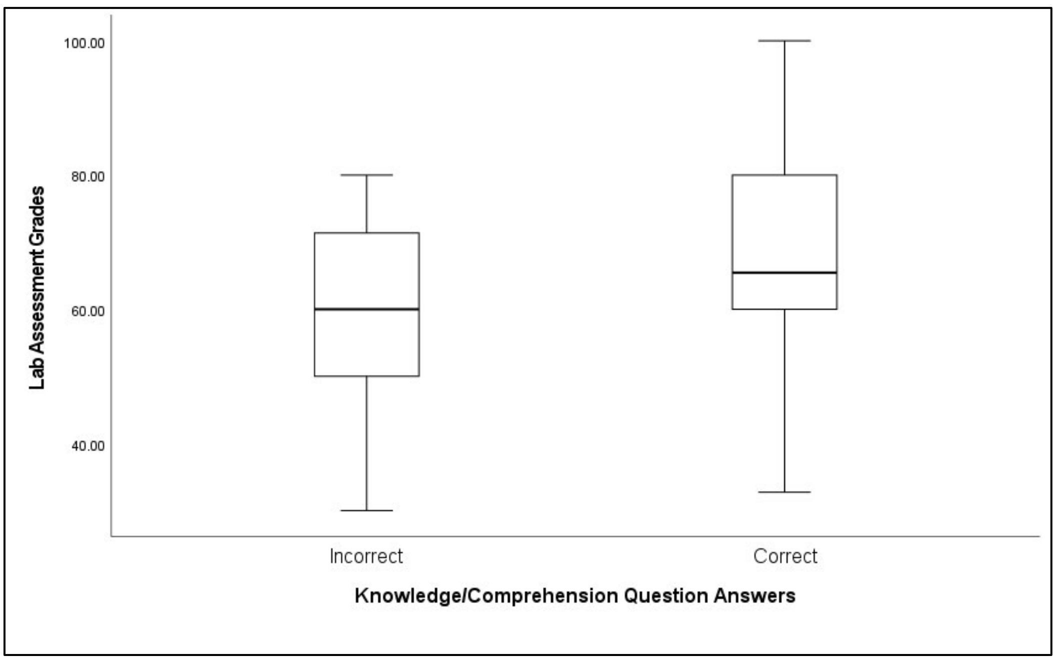


Figure 2 portrays the absence of outliers in the quantitative correlational study and shows the knowledge/comprehension answers (incorrect *vs* correct), a dichotomous variable, and the matching laboratory grades, the continuous variable. The x-axis for the box plot of Figure 2 is the knowledge/comprehension answers (incorrect *vs* correct) and the y-axis represented the lab assessment grades. Outliers are data points outside the whiskers of the boxplots, and according to Figure 2, there are no outliers in the data, as assessed by the inspection of the boxplots for values greater than 1.5 box-lengths from the edge of the box.

Figure 3

Box Plot of Application/Analysis Question Answers

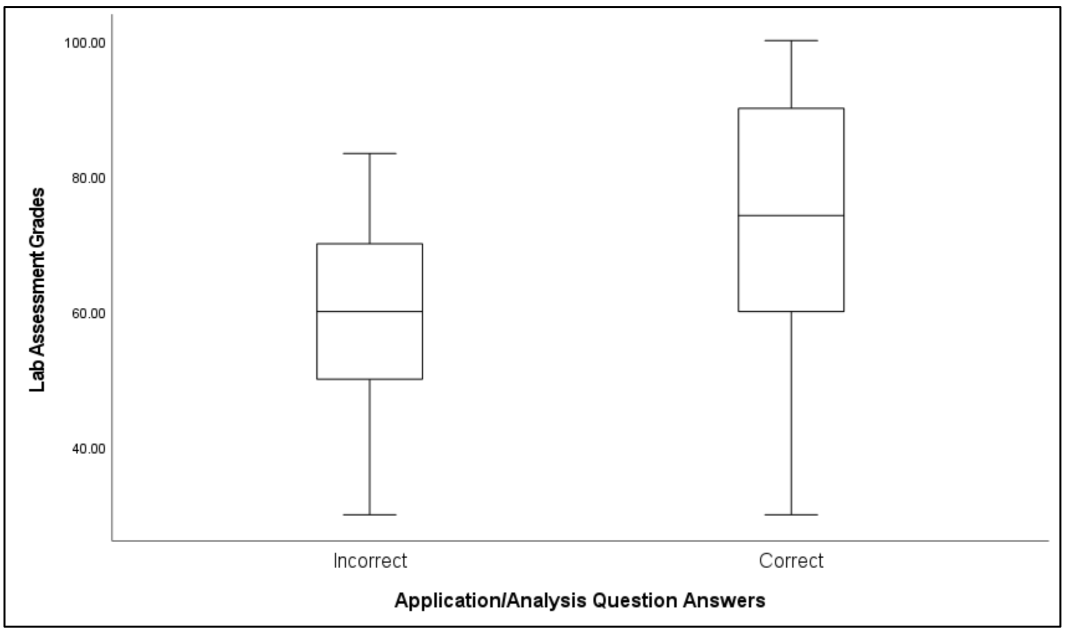


Figure 3 portrays the absence of outliers in the quantitative correlational study and shows the application/analysis answers (incorrect *vs* correct), a dichotomous variable, and the matching laboratory grades, the continuous variable. The x-axis for the box plot of Figure 3 is the application/analysis answers (incorrect *vs* correct) and the y-axis represented the lab assessment grades. Outliers are data points outside the whiskers of the boxplots, and according to Figure 3, there are no outliers in the data, as assessed by the inspection of the boxplots for values greater than 1.5 box-lengths from the edge of the box.

Figure 4: *Box Plot of Synthesis/Evaluation Question Answers*

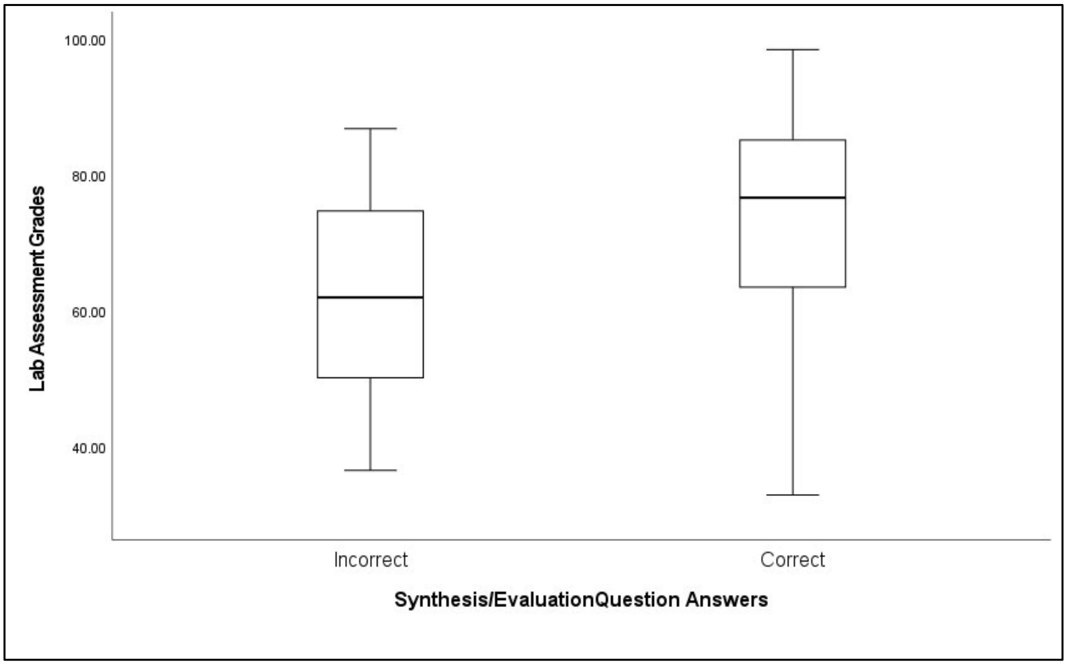


Figure 4 portrays the absence of outliers in the quantitative correlational study and shows the synthesis/evaluation answers (incorrect *vs* correct), a dichotomous variable, and the matching laboratory grades which is the continuous variable. The x-axis for the box plot of Figure 4 is the synthesis/evaluation answers (incorrect *vs* correct) and the y-axis represented the lab assessment grades. Outliers are data points outside the whiskers of the boxplots, and according to Figure 4, there are no outliers in the data, as assessed by the inspection of the boxplots for values greater than 1.5 box-lengths from the edge of the box.

Table 2 displays the results for the absence of outliers, Levene's test for equality of variances, and the Shapiro-Wilk test for normality. No outliers for any of the data existed, including knowledge/comprehension, application/analysis, and synthesis/evaluation answers (*incorrect vs correct*). Homogeneity of variances for the lab assessment scores for *incorrect versus correct* were assessed by the Levene's test for equality of variances where p = .452, p =

.064, and $p = .958$ for knowledge/comprehension, application/analysis, and synthesis/evaluation respectively, and overall, $p > .05$ for all three categories of Bloom's Taxonomy. The lab assessment scores for each level of incorrect versus correct answers were normally distributed, as assessed by the Shapiro-Wilk's test ($p > .05$).

Table 2

Assumption Testing Results for Outliers, Levene's Test, and Shapiro-Wilk's Test for the General Biology I Course Assessments

		K/C	A/A	S/E
Outliers		None	None	None
Levene's Test *p*-value		.452	.064	.958
Shapiro-Wilk's Test	Incorrect answers- *p*-value	.091	.430	.609
	Correct answers- *p*-value	.197	.076	.106

Note. *p*-value > .05; K/C: Knowledge/Comprehension; A/A: Application/Analysis; S/E: Synthesis/Evaluation

Table 3 displays the Descriptive Statistics data for General Biology I assessments. The table shows the mean, median, standard deviation, minimum, and maximum of the matching laboratory grades. Three sets of Bloom's Levels include knowledge/comprehension, application/analysis, and synthesis/evaluation. Lecture examinations were based on Bloom's Taxonomy levels. The answers to the questions in various Bloom's categories include correct versus incorrect belonging to 51 students. These answers were given "0" for an incorrect answer and "1" for a correct answer (see Appendix G). The matching laboratory grades were recorded for the respective correct versus an incorrect answer to find a correlation between lecture assessments and laboratory grades.

Table 3

Descriptive Statistics for General Biology I Examinations

Bloom's Levels	Mean (%)		Median (%)		Standard Deviation (%)		Minimum (%)		Maximum (%)	
	I	C	I	C	I	C	I	C	I	C
K/C	60.36	68.42	60.00	65.45	15.82	18.13	30.00	32.73	80.00	100.00
A/A	61.27	73.93	60.00	74.17	13.39	18.73	30.00	30.00	83.33	100.00
S/E	61.15	72.79	61.82	76.51	15.23	16.15	36.36	32.73	86.67	98.33

Note. K/C: Knowledge/Comprehension; A/A: Application/Analysis; S/E: Synthesis/Evaluation
I: Incorrect Answers; C: Correct Answers

To address the research questions and the three hypotheses in the quantitative correlational study, a Point-Biserial Correlation was conducted on the data. The Statistical Package of the Social Sciences, Version 27 was used to generate the correlation coefficient. The variables used for the analyses include the dichotomous variable, the answers (correct *vs* incorrect) to the questions based on Bloom's levels. The matching laboratory grades received by the students is the continuous variable. Table 4 is a summary of the results of the Point-Biserial Correlation analyses.

An accessible population, or the total sample for the quantitative correlational study, was 51 students. From Table 4, the alpha value used in the quantitative correlational study was 0.05, meaning a 5% margin of error was present in the analysis. For all three research questions, preliminary analyses showed there were no outliers, the lab assessment score was normally distributed assessed by the Shapiro-Wilk's test ($p > .05$), and there was homogeneity of variances assessed by the Levene's test for equality of variances.

For Research Question 1, Table 4 shows a point-biserial correlation, run between the lecture assessment Bloom's Taxonomy knowledge/comprehension question answers (correct *vs* incorrect) and the matching laboratory grades received by 51 students. Data are mean ± standard deviation from descriptive statistics, according to Table 4. The correlation is not statistically significant between knowledge/comprehension answers (correct *vs* incorrect) and the matching laboratory grade score r_{pb} (49) = .209 (Table 4), with the correct answers giving rise to a better laboratory grade versus the incorrect answers (68.42 ± 18.13 versus 60.36 ± 15.82; Table 3). The number 49 in r_{pb} (49) are the degrees of freedom (N-2), where N is the sample size, the participants included in the correlation. Magnitude of the point-biserial correlation is .209, indicating a small correlation. As the *p*-value is .140 and greater than the 0.05 level (2-tailed), the result is not statistically significant. As a result, there is evidence to fail to reject the null hypothesis for Bloom's level knowledge/comprehension answers (correct *vs* incorrect) and the matching laboratory grades received by students.

Table 4

Point-Biserial Correlations Between Lecture Assessment Question Answers Based on Bloom's Levels and Matching Laboratory Grades in General Biology I

Bloom's levels	r_{pb}	*p* value
Knowledge/comprehension	.209	.140
Application/analysis	.355*	.011
Synthesis/evaluation	.333*	.017

Note. Alpha level of 0.05; N = 51 (sample size); r_{pb} is the point-biserial correlation coefficient; *p* value is the probability value.
* Indicates significant correlation (two-tailed).

For Research Question 2, Table 4 shows a point-biserial correlation, run between the lecture assessment Bloom's Taxonomy application/analysis question answers (correct *vs* incorrect) and the matching laboratory grades received by 51 students. Data are mean ± standard deviation from descriptive statistics, according to Table 3. This correlation is statistically significant between application/analysis answers (correct vs incorrect) and the matching laboratory grade score r_{pb} (49) = .355 (Table 3), with the correct answers giving rise to a better laboratory grade versus the incorrect answers (73.93 ± 18.73 versus 61.27 ± 13.39; table 3). The number 49 in r_{pb} (49) are the degrees of freedom (N-2), where N is the sample size, the participants included in the correlation. The magnitude of the point-biserial correlation is .355, indicating a medium correlation. As the *p*-value is .011 and smaller than the 0.05 level (2-tailed), the result is statistically significant. As a result, there is evidence to reject the null hypothesis and accept the alternate hypothesis for Bloom's Level Application/Analysis answers (correct *vs* incorrect) and the matching laboratory grades received by students.

For Research Question 3, Table 4 shows a point-biserial correlation, run between the lecture assessment Bloom's Taxonomy synthesis/evaluation question answers (correct *vs* incorrect) and the matching laboratory grades received by 51 students. Data are mean ± standard deviation from descriptive statistics, according to Table 3. The correlation is statistically significant between synthesis/evaluation answers (correct vs incorrect) and the matching laboratory grade score r_{pb} (49) = .333 (Table 4), with the correct answers giving rise to a better laboratory grade versus the incorrect answers (72.79 ± 16.15 versus 61.15 ± 15.23; table 3). The number 49 in r_{pb} (49) are the degrees of freedom (N-2), where N is the sample size, the participants included in the correlation. The magnitude of the point-biserial correlation is .333, indicating a medium correlation. As the *p*-value is .017 and smaller than the 0.05 level (2-tailed), the result is statistically significant. As a result, there is evidence to reject the null hypothesis and accept the alternate hypothesis for Bloom's Level Synthesis/Evaluation answers (correct *vs* incorrect) and the matching laboratory grades received by students.

The coefficient of determination is r_{pb}^2 and is expressed as a percentage. For Research Question 1, the correct versus incorrect answers accounted for 4.4% of the variability in the laboratory assessment scores. For Research Question 2, the correct versus the incorrect answers accounted for 12.6% of the variability in the laboratory assessment scores. For Research Question 3, the correct versus the incorrect answers accounted for 11.1% of the variability in the laboratory assessment scores.

Figures 5, 6, and 7 demonstrate the correlations in the form of a scatterplot between the dichotomous variables (correct *vs* incorrect) on the x-axis and the continuous variable on the y-axis for the General Biology I course. The dichotomous variables on the x-axis in the three graphs below in order, are the knowledge/comprehension, application/analysis, and synthesis/evaluation answers (correct *vs* incorrect). The continuous variable on the y-axis is the matching laboratory assessment grades for General Biology I in all three plots. Figures 5, 6, and 7 are simple scatterplots demonstrating the sign of the point-biserial correlation to be positive and highlighting the differences in the mean scores between the two groups of the dichotomous variable in terms of the continuous variable. The diagonal line in every scatter plot is the line of best fit between the lab assessment grades for the incorrect lecture assessment answers versus the correct lecture assessment answers.

Figure 4

Scatterplot of the Knowledge/Comprehension Question Answers

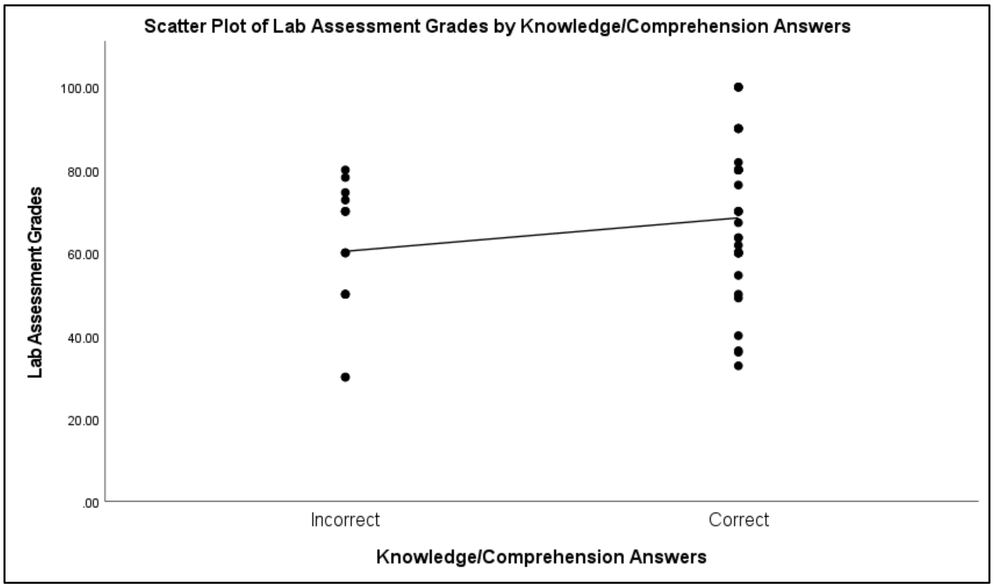


Figure 5

Scatterplot of the Application/Analysis Question Answers

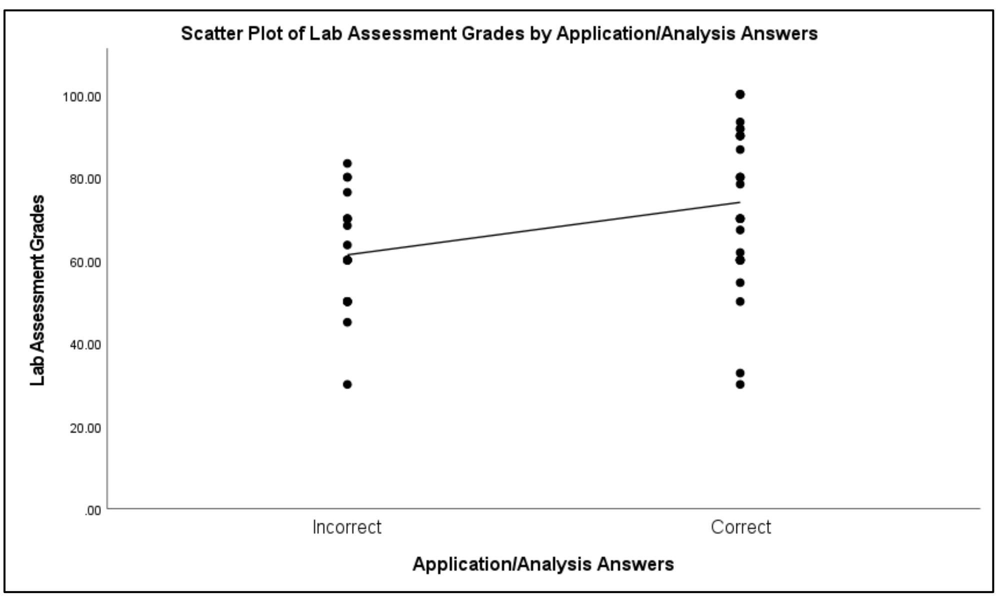
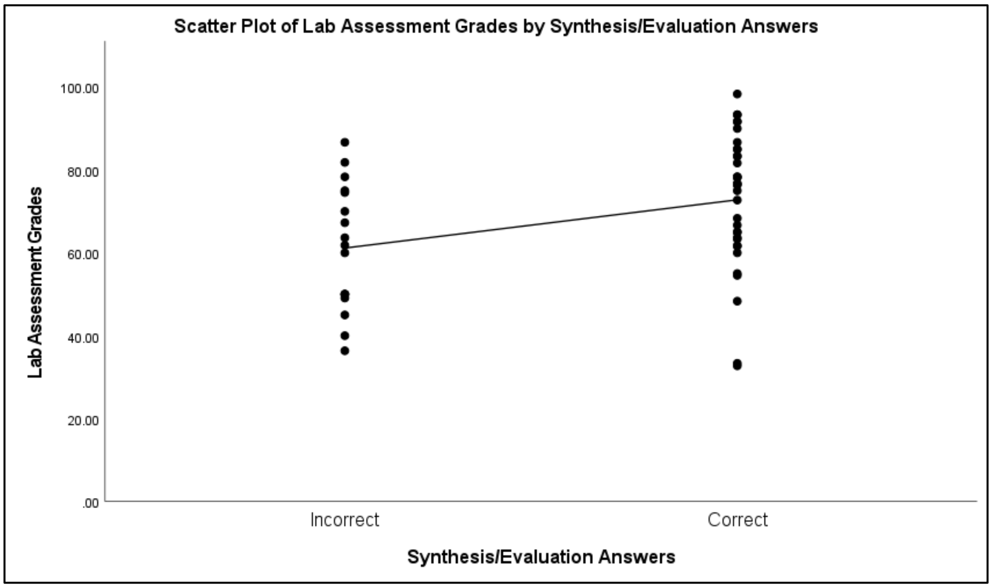


Figure 6

Scatterplot of the Synthesis/Evaluation Question Answers



In Figures 5, 6, and 7, the line of best fit intersects the mean score of the two groups of the dichotomous variable, the incorrect and the correct answers for the lecture assessment question respectively. In all three plots, the line of best fit from left to right increases and hence the scatterplots can be interpreted in terms of a positive coefficient of .209, .355, and .333 (see Table 4) for knowledge/comprehension, application/analysis, and synthesis/evaluation. Because the coefficients are positive in all three cases, the scatterplots show the group of the dichotomous variable, the "correct" variable in this case, having the highest coding and the highest mean value in terms of the laboratory grades. The meaning is more students with the correct answer for the lecture assessment question had a better laboratory grade in all three scatterplots compared to the students with the incorrect answer to the lecture assessment question. The three scatterplots also demonstrate a higher percentage of students getting the lecture assessment question correct than incorrect, leading to a better laboratory grade.

Reliability and Validity

Control for the variables used in the quantitative correlational study is the assessments used for General Biology I lecture and laboratory course. Lecture assessment questions were for each of the categories of the Bloom's Taxonomy levels and the same assessment questions were attempted by all the students. Archival data of examination grades for the quantitative correlational study were extracted using a college password-protected Moodle platform. Moodle is a learning platform, a single, secure, and an integrated platform for educators to create personalized learning environments and includes a gradebook (Feng, 2018). The archival data was the recording by the instructor who was trained to use the grade reporting software. The data has a second observer, the community college assessment assistant, who checks the grades to ensure validity. Multiple years of data from 2016 and 2017 are being used to aid in reliability.

According to a study on Moodle Learning Management System, the reliability coefficient calculated by Cronbach's alpha was 0.94, and an exploratory factor analysis was performed to show the validity of the structure (Yildiz et al., 2018). If the reliability coefficient number is higher than 0.80, the scale reliability is good, meaning there is a good overall consistency of measure. Here, the effectiveness of the Moodle Learning Management System and the positive contribution to student achievement is being measured. Validity refers to the extent an instrument measures what it is supposed to measure, and the factor analysis was used to obtain information on the validity of the scale. The related items for the scale with respect to Moodle as a learning management system include proficiency and motivation, content and feedback, usability, effectiveness, educational features, and communication. When correlations were calculated for the related items, the student opinions on Moodle in an online learning environment were positive.

The threats to internal validity of the quantitative correlational study include testing, instrumentation, and bias (Hoy & Adams, 2016). Internal validity in the quantitative correlational study is comprised of the assessments or examinations based on Bloom's Taxonomy of Educational Objectives and the grades received by students. Testing is when participants become familiar with the outcome measure and remember responses for later testing (Johnson et al., 2019). Threats to testing were minimized by having a gap of 1 month between administrations of the tests (Lee et al., 2019). Instrumentation includes the structure and pattern of the tests impacting the scores of students and the threat was minimized by using the same pattern for all tests (Creswell & Gutterman, 2019). The tests for the quantitative correlational study are based on the Blooming Biology tool (Crowe et al., 2017).

General bias is another threat to internal validity and was not involved with the quantitative correlational study. Bias refers to a tester behaving in a different way with different groups in a study and could be eliminated through blinding (Richardson et al., 2016). Blinding refers to participants and testers being unaware of what intervention is being received to avoid bias in a study (Gill & Prasad, 2019). The quantitative correlational study lacks an intervention and is not a scientific experiment leading to threats of tester bias (Streiner, 2016).

Threats to external validity could include the interaction of selection of participants and treatment, interaction of setting and treatment, and interaction of history of past results and treatment (Creswell & Creswell, 2018). The quantitative correlational study was affected by the interaction of selection and treatment because of the narrow characteristics of participants in the study. This threat was minimized by restricting claims about groups to whom the results cannot be generalized (Verenna et al., 2018). The quantitative correlational study is affected by external validity because the study is restricted to one educational institution (Cor, 2016). The threat could be minimized by conducting additional studies in new settings to see if the same results occur as in the initial setting in the future (Costa et al., 2016). Because convenience sampling is a form of non-probability sampling being used in the quantitative correlational study, the results are representative of the population sample.

The Blooming Biology Tool used in the Biological Concepts of Health course had an inter-rater reliability of 86%, being the degree of agreement between raters (Murrant et al., 2015). The inter-rater reliability of 86% assesses the degree of agreement between two or more raters in the appraisals. The Blooming Biology Tool used in the quantitative correlational study had an agreement of 86% between raters increasing the reliability of the instrument and the study.

Researcher error was prevented by exercising caution when attempting to record scores and conducting measurements in the quantitative correlational research study (Hoglund et al., 2019). Errors from environmental changes including the testing environment, were minimized by recording the measurements from all students under identical conditions (Creswell & Gutterman, 2019). Participant changes include the attitude of study participants to the examinations being changed based on circumstances. Pressure from academics would matter for lack of sleep and focus by students (Berthelon et al., 2019). Hunger and tiredness could lead to a lower mental performance and was minimized by warming up the students before the assessments (Kane & Clark, 2016).

Chapter Summary

The data collected in the quantitative correlational study explained the correlation between the assessments following the educational objectives of Bloom's Taxonomy and the grades received by students in a community college in northern New Jersey. The study addressed three research questions and hypotheses. For the first research question, no significant relationship exists between the lecture assessment Bloom's Taxonomy question for knowledge and comprehension answer (correct *vs* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey. For the second research question, a significant relationship exists between lecture assessment Bloom's Taxonomy question for application and analysis answer (correct *vs* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey. In the third research question, a significant relationship exists between the lecture assessment Bloom's Taxonomy question for synthesis and evaluation answer (correct *vs* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey.

The box plots in the data analysis of the quantitative correlational study portrayed the absence of outliers in the data sets of the grades received by 51 students. No outliers were in the data, including knowledge/comprehension, application/analysis, and synthesis/evaluation. Homogeneity of variances in the data sets, as assessed by Levene's test for the equality of variances, were evident. Normal distribution in the data sets were portrayed by Shapiro-Wilk's test. Descriptive statistics data for the General Biology I assessments were presented displaying the mean, median, and standard deviation under data analysis. The point-biserial correlation coefficient was calculated between the lecture assessment question answers based on Bloom's

Taxonomy levels and the matching laboratory grades. Scatter plots showing the line of best fit for the lab assessment grades versus the incorrect and correct lecture question answers based on knowledge/comprehension, application/analysis, and synthesis/evaluation were presented.

The following Chapter, Chapter 5 provides an analysis of the findings from Chapter 4 and a discussion of the implications, limitations, and recommendations for the quantitative correlational study will be described. Measures to improve the assessments for General Biology to obtain a significant relationship in all areas of Bloom's Taxonomy are discussed in Chapter 5. Findings, interpretations, and conclusions are highlighted in Chapter 5.

Chapter 5: Discussion and Conclusion

The purpose of the quantitative correlational study was to determine if there was a statistically significant relationship between the biology lecture examination question answers (correct or incorrect), a dichotomous variable, based on Bloom's Taxonomy, and the matching laboratory assessment grade, a continuous variable, received by 51 students in a community college in northern New Jersey. In the quantitative correlational study, students taking General Biology I lecture, and laboratory courses were tested using examinations based on Bloom's Taxonomy. A quantitative correlational study could help to establish the extent of the categories of application, analysis, synthesis, and evaluation versus knowledge and comprehension components of the Bloom's Taxonomy framework utilized to test freshman students (Gershon, 2018). The data used was extracted from archival data of the community college. Archival data from various semesters spanning 2016 and 2017 were extracted to study the correlation between the examinations taken by students and the grades received.

The overall area of interest for the study involved the observation of academic achievement in lecture and laboratory courses of General Biology using Bloom's Taxonomy of Educational Objectives at a community college in northern New Jersey. As revealed in Chapter 2, a general problem when using Bloom's Taxonomy in teaching is the lack of coverage of all the six major categories including knowledge, comprehension, application, analysis, synthesis, and evaluation (Kuzu et al., 2019). The specific problem when using Bloom's Taxonomy is to gauge the application of the six categories in student assessments by demonstrating if a relationship between assessments and student performance exists or not (Crowe et al., 2017).

The key findings of the quantitative correlational study from Chapter 4 included the determination of academic quality using Bloom's Taxonomy of Educational Objectives. The main idea was to determine if there was a correlation between the lecture and laboratory assessments in General Biology following Bloom's Taxonomy and the grades received by students. In addition, key findings revealed one non-significant correlation and two significant correlations using archival data.

Based on the research questions addressed in Chapter 4, for the first research question, no significant relationship exists between the lecture assessment Bloom's Taxonomy question for knowledge and comprehension answer (correct *vs* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey. For the second research question, a significant relationship exists between the lecture assessment Bloom's Taxonomy question for application and analysis answer (correct *vs* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey. For the third research question, a significant relationship exists between the lecture assessment Bloom's Taxonomy question for synthesis and evaluation answer (correct *vs* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey.

Chapter 5 provides a discussion of the findings, interpretation, and conclusions of the quantitative correlational study. Limitations of the study are also presented in the chapter in addition to recommendations to shift to a more global perspective of the findings. Chapter 5 provides implications for leadership and the potential impact for a positive social change at the appropriate level is also described.

Findings, Interpretations, and Conclusions

Findings include the data analysis performed in Chapter 4 and describe the statistical relationship in the study. Interpretations describe the results of the study and how the results can be explained. The conclusions answer the research questions posed in the study.

Findings Related to Research

The results of the data analysis performed in Chapter 4 provided the information to address and reflect on the findings in the current chapter. According to the findings from Chapter 4, there was both a significant and a nonsignificant relationship between the examinations based on Bloom's Taxonomy of Educational Objectives and the grades received by students. Bloom's Taxonomy was divided into three categories for the questions in the examinations, including knowledge/comprehension, application/analysis, and synthesis/evaluation. According to Bloom's Taxonomy, knowledge/comprehension questions reflect lower order thinking skills, whereas the synthesis/evaluation questions reflect higher-order thinking skills (Spence, 2019).

Findings confirm no significant relationship between the lower-order thinking skill multiple choice questions and the examination grades of students in General Biology I and a significant relationship between the higher-order thinking skills and the grades of students. The result does not confirm the finding of Erdimez et al. (2017) where higher level thinking skills are not required for multiple choice tests. This study does not entirely confirm the inquiry on higher education teaching strategies based on Bloom's Taxonomy, stating only lower-level thinking skills namely knowledge, comprehension, and application are being taught in colleges (Revati & Meera, 2017). The conclusions extend knowledge in the discipline by portraying an uncertain relationship between the lower-order thinking skill questions and the grades received by students agreeing with the study, implying students are being tested on lower levels of Bloom's

Taxonomy by using multiple choice questions in various examinations (Singh et al., 2016). Literature portrays current biology examination as procedures being able to promote only low-level learning (Darwazeh, 2017). The quantitative correlational study can support the fact where majority of the points are allocated to the lower objectives of Bloom's Taxonomy. Despite the fact, there was no significant relationship between the lecture assessment Bloom's Taxonomy knowledge and comprehension answers and the laboratory grades received by the students.

Interpretation of Findings

The results of the study had some contradictory results with certain articles discussed in the literature review. The framework for this study was created by combining descriptive theory, meta-theory, and Bloom's Taxonomy (Bloom, 1956). The dimensions of both theories support the purpose of the study and help understand the relationship between the effect of biology examinations based on Bloom's Taxonomy and the grades received by students. Based on the findings, the professors could set goals for students to improve the lower and higher-order thinking skills in General Biology. No regular pattern in attainment of mastery in the General Biology lecture and laboratory existed based on the six levels of Bloom's Taxonomy including knowledge, comprehension, application, analysis, synthesis, and evaluation (Spence, 2019). A significant relationship was observed in the Application/Analysis and Synthesis/Evaluation questions in the examinations and the grades received by students in General Biology I. The knowledge/comprehension questions did not show a significant relationship. Some of the examinations in General Biology I and General Biology laboratory assessments did not show a significant relationship between the questions in the examinations based on Bloom's Taxonomy and the grades of students (Watkins, 2020). Descriptive and Meta theories uncovered the mechanism of scientific change to students, but did not influence grades of students, as the results of the quantitative correlational study were partly not significant (Collazos et al., 2019).

The interpretations, inferences, and conclusions did not exceed the data, findings, and scope of the study, as the results are based on a quantitative correlation. Interpretations were based on statistical significance or non-significance. Out of the three sets of assessments discussed for General Biology I, the inferences were based on statistical data. The conclusions were dependent on the results of statistical analysis where there were two significant relationships and one non-significant relationship for General Biology I lecture examinations. The interpretations did not exceed the scope of the study as only the examinations based on Bloom's Taxonomy and grades received by students were used to explore the study. These inferences did not exceed the data of the study as the study was based entirely on archival data extracted from the College.

No opinions, biases, and prior knowledge affect the quantitative correlational study as it pertains to a community college in northern New Jersey and the examination results of the students are unique to the college in study. The Point-Biserial Correlation was conducted on the data to address the hypotheses. For Research Question 1, based on the results of the study, no significant relationship exists between the lecture assessment Bloom's Taxonomy question for knowledge and comprehension answer (correct *vs* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey. Literature portrays where many examinations had knowledge and comprehension questions but lacked the synthesis and evaluation questions needed for higher-level thinking. The result for Research Question 1 of the quantitative correlational study did not fall into the normal pattern of examinations conducted in other places, where knowledge and comprehension were the easiest sections in an examination. The result could change with a larger sample size and when more data spanning over different years of the community college are used.

For Research Question 2, based on the quantitative correlational study, a significant relationship was found between the lecture assessment Bloom's Taxonomy question for application and analysis answer (correct *or* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey. Based on the literature information on the English subject, more than half of the questions discussed in the textbooks emphasized the comprehension level, and the knowledge and application level had less than half the frequency of the comprehension level questions. Because the number of application-level questions was less in number when compared to the knowledge level questions, the number of times a student gets these questions right can be higher. If a student in the quantitative correlational study got the application/analysis question right, then the same student received a higher laboratory grade.

For Research Question 3, a significant relationship was found between the lecture assessment Bloom's Taxonomy question for synthesis and evaluation answer (correct *vs* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey. Modern mobile learning including tablets, computer notebooks, and mobile phones could be one of the reasons for students performing well at the synthesis and evaluation level (Gershon, 2018). Modern methods broaden the learning environment for students and the students were found to be immersed in all six levels of Bloom's Taxonomy, besides the difficult synthesis and evaluation level (Zhang et al., 2019). Various studies based on science curricula and the curricula of life studies did not focus on synthesis and evaluation (Bozdemir et al., 2019). The current quantitative correlational study involved synthesis and evaluation questions in examinations in biology, although the number of questions varied. Overall, changes must be made in the science curricula to increase the number of synthesis and evaluation questions to improve student learning and thinking (Darwazeh, 2017).

Although there are six levels of Bloom's Taxonomy, the questions in the examinations covered included two levels overlapped at one time, such as knowledge/comprehension, application/analysis, and synthesis/evaluation (Campbell et al., 2018). Students were tested on all the levels of Bloom's Taxonomy where two levels were blended into one question at one time. The overlapping levels include the knowledge/comprehension level, the application/analysis level, and the synthesis/evaluation level. The questions were based on the Blooming Biology Tool.

Conclusions

The conclusions of the quantitative correlational study include two significant relationships and one non-significant relationship. An unusual finding of this study as related to existing peer reviewed studies was not to have a significant relationship between the knowledge and comprehension answer (correct *vs* incorrect) and the matching laboratory grade received by associate degree students in a community college in northern New Jersey. Literature supports class assessments mainly test on knowledge and comprehension levels and not on application, analysis, synthesis, and evaluation levels. The quantitative correlational study employed the Point-Biserial Correlation to study the data. The knowledge and comprehension level questions should be refined for a better response from the students. Questioning skills of the professor of the course can change the assessment results in the classroom on any subject (Darwazeh, 2017).

The purpose of the quantitative correlational study was supported by the application of the dimensions of the descriptive theory and the dimensions of the meta-theory by providing the classification of various educational objectives professors may use to set goals for the students (Watkins, 2020). The framework of Bloom's Taxonomy is created on the descriptive and meta-theory (Collazos et al., 2019). This framework can be connected to the implications, as the examinations based on Bloom's Taxonomy were effective in creating educational models, and to promote a cognitive learning process of deeper analysis and procedure evaluation. This study of academics includes questions based on the six levels of Bloom's Taxonomy aligns with descriptive theory, as there are propositions to describe and explain the world based on academics (Watkins, 2020). In the quantitative correlational study, descriptive theory was applied to make effective decisions (Sebastien, 2016). As descriptive theories explain how learning occurs, the quantitative correlational study can use the principles to comprehend the unusual result of the first research question (Campbell et al., 2018). Bloom's Taxonomy used in the study is an effective tool for a unique kind of thinking including constructive and creative thinking and meta-theory can be used to support student engagement in the classroom (Apolskii et al., 2019).

The quantitative correlational theory was related to the observation of the performance of students on assessments based on Bloom's Taxonomy (Spence, 2019). Conclusions of the two significant relationships found in the study can support the purpose of the descriptive theory. Descriptive theory predicts the relationship and effectiveness of the variables of teaching (Collazos et al., 2019). When a significant relationship was found between the application/analysis and synthesis/evaluation questions and the laboratory grades of students, the conclusion of a strong relationship between the lecture and laboratory components of the course can be seen. Similarly, a non-significant relationship between the knowledge comprehension questions and the laboratory grade can be explained to have an ineffective variable of teaching. Meta-theory is related to academic improvement and hence the conclusion of Bloom’s Taxonomy levels related to cognitive development can be seen. Various topics covered in General Biology I course of the quantitative correlational study, including evolutionary theory, are on the way to becoming a metatheory for cognitive development.

Limitations

The internal validity in the quantitative correlational included a treatment and an outcome (Creswell & Gutterman, 2019). The treatment was comprised of the examinations based on Bloom’s Taxonomy of Educational Objectives and the outcome was the grades received by the students. These limitations to internal validity could include areas such as testing and instrumentation (Hoy & Adams, 2016). Limitations to testing can include examinations having some questions repeated from previous examinations (Campbell et al., 2018). Instrumentation included the Blooming Biology Tool (BBT), an assessment tool based on Bloom’s Taxonomy (Crowe et al., 2017). This tool can include questions on labeling, filling in the blanks, multiple-choice, short answer, and essay questions (Gershon, 2018). The limitation in the quantitative correlational study with respect to instrumentation includes an excessive usage of multiple-choice questions in most of the examinations.

Limitations to external validity include the interaction of the selection of participants and treatment, interaction of setting and treatment, and interaction of the history of past results and treatment (Creswell & Creswell, 2018). This study was affected by the interaction of selection of participants and treatment because of the narrow characteristics of participants in the study. The participants only belong to the General Biology courses group and the results were not based on a multitude of other science courses. External validity is the application of the outcome of a study to a variety of settings (Creswell & Gutterman, 2019). The study was affected by the setting as the examinations and grades were observed for one community college alone and the results cannot be generalized to multiple community colleges. Interaction of the history of past results and treatment is not seen as the results were mixed and inconclusive based on the literature review in Chapter 2 and the study was based on archival data extracted from the community college. Limitations to construct validity of the study include unstated demands like the desire to cooperate and anxiety about evaluation by the participants.

The number of students used in the quantitative correlational study was 51 and the grade data from the accessible assessments of the years 2016 and 2017 were used in the study. Questions belonged to knowledge and comprehension, application and analysis, and synthesis and evaluation levels. The categorical variable in the quantitative correlational study is the lecture assessment questions based on Bloom's Taxonomy with two categories of *correct versus incorrect*. The continuous variable is the matching laboratory assessment grades of students, varying based on the differences in questions built on Bloom's Taxonomy categories. A topic tested in the lecture assessment and the answer (correct *vs* incorrect) was related to the matching grade in the respective laboratory assessment as the same topic tested in lecture is covered in the laboratory assessment. In the quantitative correlational study, the number of examinations and the nature of examinations were different for General Biology I lecture and laboratory assessments. No extraneous variables statistically affected the results of the quantitative correlational study and because of the nature of the different examinations, there was a difference in the pattern of the grades of students.

Limitations to reliability include researcher error, environmental changes, and participant changes (Creswell & Creswell, 2018). Reliability measures repeatability, and consistency (Creswell & Gutterman, 2019). Researcher error is possible when conducting various examinations and during the process of grading and recording the grades of students (Hoglund et al., 2019). All examinations may not have the same ratio of questions based on different levels of Bloom's Taxonomy including knowledge/comprehension, application/analysis, and synthesis/evaluation. Environmental changes include the testing environment where the lecture setting could be different from a laboratory setting for taking examinations, which can act as a limitation to reliability. Participant changes include the mood and stress levels of students when taking different examinations. Lack of sleep and focus and tiredness of students on the day of the test could pose as a limitation to reliability.

Recommendations

Shifting to a more global perspective, the study could be conducted in more community colleges across New Jersey and the United States and the world, as the quantitative correlational study from Chapter 4 demonstrated mixed results. Educators in community colleges teaching General Biology courses can record data using examinations based on Bloom's Taxonomy and grades and analyze the pattern. Cognitive weaknesses of students can be identified using Bloom's Taxonomy and the levels of knowledge, comprehension, application, analysis, synthesis, and evaluation (Spence, 2019). Laboratory and lecture assessments can include higher and lower order thinking skill questions based on Bloom's Taxonomy until the class is comfortable both with lower and higher-order thinking skill questions. Bloom's Taxonomy of Educational Objectives can be used for lesson planning, assessment, and measurement of learning outcomes across the country by educators (Ramirez, 2017). The competitive examinations in the biological sciences can include higher-order thinking, including evaluation, where assessing theories, comparing ideas, and evaluating outcomes are tested. Students must be given time to learn and digest the information, especially in the sciences, as there are complex topics and concepts.

The recommendations for further research grounded in the study include extracting data from other community colleges in New Jersey and comparing to explain the research about the non-significant correlation between examinations based on Bloom's Taxonomy at the knowledge/comprehension level and the grades received by students. The scope of the quantitative correlational study limits the generalizability of the conclusions to be applied to other community colleges beyond the study site, and the reason for the recommendation of further research in other community colleges. Further research can be conducted in terms of changing the method of teaching the different levels of Bloom's Taxonomy by educators for increased student performance and results. Because students do have trouble with the knowledge level questions considered to be the basic level in Bloom's Taxonomy, the approach to address the scientific concept and to capture the interest of the student in the subject is required. The language barrier present in some community colleges across the state of New Jersey can be addressed and accommodated by faculty before testing the students, as this issue can create an abnormal pattern of grades (Sonmez, 2019). The pattern of testing in the sciences can be revised to improve critical thinking, creative thinking, and entrepreneurship by changing and tweaking the curriculum and the style of questions in the examinations. Further research needs to be done in minority populations, such as Black and Hispanic populations in terms of the approach towards examinations by the students and the pattern of grades, as only one minority community college was addressed in the study.

As a result of the quantitative correlational study, teaching styles can be improved, and the curriculum framed by professors can be upgraded based on the results. The examinations must include various types of questions including multiple choice, true or false, fill in the blanks, essay, and short answer questions to test the overall capabilities of students. If Bloom's Taxonomy of Educational Objectives does influence the grades of students negatively, then strategies to improve the performance of students should be put in place. Based on the results, there is no significant correlation between the examinations based on Bloom's Taxonomy at lower levels and the grades received by students, meaning students can and cannot perform well, independent of the nature of the questions. Educators can attain clarity in setting direction and for designing the teaching process based on Bloom's Taxonomy and on the results of the quantitative correlational study at the community college. The curriculum for General Biology I lecture can be ameliorated or the textbook that is followed can be changed for better language comprehension by minority students in the community college. College instructors must provide students with more opportunities in terms of office hours and class time for students to come and discuss the topic under study.

Future implications can include working on the qualitative aspects of student and faculty input on the examinations based on Bloom's Taxonomy, and future research should try to demonstrate the need for changes based on the nature of a particular institution and not just based on too many generalizations. Moving in a different direction, because mobile devices are integrated into science, mathematics, social studies, art, and special education, the current study should help promote mobile learning in the future for lecture courses in general biology. Quizzes and examinations with higher and lower order thinking skills should be developed until students grasp the fundamentals of the subject like Biology. According to Gummineni (2020), Bloom's Taxonomy should help educators attain clarity in setting direction and for designing the teaching process. Special methodologies should be put in place to address the group of students who cannot synthesize and evaluate at the higher levels of Bloom's Taxonomy of Educational Objectives (Gershon, 2018). More assessments should be administered to different groups of students in different majors besides the sciences to understand the effect of Bloom's Taxonomy on academic quality. Certain modifications should be made to Bloom's Taxonomy of Educational Objectives, providing an excellent framework for teaching, learning, and assessment based on student and faculty feedback observed from a sizeable number of institutions.

Implications for Leadership

The potential effect for a positive social change at the organizational level should be observed based on the quantitative correlational study. Because the organization under study is a community college, the study should benefit all the students to improve academic quality. A universal language like Bloom's Taxonomy is required by college professors and university examiners to set clear educational aims (Spence, 2019). An objective framework for the greater good of society is required and policy makers could create the same by employing Bloom's

Taxonomy to be accessible, communicable, and indispensable (Gummineni, 2020). Various assessment driven interventions should be provided at the individual level to increase the undergraduate underrepresented minority student success. A community college education should provide good academic quality to educate a family and to improve the standard of living in the lower classes of society and moving families to a middle-class level. A good community college education can provide an associate degree and could enable and qualify individuals for better jobs.

A theoretical implication for stakeholders is to transform the education system through the potential of artificial intelligence (Jaiswal & Arun, 2021). Colleges can shift to smart learning systems to enhance the learning experience of students. Personalized learning and adaptive assessments should be improved for students taking the laboratory sciences like General Biology I. A methodological implication for leadership is including lot of hands-on activities in the form of updated experiments using gadgets such as cell phones, tablets, and laptops to stay up to date in the modern world. In the sciences, the ability to design and interpret controlled experiments is an important scientific process (Schwichow et al., 2016). An empirical implication for stakeholders such as educators includes producing a common testing plan for all students based on Bloom’s Taxonomy of Educational Objectives to ensure equity in testing. All students taught by different professors at the same community college must be tested the same way to check the respective course standards listed by the College.

Conclusion

The quantitative correlational study examined the problem, the purpose and the methods used to address the research questions of the study, and the hypotheses. The study reflected on new results showing two significant relationships and one non-significant relationship. Two significant relationships and one non-significant relationship were found between lecture assessments based on the different levels of Bloom's Taxonomy and the laboratory grades received by students. Results were not consistent with some studies reported in the literature review. The sample size could have been smaller in the quantitative correlational study, being a reason for certain inconsistencies. This study was limited to one community college, creating a limitation in generalizing the results. The significance of the study was to help professors in colleges to improve the way of teaching, by understanding the relationship between lecture examinations based on the six levels of Bloom's Taxonomy and laboratory examination grades in a General Biology course.

The chapter included the findings, interpretations, and conclusions of the quantitative correlational study. Limitations to internal and external validity were discussed, besides reliability. Recommendations and implications for leadership were listed as the study can be performed covering multiple community colleges. The results allow educators to improve the method of teaching in terms of all levels of Bloom's Taxonomy including knowledge, comprehension, application, analysis, synthesis, and evaluation. Colleges and administrators should try to improve the curriculum and standards in a way to include diversity and equity factors. All stakeholders including college administrators, staff, and community leaders must work together in the process of education at a community college.

The new knowledge obtained from the quantitative correlational study explains how the knowledge/comprehension questions are not always answered correctly by all students when compared to the application/analysis and synthesis/evaluation questions. The nature of the relationship between lecture assessments based on the six levels of Bloom's Taxonomy and the laboratory assessment grades received by students in a community college was not as expected from the literature. This result shows how students are not able to perform, as well in the knowledge/comprehension level question versus the application/analysis and synthesis/evaluation questions. Based on literature, many students tend to perform well in the knowledge/comprehension questions. Many colleges and universities, as a result, are inclined to base the assessments with more knowledge/comprehension questions instead of application/analysis and synthesis/evaluation questions. The critical outcomes of the quantitative correlational study include the challenge of improving the academic standard of students with respect to the lower levels of Bloom's Taxonomy in addition to the higher levels and to improvise the teaching styles of professors at a community college. As Bloom's Taxonomy intends to promote advanced learning, the assessments must be examined with caution without immolating the rigor of the assessments and at the same time retaining the fundamentals of a course. The lecture and laboratory courses at a community college must be aligned better for students to score well at all levels of Bloom's Taxonomy.

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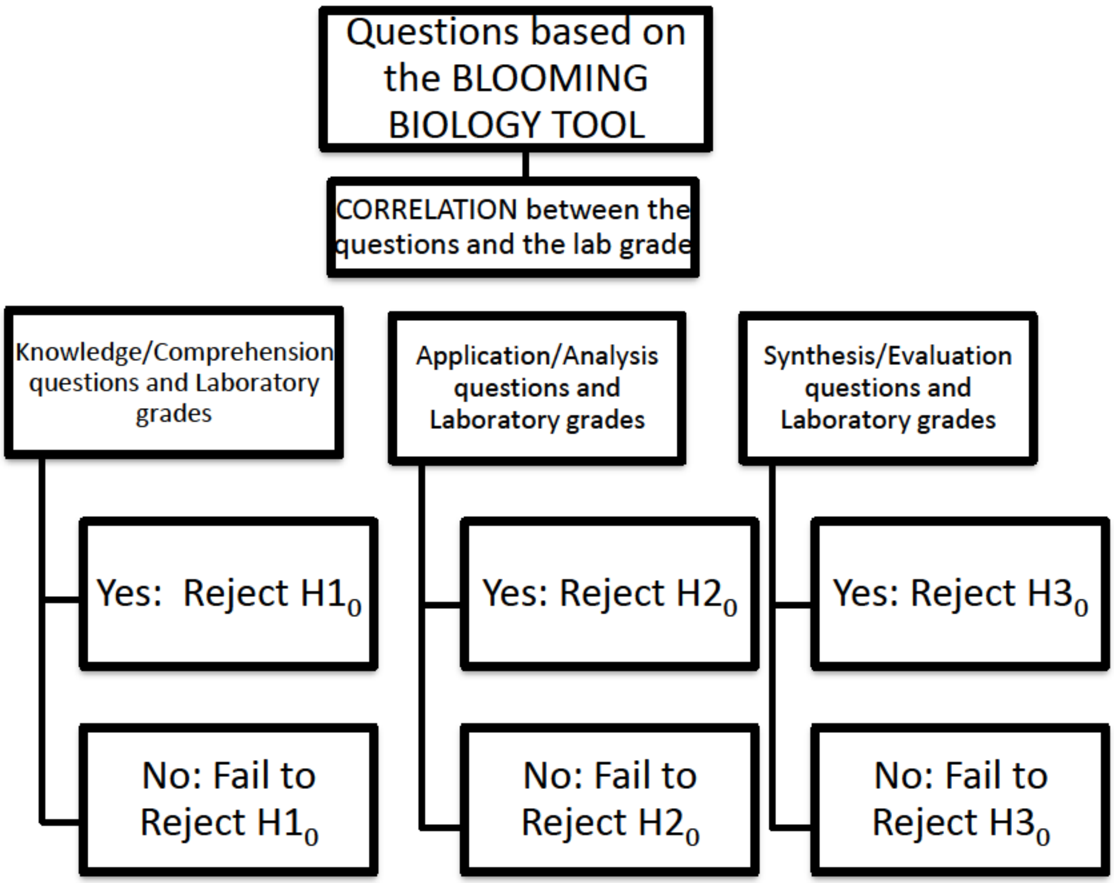
Appendix A

Words Used in the Six Levels in Bloom's Taxonomy

Evaluation	Judge, critique, justify, verify, assess, and recommend
Synthesis	Create, construct, design, improve, produce, and propose
Analysis	Compare, contrast, classify, categorize, derive, and model
Application	Calculate, solve, determine, and apply
Comprehension	Explain, and paraphrase
Knowledge	List, and recite

Appendix B

Relationship Between Bloom's Taxonomy of Educational Objectives and the Research Questions



Appendix C

Sample Questions Used in General Biology I Lecture Assessments Based on the Blooming Biology Tool

1) Which of these classes of biological molecules consist of both small molecules and macromolecular polymers?
A) lipids
B) carbohydrates
C) proteins
D) nucleic acids
E) lipids, carbohydrates, proteins, and nucleic acids all consist of only macromolecular polymers.

Answer: B
Topic: Concept 5.1
Skill: Knowledge/Comprehension

2) How many grams of acetic acid ($C_2H_4O_2$) would you use to make 10 L of a 0.1 *M* aqueous solution of acetic acid? (*Note*: The atomic masses, in Daltons, are approximately 12 for carbon, 1 for hydrogen, and 16 for oxygen.)
A) 10 g
B) 0.1 g
C) 6.0 g
D) 60 g
E) 0.6 g
Answer: D
Topic: End-of-Chapter Questions
Skill: Application/Analysis

3) *Halobacterium* has a photosynthetic membrane that is colored purple. Its photosynthetic action spectrum is exactly complementary (opposite to) the action spectrum for green plants. What wavelengths of light do the *Halobacterium* photosynthetic pigments absorb?
A) red and yellow
B) blue, green, and red
C) green and yellow
D) red and green
E) blue and red
Answer: C
Topic: Concept 10.1
Skill: Synthesis/Evaluation

Appendix D

Granted Permission Letter from the College

[redacted]

EXECUTIVE DEAN OF FACULTY AND ACADEMICS

[redacted]

November 12, 2020

Dr. Anthony Bretti

[redacted]

Dear Dr.Bretti:

I have been contacted by Ms. Sujatha Ramakrishnan, [redacted] Biology, Chemistry & Physics Division, requesting permission to review and use 2014-19 archived student data in her dissertation research. She originally made this request one year ago to [redacted] Dean of STEM & Heath Sciences, who granted her approval to Ms. Ramakrishnan in an email, copy to you, on January 15, 2020. I understand this permission was considered to be invalid because it was not presented to your office on official [redacted] letterhead, and therefore, must be reissued.

At the beginning of this Academic Year, our College underwent a complete reorganization of the Academic Affairs area. Specifically, the positions of Vice President/Chief Academic Officer, Dean of STEM & Heath Sciences and Dean of Business & Liberal Arts were eliminated and replaced by a single Executive Dean of Faculty & Academics. I currently hold that position on an interim basis, until a permanent replacement is appointed. All Academic Divisions and their faculty are under my supervision.

I have reviewed the Institutional Review Board (IRB) application completed by Ms. Ramakrishnan on December 5, 2019 and also had an extensive discussion with her on the nature of her research. She has satisfactorily completed all the requirements for permission to use the archived student data in her research and I grant her permission to do so as stated in the IRB.

Please contact me if you have any other questions.

Sincerely,

[redacted]

Professor Emeritus
Interim Executive Dean of Faculty & Academics

[redacted]

[redacted] [redacted]

Appendix E

Blooming Biology Tool

	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
Key Skills Assessed	Lower-order cognitive skills (LOCS) identify, recall, or label	LOCS Describe or explain in own words, re-tell, or summarize	LOCS Higher-order cognitive skills (HOCS) Predict an outcome using several pieces of information	HOCS Infer; understand how components relate to each other and to the process as a whole	HOCS Create something new.	HOCS Determine/ Critique
General examples of biology exam questions	Identify the parts of a eukaryotic cell	Describe nuclear transport to a lay person	Predict what happens to X if Y increases	Interpret data, graphs, or figures	Develop a hypothesis, design an experiment	Critique an experimental design or a research proposal
Type of question						
True-false	X	X	X	X		
Multiple choice	X	X	X	X		X
Short answer	X	X	X	X	X	X
Characteristics of multiple-choice questions	Information recall	Understanding	Prediction	Interpret-ation	Synthesize	Assessment

Appendix F

Permission Letter to the College

Date: 12/03/2019

Dr. XXX XXXX
Dean of Science, Technology, Engineering, Mathematics, and Health Sciences
xxxx@essex.edu

Dear Dr. XXXX,

My name is Sujatha Ramakrishnan, and I am a doctoral candidate at the American College of Education in Indianapolis, writing to request permission to review and use data from the Moodle platform for the years 2014-2019. This information will be used for my dissertation research related to a quantitative examination of academic improvement using Bloom's Taxonomy in the biological sciences. The purpose of this quantitative correlational research design study will be to determine the effect of biology examinations based on Bloom's Taxonomy, which is the independent variable, and the grades received by 100 students which is the dependent variable.

Principal Investigator: Sujatha Ramakrishnan
E-mail: xxxxx@gmail.com
Phone: xxx-xxx-xxxx

Dissertation Chair: Dr. Anthony Bretti
E-mail: xxx.xxxx@ace.edu
Phone: xxx-xxx-xxxx

Thank you for your cooperation and I hope to hear a response from you soon. I appreciate your time and consideration of my request.

Regards,

Sujatha Ramakrishnan

Appendix G

Raw Data

Student	K/C Question	Lab Grade	A/A Question	Lab Grade	S/E Question	Lab Grade
1	1	100.00	1	100.00	1	83.33
2	0	60.00	0	60.00	0	70.00
3	0	80.00	0	80.00	1	91.67
4	0	60.00	0	60.00	1	78.33
5	1	90.00	1	90.00	1	86.67
6	1	100.00	1	100.00	0	45.00
7	1	70.00	1	70.00	0	78.33
8	1	90.00	1	90.00	1	93.33
9	1	80.00	1	80.00	1	68.33
10	1	80.00	1	80.00	1	91.67
11	1	60.00	0	60.00	0	50.00
12	1	80.00	1	80.00	0	50.00
13	1	60.00	0	60.00	1	32.73
14	1	90.00	1	90.00	0	60.00
15	1	60.00	1	60.00	1	76.36
16	1	80.00	0	80.00	1	63.64
17	1	70.00	0	70.00	0	61.82
18	1	100.00	1	100.00	1	54.55
19	1	60.00	1	60.00	0	67.27
20	1	32.73	1	90.00	0	49.09
21	1	60.00	1	100.00	0	36.36
22	1	76.36	1	100.00	0	74.55
23	1	63.64	1	90.00	0	40.00
24	1	61.82	1	100.00	0	81.82
25	1	54.55	1	100.00	1	72.73
26	1	67.27	1	100.00	0	63.64
27	1	49.09	1	70.00	1	60.00
28	1	36.36	1	70.00	1	78.18
29	0	74.55	0	100.00	1	76.67
30	1	40.00	1	60.00	1	90.00
31	1	81.82	1	100.00	0	75.00
32	0	72.73	0	90.00	1	85.00
33	1	63.64	0	60.00	1	48.33
34	1	60.00	1	90.00	1	85.00
35	0	78.18	0	50.00	1	83.33

36	1	36.00	1	70.00	0	50.00
37	1	90.00	0	50.00	1	66.67
38	0	50.00	0	70.00	1	93.33
39	0	70.00	1	60.00	1	55.00
40	0	50.00	1	80.00	1	78.33
41	1	70.00	1	30.00	1	81.67
42	1	60.00	0	60.00	1	76.67
43	1	80.00	0	30.00	1	65.00
44	0	30.00	1	70.00	1	33.33
45	1	60.00	0	50.00	1	61.67
46	0	30.00	1	60.00	1	65.00
47	0	70.00	1	50.00	0	86.67
48	1	50.00	0	70.00	1	63.33
49	0	60.00	0	83.33	1	61.67
50	0	50.00	1	70.00	1	75.00
51	0	70.00	1	91.67	1	98.33

Key: K/C → Knowledge/Comprehension

A/A → Application/Analysis

S/E → Synthesis/Evaluation

Appendix H

Protecting Human Research Participants

CITI PROGRAM

Completion Date 20-Feb-2020
Expiration Date 19-Feb-2023
Record ID 35441765

This is to certify that:

Sujatha Ramakrishnan

Has completed the following CITI Program course:

Social-Behavioral-Educational Researchers (Curriculum Group)
Social-Behavioral-Educational Researchers (Course Learner Group)
1 - Basic Course (Stage)

Under requirements set by:

American College of Education

CITI
Collaborative Institutional Training Initiative

Verify at www.citiprogram.org/verify/?w934817c6-6864-4cdf-9db5-595b12dae06b-35441765

Appendix I

Permission Letter for the Instrument

Date: October 22, 2019

To
Dr. XXX XXXX
Department of Biology
University of Washington
Seattle, WA

Dear Dr. XXXX,

My name is Sujatha Ramakrishnan, and I am a doctoral candidate at the American College of Education (ACE) writing to request permission to use your Blooming Biology Tool (BBT) instrument. This information will be used for my dissertation research related to a quantitative examination of academic improvement using Bloom's Taxonomy in the biological sciences. The purpose of this quantitative correlational research design study will be to determine the effect of biology examinations based on Bloom's Taxonomy, which is the independent variable, and the grades received by 100 students which is the dependent variable, in a county college in northern New Jersey.

Important Contacts for this study include:

Principal Investigator: Sujatha Ramakrishnan
E-mail: xxxxx@gmail.com
Phone: xxx-xxx-xxxx

Dissertation Chair: Dr. Anthony Bretti
E-mail: xxxxx@ace.edu
Phone: xxx-xxx-xxxx

Thank you for your attention to this issue and I hope to hear a response from you soon. I appreciate your time and consideration of my request.

Regards,

Sujatha Ramakrishnan

Appendix J

Granted Permission Letter for the Instrument

Blooming Biology Tool Permission Letter

XXX XXXX <xxxx@uw.edu> Wed, Oct 23, 2019, at 1:09 PM
To: Sujatha Ramakrishnan <xxxxxx@gmail.com>

Hi Sujatha,
Thank you for your interest. You are very welcome to use the BBT. This tool was not formally validated. We developed the tool during a project in which we were assigning bloom categories to several hundred exam questions. The paper in which we used the tool, and that process is:
https://science.sciencemag.org/content/319/5862/414
Cheers,
XXX XXXX
[Quoted text hidden]
[Quoted text hidden]
<PermissionLetter.docx>
Dr. XXX XXXX
Chair, UW Biology Undergraduate Program Committee
Principal Lecturer, Department of Biology
University of Washington