THE IMPACT OF ONLINE HOMEWORK, TIME ON HOMEWORK, GENDER, AND METACOGNITION IN IMPROVING STUDENT ACHIEVEMENT IN UNDERGRADUATE BIOLOGY COURSES

by

Donald Bishop Cook, Jr.

Liberty University

A Dissertation Presented in Partial Fulfillment

Of the Requirements for the Degree

Doctor of Education

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ABSTRACT

This study sought to address a gap in the literature to determine whether a relationship exists between use of online homework and student achievement in undergraduate biology courses. Previous studies have examined other STEM courses, but few have considered biology. The purpose of the study was to determine whether homework grades in online homework systems can predict student achievement in introductory undergraduate biology courses. This study utilized a correlational analysis by multiple regression using archival data to determine whether final course grades in undergraduate biology courses can be predicted by grades on online homework, time spent on online homework, gender, or participation in a course on metacognition. A second question considered whether performance on a major assignment in a course on metacognition correlated with biology course grades and found a moderate correlation. The study took place at a small private Christian university in the Southeast, with 311 participants. The study found that there is a significant predictive ability to use these variables in determining course grades. Homework scores were most predictive, but time spent on homework and gender were also significant. Participation in a course on metacognition gave inconclusive results and is one suggestion for further research.

Keywords: STEM, online homework, academic achievement, metacognition

Dedication

I would like to dedicate this work to my wife, Jennifer, and my three boys: Bishop, Charlie, and Evan. Thanks for understanding as I missed many a Sunday night game night because I was in my office working on a paper or reading articles for this dissertation. Your support means everything to me, and I'm proud to be husband and dad to you.

Acknowledgments

I'd like to thank my committee for their insight and encouragement in completing this. Dr. Horne, you made it a much better work, and I appreciate your guidance throughout the process. Dr. Glenn, thanks for being my cheerleader and for helping me to decide to pursue the doctorate in the first place. Dr. Barthlow, I know that God placed you as my chair even though you weren't technically available at the time I began searching. You've gotten me through some difficult times and understood when I had struggles like no one else could have. Whenever I needed them, I could always count on you for some "magic words;" you always knew just what to say to help me get back on track.

I'd like to thank many of my coworkers for consistently asking me how it was going and being genuinely interested in my project. These include Greg Moffatt, Wye Huxford, Jim Donovan, Steve Hooks, and many others who have been behind me throughout this process. Most of all, I have to thank my Department Chair and friend Dedra Woolfolk, who tediously went through her grades and each student's scores and time on task in the Connect™ system to get my data for me.

Of course, I'm thankful to God and the ability He gave me to pursue this degree while working full time and for surrounding me with people who were excited to see me succeed.

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Analysis of Variance (ANOVA)

Homework (HW)

Personal Computer (PC)

Statistical Package for the Social Sciences (SPSS)

Science, Technology, Engineering, and Mathematics (STEM)

CHAPTER ONE: INTRODUCTION

Overview

This study sought to determine whether a correlation exists between the use of homework completed through an online system such as McGraw Hill's Connect™ in undergraduate biology courses and academic achievement in the form of final course grades. It has been shown that completion of homework correlates with higher grades in science, technology, engineering, and mathematics (STEM) courses (Eichler & Peeples, 2013). However, getting students to complete homework can be problematic, especially if it is not graded or little credit is offered for its completion. In addition, outside demands for students' time, such as work responsibilities or athletic practices and games, often force students to prioritize their time, and they may not see the benefit of completing homework in these instances. Many calls for change in pedagogy include elements of getting students to be more engaged with the material. One way of doing this is through the use of online homework systems that offer immediate feedback as students interact with learning assignments.

Background

The Net generation must be taught differently from students in the past. These students did not grow up going to libraries or using dial-up connections; they are more accustomed to rapid access to information and are adept at multi-tasking (Garrison, McDaniel, & Daday, 2015). In addition, teaching in the STEM disciplines has been undergoing significant change in the past two decades. As STEM professions become more prevalent throughout society, problem solving and critical thinking will be skills that are more and more in demand. Traditional lectures are insufficient for teaching these skills and are gradually being abandoned for methods that are more student-centered (Thomas & McRobbie, 2013). Finding best practices for teaching and assessing STEM curriculum has been the subject of much research. Chemistry, for example, can be especially challenging because of its multidimensional focus on macroscopic phenomena while at the same time considering the molecular or microscopic causes (Thomas & McRobbie, 2013). Pedagogical considerations have included greater emphasis on learning styles, flipping the classroom, moving to authentic learning environments, and the use of technology in presentation of content and in practice solving problems.

One way to promote student engagement with the material is to offer regular feedback. However, in undergraduate classes, especially those at lower levels with large enrollments, feedback on homework has been limited to finding answers at the back of the book, or in the extra purchase of solutions manuals. It is often difficult for professors and teaching assistants to provide written feedback at any higher level than mere numerical grades (Diegelman-Parente, 2011). For this reason, much of the homework assigned in college STEM courses goes ungraded, and often not even completed since there is no immediate penalty for not completing the assigned work (Galyon, Voils, Blondin, & Williams, 2015). There are both internal and external motivating factors for students in completing homework. Since professors can primarily affect the external factors, researchers suggest that homework carry enough weight to encourage students to complete it and can even carry extra weight as a form of formative assessment as opposed to the summative assessment found in many traditional introductory courses (Galyon et al., 2015).

Many STEM professors have adopted the use of web-based systems for delivery of homework (Halcrow & Dunnigan, 2012). Online homework has the ability to offer the same problems to large numbers of students through algorithmic means, so that students encounter the same problems, but with different parameters. Therefore, the correct answers will vary from student to student. In addition, feedback is programmed into the systems at varying levels. Some will only state whether the answer provided is right or wrong, but more sophisticated systems can provide hints specific to the current problem and possibly even increasing levels of feedback based on the answer a student provides. These prompts are usually based on known mistakes that are common on a given type of problem and can point students in the proper direction (Halcrow & Dunnigan, 2012).

Initial research on online homework systems did not reveal any improvement over traditional pencil-and-paper assignments (Allain & Williams, 2006), but further study has demonstrated a definite benefit from these systems (Phillips & Johnson, 2011). Both instructors and students can benefit from online homework. Reducing the amount of grading is a consistent topic across the literature for instructors. Arasasingham, Martorell, and McIntire (2011) studied the use of online homework for a single chemistry instructor and then expanded the study to a larger group consisting of multiple sections taught by several instructors and found that there was improvement in those students using this resource. Since that time, the consensus from research has been that the use of online homework does lead to higher student achievement (Parker & Loudon, 2013; Revell, 2014; Richards-Babb, Curtis, Georgieva, & Penn, 2015; Titard, DeFranceschi, & Knight, 2014; Woolley, 2015). None of these studies, however, address the use of online homework in biology courses.

In the 1960's, John Carroll (1963) pointed out that students differ in terms of the time required to learn material. Later, mastery was introduced through Bloom's (1968) model of learning for mastery and Block's (1971) refinement of mastery as an instructional method, which posits that it is better for students to fully understand (master) one concept before moving on to the next. In this way, about 80% of students can reach a top achievement level only reached by about 20% of students in a traditional setting (Bloom, 1974). A course design incorporating mastery can designate a level of mastery for students to reach to achieve a passing or average grade, while giving them the option to do more for a higher grade. This notion requires an effective method for instruction, feedback, and enrichment (Diegelman-Parente, 2011). All these things can be provided within the confines of a quality online homework system and can help establish a shift toward the process of learning and away from the sole focus on a grade.

Proposals for science education reform have stressed the need to transform teaching from its typical focus on transmission of knowledge from professor to student with only individual grading to a more engaging and constructivist approach where students are coached by teachers and work with peers in inquiry-based learning environments that address the needs of all types of learners. This approach would take the macroscopic, molecular, and symbolic aspects of chemistry and add the human element, or contextual component, increasing involvement and making learning more process-oriented (Lewthwaite & Wiebe, 2014). Situated cognition theories encourage becoming involved in communities of practice that have a base of knowledge; learning occurs by participating and sharing in such a community (Blas & Paolini, 2014). Process-oriented guided inquiry learning is one method by which students learn in groups and are encouraged to think like scientists. They form hypotheses and work through problems in lieu of traditional lecture. This method has been shown to reduce the incidence of misconceptions in chemistry at both the secondary and undergraduate levels (Barthlow & Watson, 2014).

One theory which has been employed to a large extent in teaching STEM is that of activity theory (Thomas & McRobbie, 2013). Russian psychologists Rubinstein and Leontiev first postulated activity theory in the early 20th century. More recently, science education has incorporated the idea into Cultural Historical Activity Theory (CHAT), in which an activity itself is the central construct of the approach. It is based in constructivism and asserts that learning occurs through experiences of the learner, who is able to build knowledge based on those experiences. In this theory, an activity system is "any ongoing, object related, historically conditioned, tool-mediated human interaction" (Jonasson, 2000, p. 94). In an activity system, teachers and students share and construct meaning through participation in activities. According to Theodoraki and Plakitsi (2013), the object of learning changes constantly according to the objectives of the activity. The object of learning also manifests itself in different ways and at different times for each learner involved in the process. Because of this fluidity of the object of learning, the traditional lecture method is insufficient for teaching the complex ideas found in many STEM subjects, but time and space make it difficult for much innovation that would truly help students master the material.

Problem Statement

It has been established that completion of homework correlates to higher grades in STEM courses (Eichler & Peeples, 2013; Cuadros, Yaron, & Leinhardt, 2007). However, this homework is often ungraded and therefore obtains minimal feedback from professors (Galyon et al., 2015). Additionally, many STEM disciplines must incorporate multiple levels of understanding simultaneously within the curricula. Traditional lectures are insufficient for teaching these skills and are gradually being abandoned for methods that are more student-centered (Thomas & McRobbie, 2013). This can include laboratory work, though it must be carefully related to the lecture. These researchers studied visualization activities that were meant to aid students in making connections between the macroscopic and molecular levels (Thomas & McRobbie, 2013). Online homework can incorporate similar activities through tutorials, computer simulations, and molecular manipulation in order to achieve the desired results (Arasasingham et al., 2011).

Organic chemistry is one STEM field requiring a great deal of conceptual understanding. Richards-Babb et al. (2015) recognize that organic chemistry requires effective pedagogy, including encouraging student-faculty contact, cooperation among students, active learning, prompt feedback, emphasizing time on task, communicating high expectations, and respecting different ways of learning. Utilization of online homework directly addresses the active learning, time on task, and prompt feedback. It also indirectly represents faculty contact with students. Biology is another field requiring conceptual understanding that has been addressed very little in the literature.

Overall, online homework ranked above the traditional methods as a source of learning in chemistry, physics, and math courses, demonstrating its efficacy through improved exam scores in those areas (Richards-Babb et al., 2015). The problem was to find out whether these systems are effective in undergraduate biology courses, as they have proven to be in other STEM disciplines.

Purpose Statement

The purpose of this quantitative, correlational study was to determine whether homework grades in online homework systems can predict student achievement in introductory undergraduate biology courses. The criterion variable, final course grades, was defined as the final numerical course grade achieved in Biology I or Biology II. Overall homework score as recorded by McGraw-Hill's Connect™ system was one predictor variable. Another was the total time spent over the course of the term toward completion of that homework, and a third variable was gender of the participants. Any student who has completed a course in metacognition defined a final predictor variable. The study focused on undergraduate biology students enrolled in general biology classes at a small private Christian college in the Southeast.

Significance of the Study

STEM fields have been heavily emphasized in educational literature for more than two decades. It is widely held that STEM knowledge is important even in other fields (Capobianco, Diefes-Dux, Mena, & Weller, 2011). For those training in STEM-related fields, mastery of the concepts and problem-solving techniques are critical for success. Research on pedagogy has evaluated the idea of the flipped classroom, where content is received out of class, and homework is done in class (Davies, Dean, & Ball, 2013); use of tools such as tablet PC's and clickers (Revell, 2014; Wooley, 2015), and use of online homework to aid in grading and offering feedback from assigned homework are also common. With regards to online homework, previous studies have focused on the relationship between online homework and traditional pen-and-paper homework in undergraduate STEM courses (Parker & Loudon, 2013; Revell, 2014; Richards-Babb et al., 2015; Titard et al., 2014; Wooley, 2015). Most studies in STEM fields have been conducted on chemistry and physics courses, due to the more quantitative nature of these fields. There have been relatively few studies on relationships between online homework systems and student achievement in undergraduate biology courses. This study sought to address the gap in the literature for biology courses and determine whether such a relationship exists.

Research Questions

RQ1: How accurately can student achievement in biology courses be predicted from the linear combination of online homework scores, time spent on homework, gender, and completion of a metacognition course for undergraduate students at a small private Christian college in Georgia?

RQ2: Is there a correlation between scores on a major metacognition assignment in a course on metacognition and final course grades in Biology I or Biology II?

Definitions

1. *Homework*—any academic, course-related task assigned by the instructor and intended for students to carry out during non-class hours (Planchard, Daniel, Maroo, Mishra, & McLean, 2015).
2. *Online homework systems*—software systems that function by promoting active learning, giving prompt feedback, and emphasizing time on task for assigned homework problems (Parker & Loudon, 2013).
3. *Academic achievement*—the grade a student receives, either for a course or for a specific assignment (Planchard et al., 2015).
4. *Self-directed study*—all of the activities in which students engage to prepare for formal assessments and to keep up with the material (Cuadros et al., 2007).
5. *Guided activities*—all of the activities designed by the instructor to promote learning—both the informational presentation and the design of homework (Cuadros et al., 2007).
6. *Metacognition*—self-regulation and reflection on one's own learning, including planning, monitoring success, and making corrections when necessary (Bransford, 2000).

CHAPTER TWO: LITERATURE REVIEW

Overview

Chapter Two will discuss the literature found on the topics of the study, including the use of homework at the college level and a potential transition in some areas to online homework. The chapter will also survey theoretical frameworks that potentially influence learning in STEM courses, such as Schema Theory and Activity Theory. The chapter will also explore a move toward active learning, along with the role that online systems play in that movement.

Theoretical Framework

Introduction

Schema theory and activity theory play a role in the use of homework for undergraduate STEM courses. These theories share a number of attributes. To begin, a theory of learning must address four fundamental questions. The first considers who the subjects of learning are; the second asks what motivates them to learn. The third addresses what they learn, while the fourth is concerned with how they learn, or what the key learning processes are (Engeström, 2001).

Spencer (1999) found that students can memorize enough to do well on chemistry exams without actually developing a conceptual understanding of the material. Engagement within the classroom can enhance the experience and bring students to learn the material from interest in it, as opposed to viewing the material as a mere means to an end (Diegelman-Parente, 2011). Johnstone (1997) was one of the first chemistry educators to begin styling a theory of how to best present the information to students. He says that the traditional way of teaching does not fit the way students learn, as it requires them to process information that may overload working space in the brain. This space is responsible for both holding and processing of information, and students at differing stages have different amounts of storage available. In processing incoming knowledge, learners try to make sense of new information in light of their existing body of knowledge. New ideas may be rejected if they do not fit well into that body. Before the processing even begins, each person has a perception filter through which they process incoming information (Ausubel, 2000). This filter is affected by prior knowledge, interests, prejudices, and beliefs. Information must also come through any other surrounding sensory stimuli that could prove distracting. In this way, each person will select what information reaches the working space, so that each listener will be receiving different information. Therefore, the idea that information can be transferred intact from a teacher to a learner is not valid (Johnstone, 2010).

Ausubel (2000) links the types of learning as part of a spectrum. On one end, the correct linking to existing knowledge is meaningful learning, whereas the failure to link at all is rote learning. He states that in the process of acquiring information, there is a change in both the information and of the cognitive structure to which it attaches. *Anchorage* is a term to describe this attachment of new information. Rote learning, on the other hand, has no meaningful link to cognitive structure, must be kept brief, and can only be expected to last a short period of time. It is also susceptible to interference from previously-learned ideas, possibly resulting in misconceptions (Ausubel, 2000).

Bateson (1972) offers the idea of three levels of learning. The first level involves basic conditioning, or learning the correct response, such as answers to questions in a classroom. The second level is sometimes referred to as “hidden curriculum,” where one learns what it means to be a student, how to please the teacher, and how to interact in groups. Level three results when contradictions in learning cause students to question the knowledge or process being presented.

The subjects will then seek to expand the context in order to alleviate the contradictions (Engeström, 2001).

Johnstone also proposed four ways in which storage of new information can occur. The first of these is correctly filing that information, where a new piece of information is integrated with existing knowledge in the manner in which it should be. A second way involves integrating with existing knowledge, but in a manner that is incorrect. Third, there may also be storage in a linear fashion, where knowledge can be retrieved, but only in the order in which it was conveyed, such as when we are asked to state the tenth letter in the alphabet and have to start with “A” and begin counting upward. Finally, there may be knowledge that does not attach in any way to prior experience, which can be difficult to learn and to retrieve. Learners are shaped by previous experience, background, and learning style; therefore, no two learners are the same (Wood, 2009).

If much processing is required during the learning process, then not as much information can be held. In the same way, if a high volume of information is being transmitted, not as much of it can be processed. As students mature, they have more working space, which corresponds to Piaget’s (1973) (and advocates of alternative framework) stages of development. Information that has been integrated into prior knowledge is stored long-term and becomes easily retrievable, while information memorized without integration is easily lost (Johnstone, 2010). Additionally, incoming information is used to build knowledge after it passes through a filter of each student’s own experience. To use Johnstone’s (1997) words, “learning is not the transfer of material from the head of the teacher to the head of the learner intact. Learning is the reconstruction of material, provided by the teacher, in the mind of the learner” (p. 264).

Schema Theory

This incorporation of new ideas might be explained by Schema theory. Schema theory originates with the work of Piaget (1973). He proposed that human cognitive development occurs in predictable stages that must occur sequentially. Neo-Piagetian theorists have expanded on Piaget's original four stages of development to include an additional three stages occurring later, including abstract mapping, abstract systems, and abstract principles (Knight & Sutton, 2004). All these stages represent the ability of the learner to build knowledge, where less complex skills are used to build more complex ideas. A schema is a conceptual system for understanding knowledge and comprises a single unit. Multiple schemata together form our knowledge of various concepts. These schemata are not static but are instead dynamic and ever developing. As students interact with concepts, they are building knowledge and are themselves changed in the process (Rosenblatt, 1994).

When learners build knowledge of abstract ideas, it is important that they be able to link thoughts together (abstract mapping) in order to understand the interrelationships of these phenomena. There are a great number of these abstract concepts in STEM fields, particularly in chemistry and organic chemistry. Matthews (2002) stated the difficulty faced by science teachers when trying to communicate these concepts to their students, who have no knowledge upon which to construct these concepts into new learning. Many instructors try to compensate with demonstrations and models to discuss submicroscopic phenomena, but Matthews states that this sensory information alone cannot suffice to be the foundation of this type of learning (Matthews, 2002). Johnstone (1997) posits that in order for students to process the abstract concepts in chemistry, they must attach it to a schema that exists in their long-term memory. If no such schema exists, they will (1) lose the information; (2) create a new schema, which may be difficult to retrieve in the future because it is not related to other existing schema, or (3) fit the new knowledge into an existing but inappropriate schema by modifying it, which results in an alternate conception. Here alternate conceptions might be defined as inappropriate schema that are sometimes difficult to modify with subsequent learning.

Activity Theory

Most learning theories describe learning as a process whereby individuals (or sometimes organizations) acquire knowledge or skills. This knowledge is assumed to be well-defined, and some change in the learner can be observed. There is often a capable mentor, usually a teacher who guides this process. However, these theories fail to explain how previously undiscovered knowledge is acquired. Engeström (2001) stated:

> In important transformations of our personal lives and organizational practices, we must learn new forms of activity which are not yet there. They are literally learned as they are being created. There is no competent teacher. Standard learning theories have little to offer if one wants to understand these processes. (p. 138)

As previously mentioned, another theory which has been employed to a large extent in teaching STEM is that of Activity theory (Thomas & McRobbie, 2013). Russian psychologists Rubinstein and Leontiev first postulated activity theory in the early 21st century (Jonasson, 2000). Their work takes root in the theories of Vygotsky, who emphasized the ideas of internalization and externalization, claiming that they operate at every level of human activity (Engeström, 1999). Internalization includes reproduction of culture, or learning by observing and imitating, such as a child seeing a teacher use a pencil, then using it herself. Externalization would be taking that knowledge and using it to build new constructs, such as drawing a picture with that pencil (Allen, Karanasios, & Slavova, 2011). In addition, Vygotsky determined that some students work at a low ability level when working independently and a higher level when working with a mentor. He referred to the distance between these two levels of ability as the zone of proximal development.

Engeström (2001) describes three generations through which activity theory has evolved. The first generation, developed by Vygotsky, involved an idea called *mediation,* where a connection between stimulus and response included some mediating factor. (See Figure 1.)

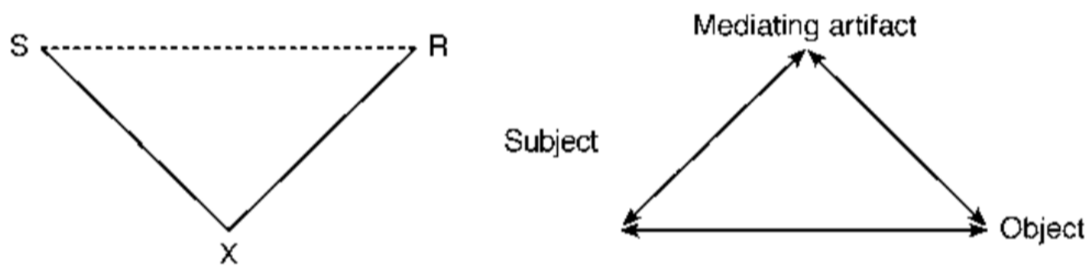


Figure 1. Vygotsky's Model of Mediation

More recent updates refer to the subject (the learner), an object (the principle involved) and a mediating artifact. This was revolutionary in the idea that the culture was crucial to the development of the individual, but that culture cannot be understood without the agency of the individuals who are using and producing these mediating factors. This is in contrast to the work of Piaget where the subject is transformed through gaining logical operations.

The second generation took activity theory beyond focus on the individual, where Leont'ev established the difference between individual actions and collective activity (Engeström, 2001). This can create *internal contradictions*, which can drive the change and development of an activity system. The third generation is the focus now and includes the possibility of multiple interacting activity systems (See Figure 2). For example, Guitterez, Rymes, & Larson (1995) illustrate an overlapping space between teacher and students where the ideas of each may “interact to form new meanings that go beyond the evident limits of both” (Engeström, 2001, pp. 135-136). Engeström’s (2001) theory of expansive learning develops Bateson’s (1972) ideas on levels of learning and identifies Learning III as learning activity “which has its own actions and tools. The object of expansive learning activity is the entire activity system in which the learners are engaged” (Engeström, 2001, p. 139). New patterns of activity are formed in expansive learning.

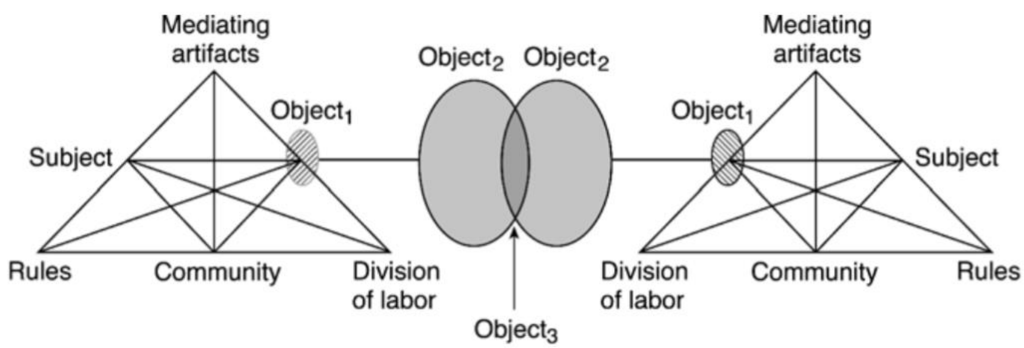


Figure 2. Multiple Activity Systems

More recently, science education has incorporated the idea into Cultural Historical Activity Theory (CHAT), where an activity itself is the central construct of the approach. It is based in constructivism and asserts that learning occurs through experiences of the learner, who is able to build knowledge based on those experiences. In this theory, an activity system is an ongoing, human interaction that is object-related, historically-conditioned, and tool-mediated (Jonasson, 2000). In an activity system, teachers and students share and construct meaning through participation in activities. According to Theodoraki and Plakitsi (2013), the object of learning changes constantly according to the objectives of the activity. It also manifests itself in different ways and at different times for each learner involved in the process. The activities also include the needs of the community and feedback from members of that community. In this way, it is much more social than traditional methods of learning (Allen et al., 2011). Following that logic as it applies toward STEM education, the traditional lecture method is insufficient for teaching the complex ideas found in many STEM subjects, but time and space make it difficult for much innovation that would truly help students master the material.

Activity theory can be summarized with the following five principles. The first is that the prime unit of analysis is the activity system itself. It may interact with other activity systems, and its object will be affected by individual and group actions. The second principle states that an activity system is multi-voiced; it is always a "community of multiple points of view, traditions, and interests" (Engeström, 2001, p. 136). Third, historicity of an activity system holds that it is important to view the sometimes-lengthy formation of an activity system throughout its progress to fully understand it. Fourth, contradictions play a central role in change and development. Engeström (2001) states, "Contradictions are not the same as problems or conflicts. Contradictions are historically accumulating structural tensions within and between activity systems" (p. 137). The introduction of new elements to an activity system may create tensions with old structures that must be resolved through integration. Fifth, expansive transformation may take place within activity systems. This might arise when individuals, when faced with contradictions, break from the norms of the system and begin to envision new outcomes and overall reconceptualization of the object beyond its original limits (Engeström, 2001).

Related Literature

Introduction

There is a call for change in teaching biology and other STEM subjects, and according to Wood (2009), there are two major forces behind it. One is the concern about America's competitiveness in the international community and its ability to train and retain students in the STEM disciplines. Too many undergraduates find introductory courses a large collection of facts to be memorized and drop out before really gaining an appreciation for what science is all about. Less than 40% of students who enter STEM majors (and less than 20% of the nonwhite students who do so) graduate with a STEM degree (Freeman, Eddy, McDonough, Smith, Okoroafor, Jordt, & Wenderoth, 2014)

The other force is educational research into how students learn. Students must be more actively engaged in the learning process, and recent studies have emphasized the transition from lecture-style learning to a more learner-centered focus (McLaren & Kenny, 2015). There are several types of change recommended, which include active learning, where students are engaged in problem-solving activities and are talking with each other about what they are doing. Another type is the flipped classroom, where students watch pre-recorded lectures before coming to class, so that problem-solving can be emphasized more in the classroom time. Still another is team-based learning, where class time is spent in small groups who help each other with the material (McLaren & Kenny, 2015).

One difficulty for STEM subjects is that they require learning on multiple levels. Chemistry, for example, is a challenging concept because of its complexity and the need to create visualizations of molecular-level phenomena and construct knowledge of empirical laws dealing simultaneously with macroscale events and microscale explanations. This requires student engagement in the learning process, not only with the material, but with the teacher and other students as well. The constructivist approach encourages a community of learning (Thomas & McRobbie, 2013). However, the traditional lecture method is still dominant in most chemistry courses, especially in large universities where introductory classes are typically quite large. Thomas and McRobbie (2013) suggest activity theory as a means to engage students with an activity that translates into a desired outcome. This can include laboratory work, though it must be carefully related to the lecture. These researchers studied visualization activities that were meant to aid students in making connections between the macroscopic and molecular levels (Thomas & McRobbie, 2013).

As an example, Tasker (2014) quotes Johnstone's (1982) idea that there are three levels of thinking in chemistry: macro, sub-micro, and representational. The macro is observable phenomena such as chemical reactions done in the lab or as demonstrations, sub-micro focuses on the atoms, molecules, and ions involved, and representational includes chemical symbols and equations. He suggests dividing the presentation into sides: one shows the macro level as a demonstration, and another shows the sub-micro level via models such as ball-and-stick models or computer animations. He quotes Kozma & Russell (1997), describing how students may find it difficult to see relationships among the three levels, especially since instructors may unknowingly switch between the language representing these different levels throughout a lecture. This tendency taxes working memory and may result in fragmented information that may have been learned only at a superficial level (Gabel, 1999). This may also result in student misconceptions, which can be any conceptualizations that differ from the accepted scientific understanding of the term (Mulford & Robinson, 2002; Nakhleh, 1992). According to Tasker (2014), many of these misconceptions result from failure of students to form an accurate model to represent the incoming information. Additionally, many are common to students regardless of their location and educational level, and they tend to be resistant to any efforts to correct them.

To complicate matters, many students are seeking to earn grades instead of mastering material. Teachers find themselves teaching to a test, and feedback is often given only in the form of numerical grades (Diegelman-Parente, 2011). In the 1960's John Carroll (1963) pointed out that students differ in terms of the time required to learn material. Later, mastery was introduced through Bloom's (1968) model of learning for mastery and Block's (1971) refinement of mastery as an instructional method which posits that it is better for students to fully understand (master) one concept before moving on to the next. In this way, about 80% of students can reach a top achievement level only reached by about 20% of students in a traditional setting (Bloom, 1974). A course design incorporating mastery can designate a level of mastery for students to reach to achieve a passing or average grade, while giving them the option to do more for a higher grade. This notion requires an effective method for instruction, feedback, and enrichment (Diegelman-Parente, 2011).

Learning must be an active process where a learner cognitively analyzes incoming information and determines where it might fit within existing structure. Some reconciliation with that existing information must take place, and any potential contradictions must be resolved. Finally, the material must be reformulated in the learner's own vocabulary, and will result in construction of new cognitive structure (Ausubel, 2000).

Active Learning

The American Association for the Advancement of Science believes that biology professors need to develop active learning methods in undergraduate courses in order to address the needs of the Net generation (Brownell & Tanner, 2012). The current generation has grown up in an environment where information is a few mouse clicks away, as opposed to the more traditional method of doing research via paper in a library (Garrison et al., 2015). This forces professors to teach in a way that they themselves were not taught, and to transform delivery of content into a more individualized and autonomous experience. However, there may be resistance to this change because of lack of time, training, and incentives. Training cannot be done in a short workshop; it requires multiple sessions with consistent feedback (Brownell & Tanner, 2012; Garrison et al., 2015). Additionally, many faculty members are unfamiliar with the concept of a student-centered classroom and may not understand what that looks like. A transformation requires additional time, and there is little external incentive for most professors to make the change. Many professors cite the lack of class time to cover the required material in a more active fashion and a shortage of time to prepare materials, especially when research is a priority that may exceed teaching responsibilities (Brownell & Tanner, 2012; Patrick, Howell, & Wischusen, 2016).

In contrast, Ausubel (2000) argues that the role of "expository teaching" does not deserve the criticism it has received in recent decades but rather believes that the delivery of information by many lecturers is lacking. He lists several unsuccessful practices, including not accounting for the cognitive maturity of students, presentation of arbitrary facts without any organizing or explanatory principles, failure to integrate new material with previously learned knowledge, and designing assessments which merely require students to recognize ideas when given in the same manner as they were originally presented. However, in the mid 1980's, physicists began to realize that students were learning fragmented facts and rote problem solving rather than the intended integration of concepts and creative problem solving. As a result, the Force Concept

Inventory was created to measure conceptual understanding, and a push toward more student-centered teaching began (Wood, 2009).

To illustrate this trend, Freeman, et al. (2014) did a meta-analysis on active learning in undergraduate STEM classrooms. They compared scores on exams or concept inventories, as well as failure rates (including withdrawing). They found that active learning increased scores by .47 standard deviations, and that lecturing increased failure rates by 55%. This was determined to be true across all STEM disciplines, in all class sizes, course levels, and course types. The authors estimate that had the students in these studies been in active learning environments, 3,516 failures might have been avoided, at a tuition savings of $3,500,000. The authors of the meta-analysis even call for the cessation of lecturing as a control group method (Freeman et al., 2014). A more recent study found that lecture methods could sometimes have no effect on conceptual understanding in physics lectures, and even result in a decrease in scores on certain questions (Heron, 2015).

To help students become active learners, instructors can facilitate student use of materials that drive independent construction of understanding, so that students become self-directed learners (Borich, 2014). Materials offered outside of class, including lectures, activities, and assessments, can engage students in their own learning processes, which can be built upon in class (Meyer, 2014). Also, metacognitive strategies can make students more aware of their own learning and encourage use of out-of-class resources such as lecture videos and online homework sets. Student perception of these tools can also influence their self-regulated learning behaviors (Sletten, 2017). Metacognition could be defined as the awareness and questioning of one's own learning process. Determining whether new information is understood, what may be lacking, and whether it can be applied to a new situation is essential for effective learning (Wood, 2009).

Metacognitive learning should be encouraged by professors through teaching students to use these skills. Students who were taught to study through metacognitive awareness outperformed their peers in undergraduate chemistry courses (Zhao, Wardeska, McGuire, & Cook, 2014).

As one alternative to lectures, Eddy and Hogan (2014) studied increased course structure, where pre-class assignments, in-class activities, and out of class practice were assigned throughout an introductory biology course. This resulted in higher exam grades for both black students and first-generation college students. The failure rate overall dropped as much as 41%. Accountability increased in the course as well, resulting in increased time spent on the course weekly and increased attendance. The authors also found support for their idea that increased structure resulted in a higher sense of community within the course, which has also been shown to increase academic performance (Eddy & Hogan, 2014).

Another avenue through which courses can be changed is technology. Garrison et al. (2015) studied pedagogical changes through looking at syllabi before and after implementation of e-texts and other e-materials, including LearnSmart™, from McGraw-Hill's online platforms. This offered an opportunity to shift from summative assessments to more formative ones, as online assessments increased, and grade percentages were set aside for tests and quizzes decreased. In an anatomy & physiology course, which requires an enormous amount of memorization, quizzes became more frequent, indicating a shift from having to learn large amounts of information for high-stakes testing to a more frequent assessment with less information each time. Woolley (2015) states that before adoption of a technology, three factors should be considered. First, the technology should improve the effectiveness and efficiency of the instructor. Second, the students should like it. Third, the technology should improve student learning. If significant gains are not accomplished in these areas, the extra expense may not be justified (Wooley, 2015).

One study offered pre-exam quizzes throughout the semester in introductory biology courses and found that participation in the quizzes significantly improved exam scores. It is worth noting that comparison was not made on the quiz grades, but rather the level of participation, using those who either completed 100% or 0% of required quizzes. Students found value in this strategy, as nearly 90% of them planned to use quizzing for preparation in future classes. More than two-thirds of students (73.42%) also said that the quizzes made them go back for additional study of the material (Orr & Foster, 2012).

Other current methods for increasing student engagement include using clickers and cooperative learning. Clickers are response tools that students use to answer questions collectively during the lecture. Students submit answers to questions posed by the professor through these clickers, and the results are displayed for the whole class to see. In this way, professors can see how effective their teaching is, and students get crucial feedback on their understanding of what was just covered (Diegelman-Parente, 2011). Cooperative learning has been shown to improve individual grades and can help students stay on task through more difficult material (Hsiung, 2014). This may be due to peer feedback in a more immediate sense than can be provided by the instructors or TAs. Meyer (2014) states that when learners are actively engaged in content-related activities, they are constructing knowledge, and this can happen with other learners in situations such as class time in flipped classrooms.

Gebru, Phelps, and Wulfsberg (2012) studied the use of clickers and online homework in general chemistry classes. There was a slightly higher average final exam score among the students in the experimental group, but it was not enough to be significant. However, they did find that retention in these courses increased as compared to the lecture-only control groups. Students in another study commented that they were more engaged and interested in the material and could apply what they'd learned in class after viewing online lectures. They also noted that the availability of these lectures prevented them from getting behind in class and promoted study skills, teaching them to be truly independent students (McLaughlin et al., 2013).

Revell (2014) introduced the addition of three technologies to the classroom: tablet PC's for students to follow along with lecture, clickers, and online homework. This combination caused a higher retention (90%) within the course and was well received by students. Both the tablet PC and clickers increased engagement within the course but did not necessarily translate to higher grades. The online homework, however, did seem to contribute to higher grades, as students who completed all or at least most of the homework performed better than those who did not.

Homework

Completion of homework has been shown to correlate with higher grades in general chemistry (Eichler & Peeples, 2013). Students know that success in college STEM courses requires a great deal of out-of-class work, but many are not motivated to do it (Halcrow & Dunnigan, 2012). Students from a generation ago could have been expected to do suggested homework and ask for help if needed, but this expectation no longer can be assumed. Professors should consider ways to help motivate students to complete homework assignments. Many STEM courses require a substantial amount of practice, which is typically accomplished through homework. It is difficult, however, for the typical professor to provide feedback to students on homework. Feedback is critical to success, but giving adequate feedback is a difficult task, given other obligations such as research, publication, and service (Halcrow & Dunnigan, 2012). These authors believe that students would do more homework if it could be graded for credit. Online homework offers instant feedback and multiple attempts in order to make it more likely that students will complete assignments.

Two primary factors in completing homework, motivation and feedback, are discussed by Gutarts and Bains (2010). Students need some sort of motivation, typically through grades, to complete assignments. They also are less likely to do homework if there is no feedback. Planchard et al. (2015) found that reinforcement (the desire to learn material or recognition of the need to do so) was the top motivating factor for homework completion, followed by credit and extra credit. Students reported that reinforcement was a strong factor in completing homework, but reinforcement alone was not as strong a motivator as students' self-reports might suggest. Students prioritized assignments that were required for credit and were less motivated by extra credit, though extra credit provided more incentive than none at all.

Students who are to succeed in STEM courses must develop problem-solving skills and conceptual understanding by engaging in the material being covered in lecture. In undergraduate classes, especially those at lower levels with large enrollments, feedback on homework has been limited to finding answers at the back of the book, or in the extra purchase of solutions manuals. It is often difficult for professors and teaching assistants to provide written feedback at any higher level than mere numerical grades (Diegelman-Parente, 2011). For this reason, much of the homework assigned in college STEM courses goes ungraded, and often not even completed since there is no immediate penalty for not doing the assigned work. Halcrow and Dunnigan (2012) state that most professors agree that while certain STEM subjects require doing a high number of homework problems, there is not time to grade that work and especially not with sufficient feedback to increase student understanding. Several options exist, including not grading the homework at all, grading only random selections of problems, or having teaching assistants (TAs) do the grading. Sometimes the latter is not even an option if TAs are not available or allotted enough time in their workload to accommodate such a demand (Richards-Babb, Drelick, Henry, & Robertson-Honecker, 2011).

Even though it is considered important, homework grading at the college level is scarce in the literature, possibly because the efficacy of it may already be assumed, or because the time required for frequent feedback through homework is lacking in the college setting (Galyon et al., 2015). It is possible, therefore, that college students do not see the value in completing frequent homework assignments. Galyon et al. (2015) illustrate the importance of graded homework in a study where paper homework was graded either by percentage of questions answered or by accuracy of answers to a randomly selected 10% of questions. The group with the randomized accuracy not only ended up completing more, they had better results as well (Galyon et al., 2015).

Students who considered themselves to be intelligent, conscientious, and who have a positive attitude toward school were more likely to complete homework regardless of credit. The question arises as to how significant these traits are in terms of directly affecting academic achievement, or whether these students' tendency to complete assignments contributes more to success. Given that feedback is a motivating factor in completion of assignments, and online homework systems offer immediate feedback, it stands to reason that conscientious students who commit to doing assignments will have a positive experience as they learn. This will lead to even greater commitment to doing work and more satisfaction from receiving feedback, resulting in a positive feedback loop that ultimately leads to greater academic achievement (Planchard et al., 2015).

Cornell and Odafe (2008) found a positive correlation between midterm and final exam grades and homework grades and concluded that graded homework assignments have a stronger impact on these grades than quiz grades do. They suggested the use of online homework to give students feedback and provide opportunities to rework incorrect problems. Planchard et al. (2015) confirmed a finding by Cuadros et al. (2007) where completion of pencil-and-paper homework problem sets correlated positively with academic achievement in the form of exam scores.

Online Homework

One option for teachers who do not have the assistance of TA's would be the use of online homework, as suggested by Cornell and Odafe (2008). In a study of small introductory physics courses, Lazarova (2015) found that scores on graded pencil-and-paper homework did not correlate with higher exam scores and decided to use WebAssign to deliver the homework problems. With the implementation of online homework, there was a positive correlation with better grades on exams. Additionally, there was a greater opportunity for monitoring and offering early intervention for students who struggled with the content (Lazarova, 2015).

Early studies on the contrast between pencil and paper homework and online homework showed little difference in academic performance (Allain & Williams, 2006). However, students overwhelmingly preferred the online method, even when considering potential drawbacks such as connectivity issues (Johnston, 2004). Students also reported spending more time on the material and using the textbook more with online homework systems (Allain & Williams, 2006). More recently, Lazarova (2015) found that students in introductory physics courses had a stronger correlation between homework assignment performance and test performance than students assigned the same problems via pencil and paper.

In a similar study, engineering students showed improvement after using online homework versus a control group using pencil and paper assignments. Researchers found that many students seemed to have access to the solutions manual when students did paper homework but found that the incidence of cheating and copying were greatly reduced for the students using *Mastering Engineering* (Arora, Rho, & Masson, 2013). Additionally, in prior years, paper homework was graded by student graders, which made feedback on assignments both limited and delayed. The online homework system, which has the ability to incorporate free-body diagrams and equations into the answers, gives feedback on common errors and provides hints that can be skipped if not needed. The students using this system not only did better in the initial course in the study; they retained the material in the next course in the sequence better than their paper homework counterparts did. Finally, the instructor was able to use the score analysis features of the online system to see where students were struggling and could modify instruction accordingly (Arora et al., 2013).

Online homework has the ability to offer the same problems to large numbers of students through algorithmic means, so that students encounter the same problems, but with different parameters. Therefore, the correct answers will vary from student to student. In addition, feedback is programmed into the systems at varying levels. Some will only state whether the answer provided is right or wrong, but more sophisticated systems can provide hints specific to the current problem and possibly even increasing levels of feedback based on the answer a student provides. These prompts are usually based on known mistakes that are common on a given type of problem and can point students in the proper direction (Halcrow & Dunnigan, 2012).

In a study of college algebra students, the online homework system provided feedback on each problem, offering at least three attempts per question. If all three attempts were wrong, students could request another similar question for credit. Additionally, students had access to examples worked step-by-step through the system and had ample opportunity to score 100% on any given homework assignment (Burch & Kuo, 2010; Mathai & Olsen, 2013).

Folami and Simmons (2012) suggested that before adopting an online homework system, professors should consider any technical issues, including error rates, availability and helpfulness of technical support staff, and internet access. Some systems use the end-of-chapter questions from the textbook, but change values in each question for each student, therefore changing the answer. (Lazarova, 2015). Using algorithms helps minimize any concern over whether students do their own work. They cannot simply copy answers from other students because those answers change from student to student, even though the wording may be the same (Folami & Simons, 2012). Students see similar problems to those found in the textbook, but since values change, each student is required to use his or her own data set to solve those problems (Lazarova, 2015).

Babaali & Gonzalez (2015) reiterate that feedback is an important benefit of an online homework system, especially if the system can provide specific and detailed responses tailored toward particular wrong answers of students. This might be similar to what a teacher would do if he or she were actually present. Another factor is the opportunity to try a problem more than once or attempt similar problems after missing one. This has a positive psychological effect, where students are more motivated to get problems right for higher scores and develop a greater sense of their ability to be successful within a course (Babaali & Gonzalez, 2015). This reiterates the positive feedback loop mentioned earlier.

One suggestion by Halcrow and Dunnigan (2012) was to use a homework system aligned with a specific text in order to minimize the effort required by the instructor. This also allows students to take advantage of the book more, because often the problems in the homework system are at least similar to examples from the book. Lazarova (2015) suggests that having the ebook available in the online homework system may increase the likelihood that students may consult the text when attempting to solve problems.

Another benefit of online homework is that accuracy and completion are both considered. Titard et al., (2014) pointed out that scores from online homework can improve course grades when included as a graded portion of the overall course grade but sought to discover whether the process of doing the homework actually improved student's learning as determined by performance on exams. They found that the mean exam score for students who earned at least 70% of the potential points assigned for online homework was significantly higher than the mean exam score for those earning less than 70%. Another advantage to this type of assessment, as previously mentioned, is the availability of instant feedback on practice problems. This is especially helpful in large-enrollment courses where time is at a premium, making feedback from grading traditional homework extremely difficult (Folami & Simmons, 2012).

While much of the research on online homework has been oriented around calculation-based problems, it is important to note that it can be beneficial for conceptual understanding as well. Organic chemistry, for example, includes symbolic representations and the ability to communicate them, mental models, interconversion among several types of representations (line structure, condensed structure, Fischer projections, etc.), as well as an ability to manage spatial aspects of the science, like rotations or applying 3-dimensional concepts when seeing only 2-dimensional representations (Richards-Babb et al., 2015). Organic chemistry is a difficult subject and therefore requires effective pedagogy, including encouraging student-faculty contact, cooperation among students, active learning, prompt feedback, emphasizing time on task, communicating high expectations, and respecting different ways of learning. Utilization of online homework directly addresses the active learning, time on task, and prompt feedback. It also indirectly represents faculty contact while incorporating aspects of different learning styles. These researchers took the overall positive results in achievement scores and positive perceptions among students and studied how organic chemistry students remediate an incorrect response. Some students admit to guessing, which obviously lowers the level of mastery from the system. Others, however, would go back to the text or to the supplemental features available in many online homework systems in order to find the correct answer and understand why they were wrong initially. They also had students rank the usefulness of online homework as compared to lecture, instructor-led review sessions, instructor-provided questions sets with answer keys, and the textbook in their studies. Overall, online homework ranked above the traditional methods as a source of learning, demonstrating its efficacy in that arena in addition to improved exam scores (Richards-Babb et al., 2015).

A recent idea involves interactive video vignettes. These are intended to promote a constructivist progression of learning where learners interact with material, engage with real-world problems, build 'scaffolding' for material, and reflect on their own learning as they receive feedback and guidance. In the process of viewing interactive video vignettes, users are asked for feedback numerous times, involving them in a real-world problem that teach them science concepts without the use of overly technical terms. These can be used to teach all students, including those with learning disabilities, as the vignettes can be viewed as many times as desired. Additionally, known misconceptions that many learners have, such as "dominance" in genetics meaning “stronger” or “more common” can be incorporated into the vignettes and explained adequately (Wright, Newman, Cardinale, & Teese, 2016).

Online homework systems can be used in a number of ways. One study found that online homework activity correlates positively with student success in terms of gaining knowledge on certain topics, measured by improvements between midterm and final exams. However, on topics on which students performed poorly and did not show improvement, there tended to be more attempts per question than those topics where students performed well or improved their performance. This indicates that they may have been guessing or manipulating answers until they are accepted by the online homework system. Spending more time on a question, as opposed to trying it repeatedly, seems, therefore, to be a more effective study strategy. One potential improvement could be increasing metacognition, so that students spend more time reflecting on why their answer is wrong, rather than simply changing their answers without understanding the concepts of a particular topic (Bowman, Gulacar, & King, 2014).

Another possibility explored by Richards-Babb et al., (2011) was using online homework as a replacement for quizzes. This resulted in the majority (90%) of students completing the assignments in addition to improved success rates in the course overall, as assessed by the number of students receiving final grades of A, B, or C, which increased by anywhere from 3.8% to 12.1%. This allows instructors to incorporate more formative assessments and students to receive increased feedback as to their performance (Richards-Babb et al., 2011).

One benefit found by Lazarova (2015) determined that online homework performance can be used to predict how much students are learning problem-solving skills. Another suggestion was to use early results from online homework assignments be to identify students who are under-performing and may need extra services, such as tutoring, since these scores are available before exam grades (Perdian, 2012; Lazarova, 2015). Lazarova (2015) found that including online homework scores in final course grades is a more realistic predictor of students' learning and does not result in grade inflation in the way the paper-based homework did. Another use would be to identify higher-performing students who could be encouraged to participate in honors programs, extra projects, or peer tutoring (Bowman et al., 2014).

Mathai and Olson (2013) found that there is a differing benefit of online homework between stronger and weaker students. Lower-performing students did better with paper homework than online homework, but the opposite was true for higher-performing students. One-third of students reported in one study that "other commitments" are a strong demotivating factor, followed by "unable to understand", as well as "too difficult" and "too long" (Planchard et al., 2015). These indicate that students were less likely to complete homework if they were too busy or deemed the assignments too complicated. Weaker students seem to benefit less from its use, which is supported by the fact that there is more of a consensus that online homework is beneficial for calculus students but there is still more of a question for students in college algebra.

Similarly, Kontur, de La Harpe, and Terry (2015) found a correlation with online physics homework performance and exam scores, but only for higher-aptitude students. One possibility for that may be that lower-aptitude students may experience cognitive overload on complicated problems. They may have only a limited number of schemas stored in long-term memory and may only learn basic skills from homework. They may be lacking in the big-picture understanding that is typically required to perform well in physics, and therefore suffer on exam performance. One solution to this might be to require mastery-based learning, which benefits lower-aptitude students more robustly than it does higher-aptitude students.

Adaptive Learning Systems and Mastery

One advance in online homework is that of adaptive learning. Adaptive learning is more than just hints and feedback given as students work through assigned problems, however. In this type of system, students work toward mastery of varying levels of concepts and skills and then move on as they become proficient within a certain topic. If they fail to obtain mastery, they are required to relearn the topic before they can move on to others. In this way, students may be working at all different levels within the same class. This allows curriculum to be adapted for each learner, so that both lower-achieving and higher-achieving students are able to maximize their learning, as opposed to the typical method of teaching to the middle learners (Eichler & Peeples, 2013). Mastery, however, is difficult to achieve in a typical first-year chemistry classroom, which is often a large-enrollment class dominated by lecture-style teaching. Learning a subject like chemistry cannot be done effectively in the classroom and must include outside study, which mostly takes the form of homework (Bowman et al., 2014).

Eichler & Peeples (2013) described an adaptive system such as ALEKS as the type of technology that not only gives a learner immediate feedback during an assignment, but also alters the flow or even the content of learning activities as the learner completes exercises. They define learning systems that merely provide hints and feedback as responsive systems. Phillips and Johnson (2011) compared the incorporation of online homework to using an intelligent tutoring system. Both groups showed improvement, but the intelligent tutoring proved to be more effective than online homework alone. With the incorporation of these types of systems within online homework platforms, it stands to reason that the improvement will be multiplied with the increased variety of tools available within one system.

ALEKS is also able to reinforce topics that may be forgotten later in the course and have students revisit those topics until they can again demonstrate mastery. A weak correlation was found between time on task and final exam scores, but it should be noted that each student will require a different amount of time according to prior preparation (for example, high school courses) and retention of material throughout the course. Students are also expected to refrain from using outside sources because any help beyond their own knowledge may lead to increased difficulty before they are ready. Eichler & Peeples (2013) found that students who participated in either Mastering Chemistry or ALEKS improved their final exam scores by 11 points, and those who completed all assignments earned 16 more points than their counterparts who did not participate. When considered separately, the students completing Mastering Chemistry assignments improved their exam scores by 10 points, and those who used ALEXS increased scores by 20 points.

Another adaptive learning system, LearnSmart™ is an example of a system that allows assessment of students as they read from the e-text. It evaluates mastery of the material and allows students an opportunity to return to the text if they miss a particular question. Additionally, they will likely see another question on that subject generated by LearnSmart™, whereas students who get the question correct will move on to other material. LearnSmart™ also asks students how confident they are about each question and is therefore able to illustrate when they have a false sense of how well they know the material, a measure of metacognition. It can also withhold the designation of mastery for certain concepts when students acknowledge that they are guessing on a question. This can help faculty see where students may be struggling and allow them to focus on certain material in class, without demanding extra time (Garrison et al., 2015). This type of system aids in the pedagogical shift necessary while addressing one of the main concerns of faculty, which is demand on their time (Brownell & Tanner, 2012).

In another study focused on mastery, Schroeder, Gladding, Gutmann, and Stelzer (2015) offered physics students in an electricity and magnetism course sets of practice problems in which they had to achieve mastery before moving on to a second set. After trying, they had access to animated solutions if they chose to watch them. One group had to achieve 85% in each set before getting the second set. Another group received a single try, no matter what their score, before moving on to the second set. A control group had no practice before taking a posttest, which was taken by all groups. Both mastery and single-try groups significantly outperformed the control group, but there was no statistical difference between the two experimental groups. The authors suggested that fatigue from the length of the experiment may have affected the treatment groups and plan to research shorter units of mastery in future experiments (Schroeder et al., 2015).

Babaali & Gonzalez (2015) tested the Hawkes Learning System accompanying a precalculus textbook. Instructors choose the number of questions to be answered by students, who must get enough correct to achieve mastery. That level is also set by the instructor. If they fail to do so, the students are allowed to practice the material until ready to try again, but with different numbers. The treatment group used the online homework system, while the control group did pencil-and-paper homework. Students using the online homework had more scores distributed in the higher ranges: more A, B, and C scores than the control group. In addition, the average score on the same final exam was approximately 15 points higher for the students in the treatment group as opposed to those in the control group (Babaali & Gonzalez, 2015).

Perceptions of Online Homework

Students will be more likely to work hard at an assessment method that they believe to be effective, so student perceptions are important (Woolley, 2015). Dweck (1999, as quoted by Nicol & Macfarlane-Dick (2006)) suggests that students have two views of their learning abilities. The entity view holds that ability is fixed, and that students believe there is a limit to what they can achieve. The incremental view is where students believe their ability is changeable and their success depends on the effort they put into a task. Quality feedback can help students see that increasing or better focusing their efforts can result in higher achievement. Students believed that the use of online homework helps them understand assignments better, and most would recommend its use in other classes. Most also indicated that it made them study more (Folami & Simmons, 2012). In one study of calculus students, comments indicated that students felt increased confidence from the immediate feedback and would say things like "I actually believed I could do and understand calculus" (Halcrow & Dunnigan, 2012). Babaali & Gonzalez (2015) found that students tend to perceive the increased use of technology such as online homework and clickers in classes helpful, but that positivity does not always translate into better grades. However, in general terms, students believe online homework systems and clickers are both effective (Woolley, 2015).

A positive correlation was found between degree of online homework use and student perception of the method in addition to a correlation with course grades. Parker and Loudon (2013) conducted a case study and found these results, which matched their initial hypothesis. However, they had also hypothesized that the students who engaged with the system more (and therefore, the course overall) would also spend time studying problems from the text, where the problems were more sophisticated, which was proved false. Students did not spend that extra time in the book, and furthermore, the researchers found that student engagement with the online homework decreased significantly when the incentive of extra credit was removed. This demonstrates that some external incentive needs to be incorporated with the use of online homework.

Students in calculus classes appreciated the ease of use, immediate feedback, and multiple attempts on problems. Halcrow and Dunnigan (2012) believe that feedback provides conceptual understanding that helps students do better on later attempts as well as on exams. Students who spent at least two hours per week on online homework were much more likely to pass the final exam in a precalculus course than those who spent fewer than two hours per week (Babaali & Gonzalez, 2015).

Halcrow and Dunnigan (2012) found that instructor perception plays an important role as well. Instructor perception influenced student perception of online homework use. If the system experienced glitches, for example, a professor might become discouraged and less enthusiastic, and the students can be expected to follow suit. They recommend teacher training for anyone planning to use an online homework system. In many subjects, online homework might cause hesitation among professors because of cheating and plagiarism. Wang, Yuan, Guo, and Liu (2013) developed a system for calculating similarity among students' assignments submitted online. However, in most STEM areas, there are calculations involved that lend themselves to algorithmic questions in which students have the same questions but the numbers for their calculations are different, and therefore their final answers will vary.

Gender

Gender has been the focus of much research concerning STEM education. Traditionally, there was a gender gap in general educational attainment, with females behind males, but in the past few decades, this gap has closed and actually reversed. However, some gap in participation remains in STEM fields (Bailey & Dynarski, 2011; Bound & Turner, 2011). Another gender difference is that females spend more time per week on homework than their male counterparts, even when considering extracurricular activities, outside employment, or caring for children in the home. This gap expanded among higher-achieving students. (Gershenson & Holt, 2015). Singha, Bhadauriab, Janc, and Gurungd (2013) found that women in business courses experienced higher spreadsheet anxiety and reported lower self-efficacy than men. Gender bias has also been shown to affect the academic life of students, especially underrepresented girls (Farland-Smith, 2015). In a flipped mathematics course, males were more interested in the topic than females (Chen, Yang, & Hsaio, 2016). Bromley & Huang (2015) found that using algorithmic cases in a study of accounting classes offered significantly better results for men than for women. This may be due to a higher willingness for females to delay gratification in academic environments (Bembenutty, 2009). When the same answers are required of everyone, men are more tempted to pursue gratification and get the answers from someone else. In algorithmic cases, everyone must do the work for each problem to get the correct answer (Abd-El-Fattah & AL-Nabhani, 2012).

Time Spent on Homework

Time spent on homework has been found to correlate with GPA, in addition to scores on homework assignments (Gershenson & Holt, 2015). Time spent doing homework is also a basic expectation in college and tied to overall academic success. One study found that older students who may be preparing themselves for college spend more time on homework and tend to do assignments alone rather than in groups. (Kackar, Shumow, Schmidt, & Grzetich, 2011). Completing online homework has been shown to increase study time overall, as well as reduce the incidence of cramming (Richards-Babb et al., 2015).

Metacognition

Many of the methods mentioned previously seek to actively engage students in learning as well as have them think about their study habits and whether they are effective (McLaughlin et al., 2013; Bowman et al., 2014; Galyon et al., 2015; Babaali & Gonzalez, 2015). Bransford (2000) of the National Research Council defines metacognition as self-regulation and reflection of performance. This includes planning, tracking success, and correcting errors when appropriate (Bransford, 2000). The importance of metacognition can be traced back to Socrates' methods of didactic questioning (Tanner, 2012). Not only should students monitor their progress, they also should incorporate a qualitative analysis on their performance, including reasons for difficulties and methods in which they might improve (Ali, Abd-Talib, Ibrahim, Surif, & Abdullah, 2016).

Active learning methods promote metacognition (Tanner, 2012), and reinforcement in homework encourages students to complete assignments (Planchard et al., 2015). In addition, feedback from online homework can provide additional evaluation to students in terms of their learning progress (Babaali & Gonzalez, 2015). Students believe that online homework helps them understand assignments better (Halcrow & Dunnigan, 2012) and makes them study more (Folami & Simmons, 2012). Sletten (2017) found that there was a strong correlation between study strategies and metacognition, self-talk, and effort.

Some online homework systems come with metacognitive tools incorporated within. For example, LearnSmart™ asks students how sure they are of an answer before they submit it. This serves to prevent achievement of mastery from guessing, but also allows metacognitive analysis of learning progress as one works through an assignment (Thadani & Bouvier-Brown, 2016). In contrast, Griff and Matter (2013) found no significant improvement in using LearnSmart™ over the use of additional quizzes for anatomy and physiology students. Likewise, a study by Thadani and Bouvier-Brown (2016) found no improvement in the use of LearnSmart™ among general chemistry students unless it was accompanied by metacognitive scaffolding questions. These questions were intended to help students become aware of areas of difficulty and make progress toward overcoming those difficulties. Students who were provided these questions showed improvements compared to students who did not have the scaffolding or did not use LearnSmart™ at all. Additionally, Sandall, Mamo, Speth, Lee, and Kettler (2014) found that students were highly receptive to receive coaching on metacognitive strategies as part of their overall curriculum.

Future Research

Bowman et al. (2014) found that student success could be predicted through online homework activity, but metacognitive effects such as time spent per question or number of attempts per question may play a role in that success as well. They suggest that fields other than chemistry be investigated. Garrison et al. (2015) stress that use of technologies such as e-text and e-learning serve to increase student learning, but more research is needed to determine the effects on faculty in regards to their teaching pedagogy.

Planchard et al (2015) called for further study into the utility of homework at the college level, especially in light of the trend toward the flipped classroom. Finding the motivating factors for doing homework and studying how homework completion affects student achievement can help faculty determine the best exercises in order to avoid demotivating factors, maximize completion, and demonstrate the value of homework for students.

Folami and Simmons (2012) suggest studying whether student satisfaction with online homework correlates with gender, major, previous use of online homework, and test grades.

Other studies might focus on the publisher of the online homework system, class level, difficulty, and quantity of online homework.

Thadani and Bouvier-Brown (2016) recommend the incorporation of training where metacognitive tools are available, such as within LearnSmart™. They studied chemistry students over one unit and recommended that use over an entire semester should be studied. Additionally, use in biology courses should be examined. Teaching metacognitive strategies to chemistry students was studied by Zhao et al (2014), who recommend the study of other disciplines as well.

Summary

In summary, students must be actively engaged in courses covering the STEM disciplines to completely grasp the concepts involved, which are often on multiple levels of understanding. This can be done through homework assignments, though traditional methods are inadequate because they lack feedback. Additionally, since most homework is not graded, students do not have as much motivation to complete it.

The use of online homework systems can overcome many of the shortcomings in the traditional lecture courses. It can encourage engagement within the class and provide immediate feedback to students toward their understanding of the problem. It can also aid in visualizing many of the difficult concepts inherent in the sciences, such as molecular phenomena. These phenomena are commonly susceptible to alternate conceptions, which can be difficult to change once established. Pedagogy in the STEM fields needs to account for the possibilities of these misconceptions and try to prevent them. It is possible that emerging technology incorporated into online homework systems, such as visualizations, may serve to aid students in building schemata that are correct and avoid alternate conceptions.

Schema theory and activity theory can help to explain how students may lack the cognitive ability to store new information gained in lectures. Deeper engagement can help to construct new learning for each student as he or she interacts with the material. The use of online homework can take on the role of working with students individually and providing immediate feedback that professors cannot do. This engagement has been studied in chemistry, a difficult subject because of the need to think in both macroscopic and microscopic realms. Other primarily computational disciplines such as math and physics have also been studied. This study will seek to fill a gap in the literature where these systems are studied in undergraduate biology courses.

CHAPTER THREE: METHODS

Overview

The purpose of this correlational study was to examine whether homework grades in online homework systems can predict student achievement in introductory undergraduate biology courses. Multiple regression analysis was used to examine the relationship between the predictor variables (online homework scores, time spent on homework, gender, and completion of a metacognition course) and the criterion variable, final course grade. Correlation was used to compare a major grade in metacognition and final biology course grades. Chapter Three will include the study design, research question, hypothesis, participants and setting, procedures, and data analysis.

Design

This quantitative study implemented a correlational design. This design was chosen due to the ability to analyze the relationship between a criterion variable and two or more predictor variables. Multiple regression was used in the analysis because it offers a versatile means to compare several variables and yields helpful information about any relationships among those variables. This method is appropriate if the relationships among variables are hypothesized to be linear (Gall, Gall, & Borg, 2007; Warner, 2013). The criterion variable was final grades in introductory biology courses. Predictor variables included homework scores, time spent on homework assignments, gender, and completion of a metacognition course. Correlation was used to compare a major grade in metacognition and final biology course grades.

Research Questions

RQ1: How accurately can student achievement in biology courses be predicted from the linear combination of online homework scores, time spent on homework, gender, and completion of a metacognition course for undergraduate students at a small private Christian college in Georgia?

RQ2: Is there a correlation between scores on a major metacognition assignment in a course on metacognition and final course grades in Biology I or Biology II?

Hypotheses

The null hypotheses for this study were:

$H_0$1: There will be no significant relationship between the criterion variable (final course grades) and the linear combination of predictor variables (online homework scores, time spent on homework, gender, and completion of a metacognition course) for undergraduate students at a small private Christian college in Georgia.

$H_0$2: There will be no correlation between scores on a major metacognition assignment in a course on metacognition and final course grades in Biology I or Biology II.

Participants and Setting

The participants for this study were from a convenience sample of students from three years of undergraduate introductory biology courses at a small private Christian university located in Georgia. The university is regionally accredited by the Southern Association of Colleges and Schools Commission on Schools (SACSCOC). The general population of the university consists of approximately 1,600 students, who are 44% male and 56% female. Students are 43% white, 38% African-American, 3% Hispanic, and 16% other or unknown racial/ethnic makeup. This study focused on the traditional undergraduate student with an age range of approximately 18 to 22 years of age. The study utilized data from the 2015-2016 through 2017-2018 school years. Participants were enrolled in one of multiple sections of the same course, which were taught by the same professor, who has approximately fifteen years of teaching experience. Most of the participants are freshman biology or exercise science majors, and many plan to attend professional schools for medicine, dentistry, veterinary medicine, pharmacy, physical therapy, or others. Approximately two-thirds are on athletic scholarships, and 70% had taken the metacognition course, which was implemented in the Spring of 2016.

In total, there were 311 participants with 155 males and 156 females. All were required to purchase the online homework system for the class, as the assignments therein will reflect a portion of their grade in the course. The system used is McGraw-Hill's Connect™. The recommended sample size was 108 participants ($N > 104 + k$), where k is the number of predictor variables (Warner, 2013, p. 570) for a medium effect size at an alpha level of .05.

Instrumentation

This study utilized archival data from McGraw-Hill's Connect™ platform, which is an online homework system designed to supplement textbooks from McGraw-Hill, Inc. Connect™ administers homework assignments, which involve student engagement with the material through interactive questions and visualizations. Connect™ records a final grade for each section, as well as the overall course, in percentage format. In addition, time spent on each assignment can be determined from the instructor's report, and an overall time spent was used in this study.

Final course grades and time spent on homework were obtained through a Microsoft Excel spreadsheet provided by the professor. Gender was provided by the registrar's office. Participation in the metacognition course and the grades on the major metacognition assignment in that course were obtained from the professor of that course.

Procedures

Following approval from Liberty University's Institutional Review Board, permission was obtained from the Institutional Review Board of the university where the study was to take place (see Appendix for IRB approvals). After obtaining that permission, the researcher utilized archival data provided by the university.

Next, all students enrolled at the institution during the semesters included in the study were assigned codes by the university registrar to protect the identities and information of study participants. In addition, the registrar assigned each of the students a gender code (1=male, 0=female). Separate spreadsheets with the student names and codes were sent by the registrar to the professor of the biology courses and to the professor of the metacognition course. The biology professor added the final numerical course grades and time spent on homework to one spreadsheet. The metacognition professor added a code for completion of the metacognition course (1=yes, 0=no) and the grades on the metacognition assignment in that course on another spreadsheet. Each professor removed the student names from the spreadsheet before sending the spreadsheet to the researcher, thus protecting the identity and confidentiality of each student.

The researcher consolidated the information for the students, which were identified solely by the participant codes, prior to entering that data into SPSS. All information was entered into SPSS with participant codes. Original documents were kept in password-protected Excel files and remained confidential; only the researcher had the password and access to these files.

All students received the same instruction throughout the semester, which consisted of the first fourteen chapters of *Principles of Biology, 2nd ed,* by Brooker (2014). Topics covered included introductory chemistry, macromolecules, cellular structure, cellular division, cellular respiration, photosynthesis, Mendelian genetics, introductory microbiology, classification of organisms, and body systems. Online homework was required of all participants and completed for a grade, which comprised 20% of the course grade for the semester. These scores as well as total time on task were utilized in the study.

Data Analysis

In this study, the first null hypothesis examined the relationship of four predictor variables to a criterion variable, the final course grade. Students who began the semester but withdrew before the end of the course were not considered in data analysis. In seeking correlations among two or more predictor variables, multiple regression was appropriate, provided the relationships were hypothesized to be linear (Gall et al, 2007; Eichler & Peeples, 2013; Bowman et al., 2014).

Before multiple regression could be deemed suitable for use, preliminary data screening and assumption tests had to be done. All calculations were performed through SPSS. The level of measurement for the criterion variable, final course grade, was ratio, as were homework grade and time spent on homework. Predictor variables may be categorical; in this study gender and completion of a metacognition course were nominal variables. In addition, the observations within each variable were independent.

Data screening also included testing for extreme outliers through analysis of box and whiskers plots, examining histograms for normality of distribution, and creating scatterplots to test for the assumption of homogeneity of slopes. Linearity was examined by adding a trend line to scatterplots and searching for the classic “cigar” shape (Warner, 2013).

After the initial screening and assumption testing, descriptive statistics were calculated, including mean, range, and standard deviation. Then a Regression Model was conducted on the data. The model included degrees of freedom (*d.f.*), r and r^2, *F*-statistics, and *p*-values to determine whether a relationship exists between the criterion variable and each of the predictor variables. The regression equation was included in this data. A 95% confidence level, as is common in educational research (Gall et al., 2007; Warner, 2013), was used to determine significance ($p < .05$) and as an indicator of whether to reject the null hypothesis. This level indicated a strong likelihood of avoiding a Type I error (rejecting a null hypothesis that is true). Additionally, the effect size was reported through r squared (r^2). According to Gall et al. (2007), effect size aids in gauging the practical significance of research results. In this study, sample sizes were checked against tables provided in Warner (2013) for a small to medium effect size ($r^2 = .20$) with a goal for statistical power of .7 at the $\alpha = .05$ level.

The second null hypothesis was tested using a correlation. The researcher utilized the same screening and assumptions testing as the data for the first null hypothesis. After screening, Pearson's r and Spearman's rho were utilized in determining whether a relationship existed between grades on a major assignment in a course on metacognition and course grades in undergraduate biology courses.

CHAPTER FOUR: FINDINGS

Overview

In Chapter Four, the descriptive statistics, data screening, and assumptions tests for multiple regression are discussed. Also, the results for the null hypothesis are presented in light of the multiple regression analysis performed.

Research Question

RQ1: How accurately can student achievement in biology courses be predicted from the linear combination of online homework scores, time spent on homework, gender, and completion of a metacognition course for undergraduate students at a small private Christian college in Georgia?

RQ2: Is there a correlation between scores on a major metacognition assignment in a course on metacognition and final course grades in Biology I or Biology II?

Null Hypotheses

$H_0$1: There will be no significant relationship between the criterion variable (final course grades) and the linear combination of predictor variables (online homework scores, time spent on homework, gender, and completion of a metacognition course) for undergraduate students at a small private Christian college in Georgia.

$H_0$2: There will be no correlation between scores on a major metacognition assignment in a course on metacognition and final course grades in Biology I or Biology II.

Descriptive Statistics

The sample size for this study was (N=311). There were 156 females (Gender = 0) and 155 males (Gender = 1). Descriptive statistics were gathered and are reported in Table 1. The mean course grade was 68.98 (S.D. = 15.628); the mean homework grade was 75.50 (S.D. =

20.708); and the mean time spent on homework was 576.85 minutes (S.D. = 457.416). There were 220 students who took the metacognition course (Course=1) and 91 students who did not (Course=0). The mean score on the major assignment in the metacognition course was 88.641.

Table 1

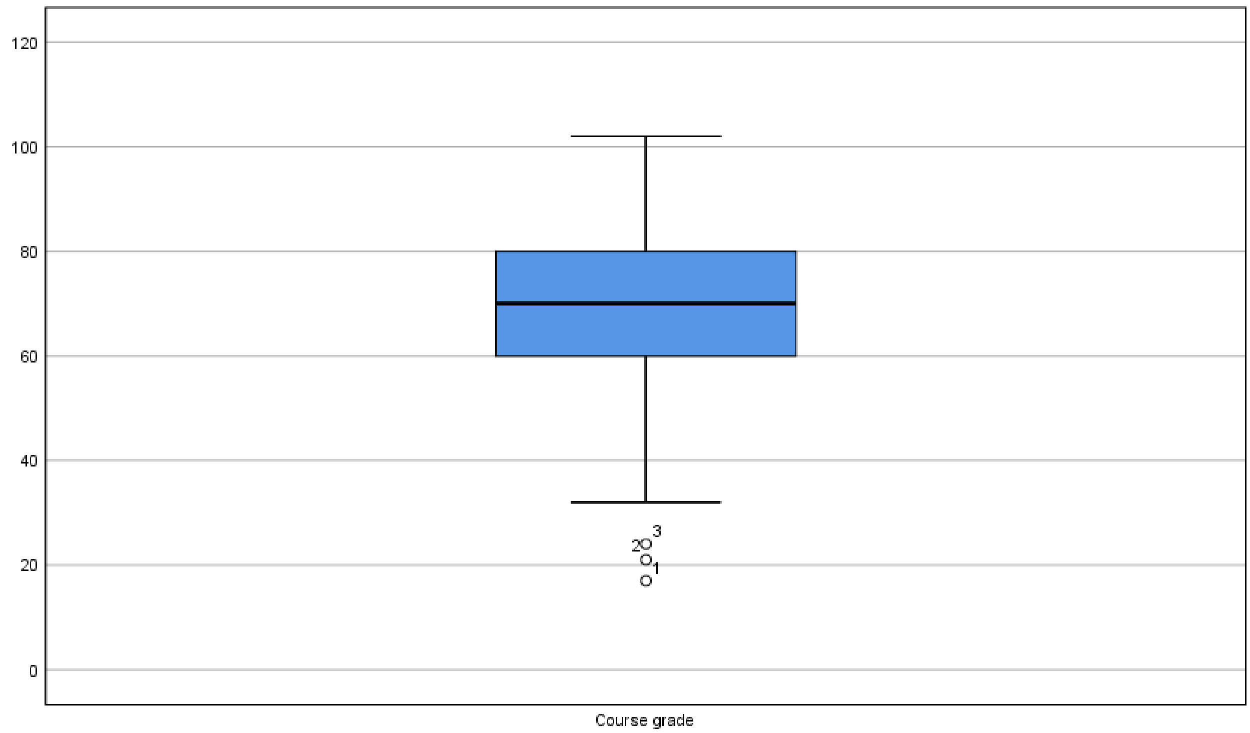
Descriptive Statistics

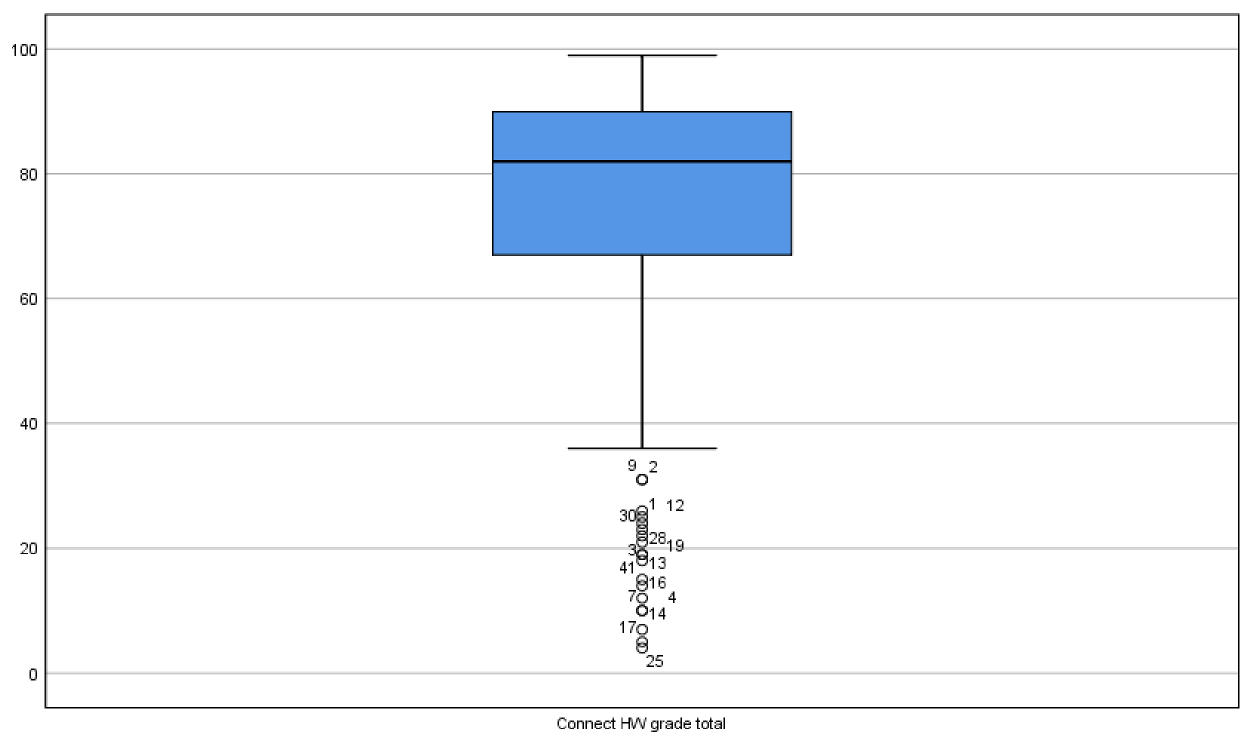
	Mean	Std. Deviation	N
Course grade	68.98	15.628	311
Connect HW grade total	75.50	20.708	311
Total Time (min)	576.85	457.416	311
Gender	.50	.501	311
Metacognition Grade	88.641	6.4990	220
Metacognition Course	.71	.456	311

Assumption Tests

Data Screening

Box and whiskers plots were used to test each of the criterion and predictor variables for outliers. Visual inspection showed several outliers. One outlier showed a student with a course grade of 1 and was assumed to be a data entry error and was therefore discarded (Warner, 2013). The box and whisker plots can be found in Figure 3.


120
100
80
60
40
20
0
3
2
1
Course grade


100
80
60
40
20
0
9
2
1
12
30
28
19
3
41
13
16
7
4
14
17
25
Connect HW grade total

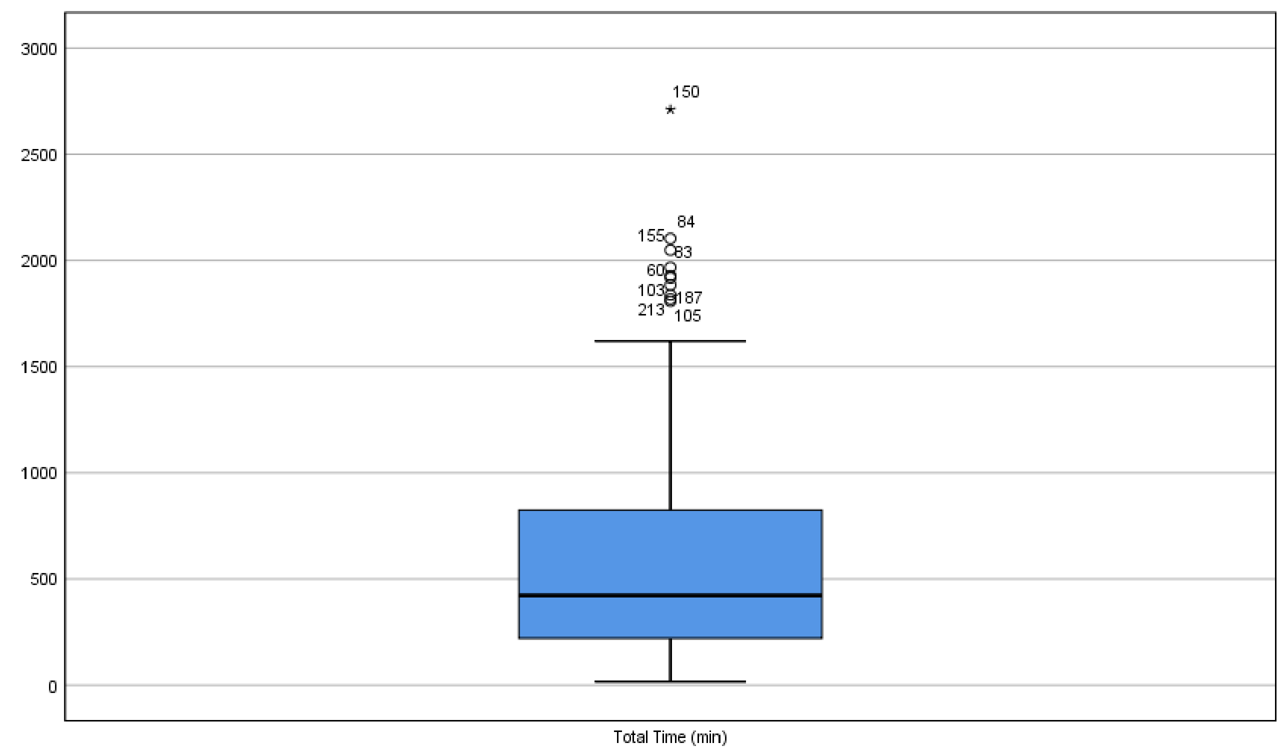


Figure 3. Box and Whisker Plots

Assumptions

Assumptions of normality were tested using the Kolmogorov-Smirnov test and a histogram of the criterion variable, course grade. The Kolmogorov-Smirnov test was not significant, and visual inspection of the histogram confirmed that the data met the assumption of normality. See Table 2 for the results of Kolmogorov-Smirnov and Figure 4 for the histogram.

Table 2

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Studentized Residual	.039	311	.200*	.994	311	.218

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

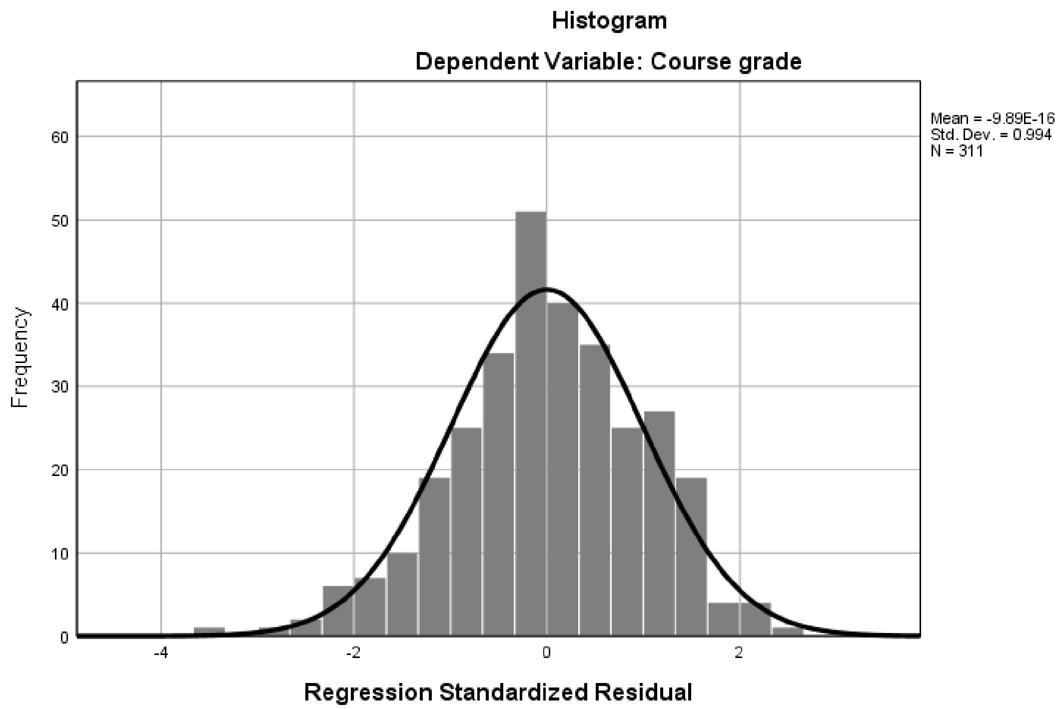


Figure 4. Histogram of Course Grades

Scatterplots were used to test the assumptions of bivariate outliers, linearity, and bivariate normal distribution. No extreme outliers were noted. Lines of best fit indicated linear relationships between all predictor variables and the criterion variable, meeting the assumption of linearity. Finally, bivariate normal distribution was evaluated by looking for the classic "cigar" shape in the scatterplots. The assumptions of linearity and bivariate normal distribution were both tenable. See Figure 5 for the scatterplots.

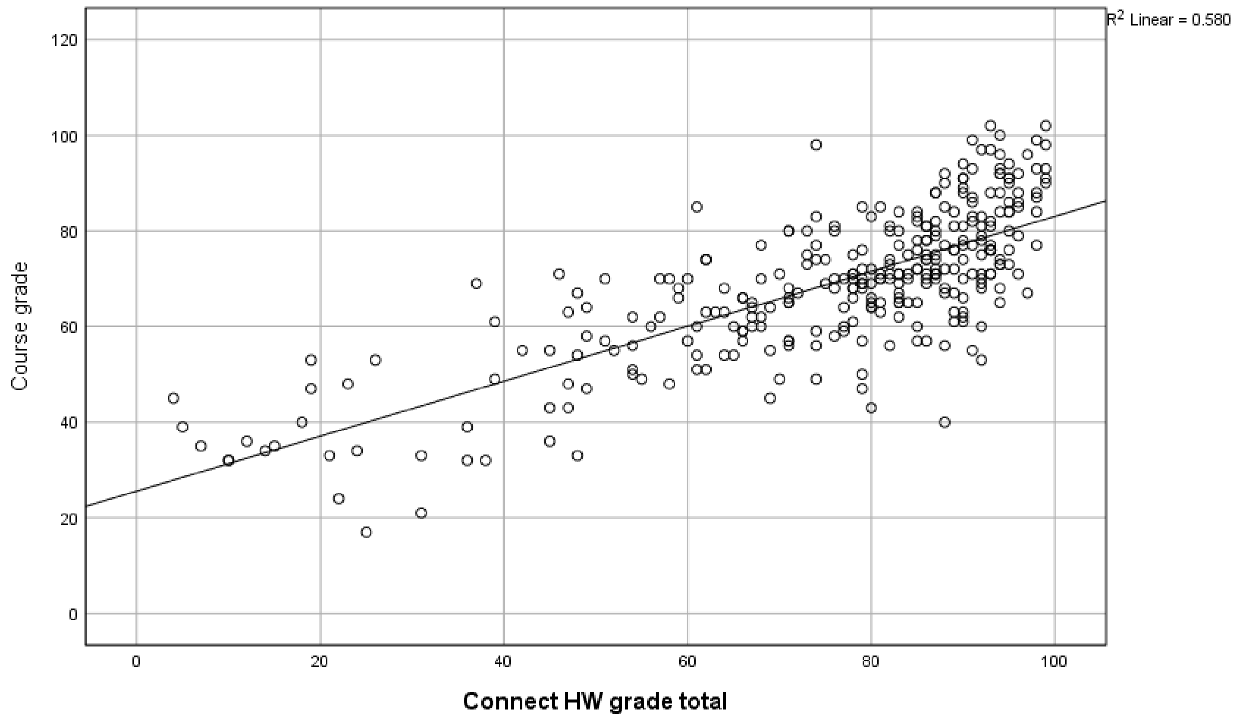


Figure 5A. Scatterplot of Course Grade vs. Overall Online Homework Score

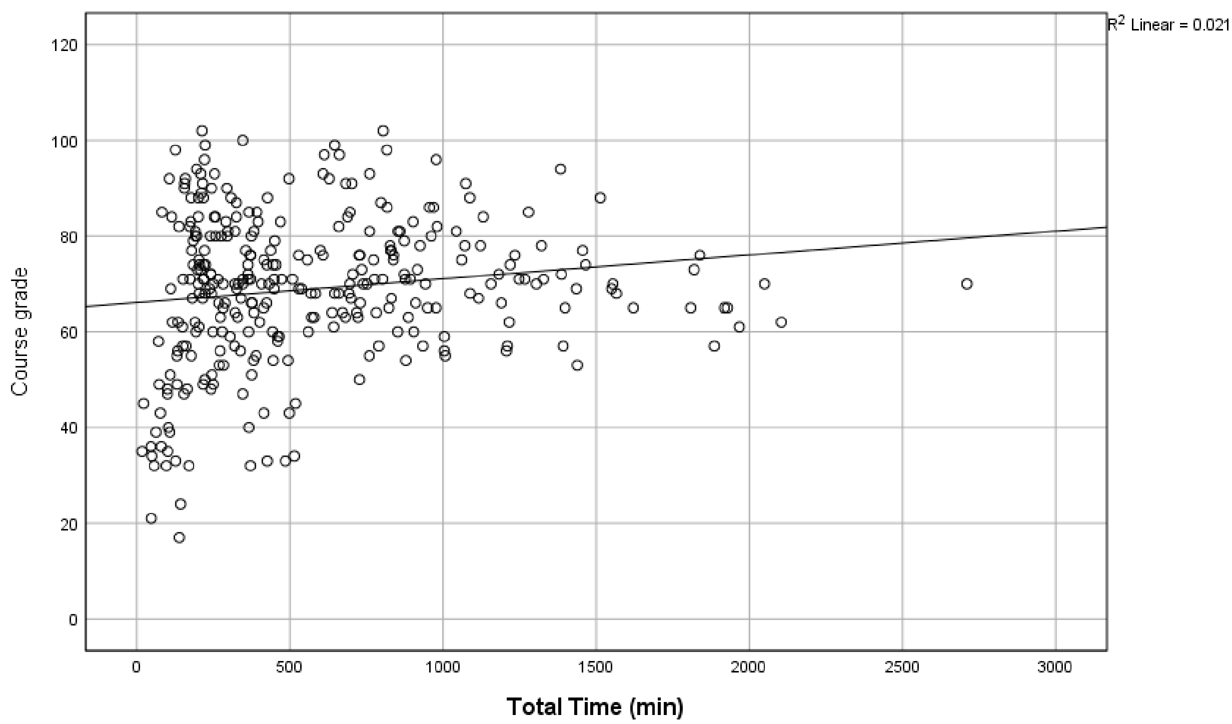


Figure 5B. Scatterplot of Course Grade vs. Total Time Spent on Homework

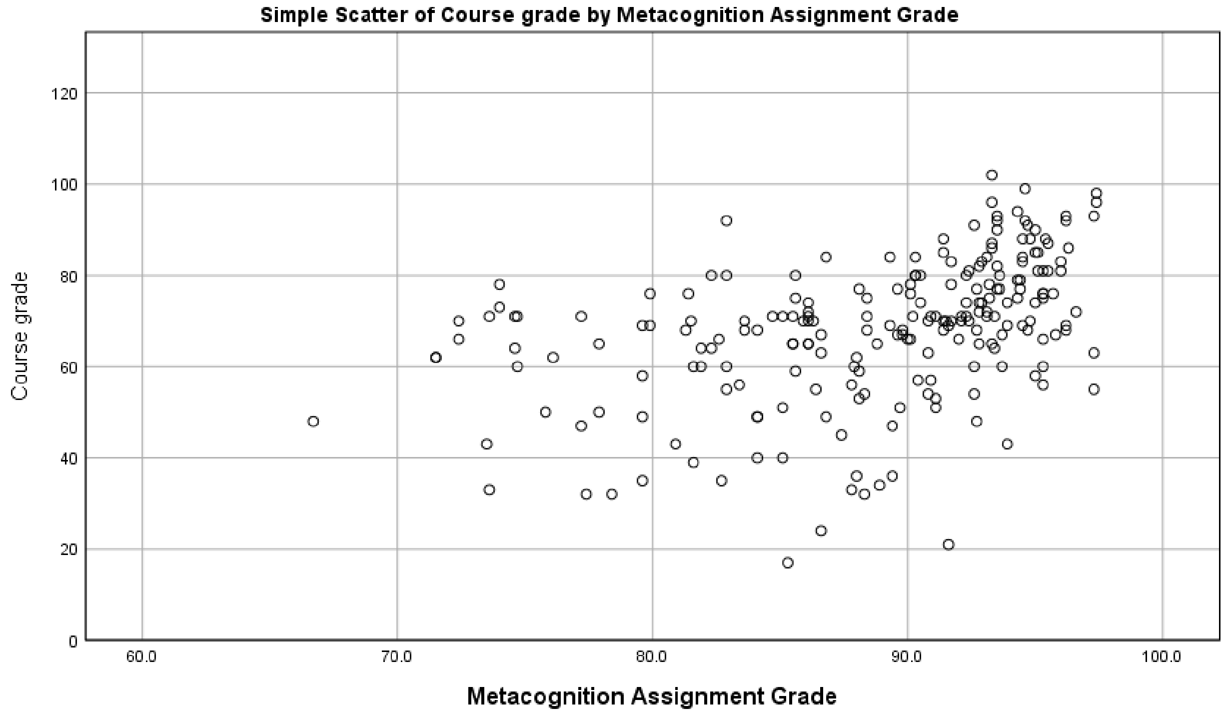


Figure 5C. Scatterplot of Course Grade vs. Metacognition Assignment Grade

Results

Null Hypothesis One

A multiple regression was calculated to predict biology end of course grade based on homework grade, time spent on homework, gender, and participation in a course on metacognition. A significant regression equation was found (F(4,307)=117.691, *p*<.001, with an R^2 of .607. Results of the ANOVA can be found in Table 3.

Table 3 ANOVA Results

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	45926.062	4	11481.515	117.961	.000[b]
	Residual	29783.822	306	97.333		
	Total	75709.884	310			

a. Dependent Variable: Course grade

b. Predictors: (Constant), Metacognition Course, Connect HW grade total, Gender, Total Time (min)

The biology course grade predicted is equal to 29.570 + .600(homework grade) – .005(time spent on homework) - 2.607(gender) – 2.432(participation in a metacognition course), where homework grade is measured as points from 0-100, time spent on homework is in minutes, gender is coded as 0 = female and 1 = male, and participation in a metacognition course is coded as 0 = no and 1 = yes. The linear combination of homework grade, time spent on homework, gender, and participation in a metacognition course predicted 60.1% of variance in final course grades (Adjusted R^2=.601). The course grade model summary can be found in Table 4.

Table 4

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.779[a]	.607	.601	9.866	1.202

a. Predictors: (Constant), Metacognition Course, Connect HW grade total, Gender, Total Time (min)
b. Dependent Variable: Course grade

An ANOVA found a significant relationship between the criterion variable and the predictor variables for α=.05 and where F(4,307)=117.961, *p*<.001. Results of the ANOVA can be found in Table 3.

The regression model showed that homework grade (*p*<.001), time on homework (*p*<.001), and gender (*p*=.024) were significant predictors of final course grade, while participation in a metacognition course (*p*=.052) was not a significant predictor. Results of the regression model can be found in Table 5.

Table 5

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	29.570	2.557		11.564	.000	24.538	34.601					
	Connect HW grade total	.600	.029	.795	20.539	.000	.543	.657	.762	.761	.736	.858	1.166
	Total Time (min)	-.005	.001	-.146	-3.791	.000	-.008	-.002	.146	-.212	-.136	.871	1.149
	Gender	-2.607	1.147	-.084	-2.273	.024	-4.864	-.350	-.198	-.129	-.081	.952	1.051
	Metacognition Course	-2.432	1.246	-.071	-1.951	.052	-4.885	.021	-.081	-.111	-.070	.973	1.028

a. Dependent Variable: Course grade

Null Hypothesis Two

The second null hypothesis was tested using a Pearson's Correlation. Of those 220 participants taking the metacognition course, the mean score on the major assignment was 88.641 (S.D. = 6.4990). See Table 1 for descriptive statistics. The assumption of normality was tested using the Kolmogorov-Smirnov test. Results were found to be significant, indicating an untenable assumption. For this reason, Spearman's rho was added to the study. See Table 6 for the Kolmogorov-Smirnov results. The Pearson's correlation was $r(218) = .430$, ($p < .001$), indicating a moderate relationship between the major metacognition assignment scores and biology final course grades. See Table 7 for correlations.

Table 6

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Course grade	.106	220	.000	.968	220	.000
Metacognition Assignment Grade	.125	220	.000	.908	220	.000

a. Lilliefors Significance Correction

Table 7

Pearson's Correlation

		Course grade	Metacognition Course Grade
Course grade	Pearson Correlation	1	.430**
	Sig. (2-tailed)		.000
	N	311	220
Metacognition Assignment Grade	Pearson Correlation	.430**	1
	Sig. (2-tailed)	.000	
	N	220	220

**. Correlation is significant at the 0.01 level (2-tailed).

Because the Kolmogorov-Smirnov assumption was not tenable, in an abundance of caution, a Spearman's rank-order correlation was also utilized to determine the relationship between 220 students' metacognition assignment grade and final course grade in biology. The results ($r_s(218) = .506$, $p < .001$) also showed a moderate relationship. See Table 8 for Spearman's rank-order correlations, which are similar to the Pearson's *r* results.

Table 8

Spearman's Correlation

			Course grade	Metacognition Course Grade
Spearman's rho	Course grade	Correlation Coefficient	1.000	.506**
		Sig. (2-tailed)	.	.000
		N	311	220
	Metacognition Assignment Grade	Correlation Coefficient	.506**	1.000
		Sig. (2-tailed)	.000	.
		N	220	220

**. Correlation is significant at the 0.01 level (2-tailed).

Because of the significant results, both null hypotheses were rejected.

CHAPTER FIVE: CONCLUSIONS

Overview

Chapter Five will summarize previous information about the variables studied and will discuss the results of the statistical analyses. Implications of these results are discussed, as well as limitations of the study. Finally, recommendations for future research are offered.

Discussion

The purpose of this study was to determine whether homework grades in online homework systems could predict student achievement in introductory undergraduate biology courses. The criterion variable was the final course grade in either Biology I or Biology II. Predictor variables included overall homework score, time spent on homework, gender, and participation in a metacognition course. The overall homework score was computed by McGraw-Hill's Connect™ online homework system from all assignments due throughout the semester. The time spent on homework was displayed in Connect™ for each assignment and added by the professor who taught the classes to obtain a total time. Gender was provided by the registrar's office of the university where the study took place. Participation in a metacognition course was provided by the professor teaching that course and was simply recorded as "yes" or "no." A separate correlation between a major metacognition assignment grade and final course grades in biology was also conducted and found to be significant. Metacognition was defined as self-regulation and reflection of performance, including planning, tracking success, and correcting errors when appropriate (Bransford, 2000).

Online Homework Score and Course Grade

There will naturally be a correlation between online homework score and course grade when the homework is a significant part of the course grade, which was the case in this study.

Past research has recommended that online homework carry enough weight to encourage students to complete it. (Galyon et al., 2015). Online homework also promotes active learning by providing immediate feedback to students and has been shown to increase exam scores (Richards-Babb et al., 2015; Kontur et al., 2015). When students get questions incorrect, they know immediately and are often able to answer a similar set and still receive full credit (Mathai & Olsen, 2013). Achieving higher scores on an assignment can motivate students to complete the work, which results in more correct answers, creating a positive feedback loop that can increase academic performance and self-efficacy in the course as a whole in addition to the assignment at hand (Babaali & Gonzalez, 2015).

Placing additional weight on homework could also allow assignments to become formative assessments and remove some weight from summative assessments within a course (Galyon et al., 2015). Access to an electronic version of the text may encourage students to consult the book more often while learning (Lazarova, 2015). Additionally, the incidences of cheating can be reduced with online homework (Arora et al., 2013). This study has reinforced previous research in which participating in online homework increases student achievement overall (Parker & Loudon, 2013; Revell, 2013; Richards-Babb et al., 2015, Wooley, 2015).

Time Spent on Homework and Course Grade

Reinforcement on homework encourages students to complete assignments (Planchard et al., 2015). That study showed that time spent on homework correlates with higher course grades. Surprisingly, this study showed that the more time participants spent on homework, the lower the course grade. This seems unexpected until upon further examination one can see that while the trend is an overall decrease in course grade with increased time on homework, there is an upward trend in the middle. The scatterplot (see Figure 5B) shows that those who spent very little time on homework did poorly in the course, but those who were closer to the mean of 577 minutes overall were also likely to be near the mean course grade of 69. Participants who spent more than 1000 minutes overall were more likely to be below the mean. This result may be from students spending more time guessing until they get an answer correct, as found by Bowman et al. (2014). This is a topic for future study.

Gender and Course Grade

Females performed slightly better than males in this study. Gershenson & Holt (2015) found that females spend more time on homework than their male counterparts. This study's model did not match that finding, however, since the general finding was that increased time on homework is a predictor for slightly lower course grades. There was also no significant difference in time spent on homework between genders. Ackerman, Kanfer, and Beier (2013) state that females are more likely to leave STEM majors and suggest that success in STEM courses might be predicted by the number of AP courses taken, the scores on AP exams, and whether calculus was taken in high school. The high school calculus predictor was especially predictive of female success in undergraduate STEM courses. This study did not take high school preparation into account, but that is an avenue for future study.

Metacognition and Course Grade

This study found no significant effect on course grades from having completed a metacognition course. This differs from the literature showing that engaging in metacognitive activities improves academic performance (Bowman et al., 2014; Galyon et al., 2015; Babaali & Gonzalez, 2015). Since the Connect™ system provides feedback, and reinforcement and feedback encourages students to complete assignments (Planchard et al., 2015) and can give students an idea of their learning progress (Babaali & Gonzalez, 2015), metacognition is supported within the online homework system. This study's result does agree with previous research in which using LearnSmart™ (which is a subsystem within Connect™) did not necessarily improve student performance (Thadani & Bouvier-Brown, 2016; Griff & Matter, 2013). Additional guidance in metacognitive strategies has been shown to increase success in general chemistry students using LearnSmart™ (Thadani & Bouvier-Brown, 2016), and students have been generally receptive to coaching in metacognitive strategies (Sandall et al., 2014). This study's result was inconclusive (p = .052 on metacognition) and may be a result of only looking at participation and not actual performance within the metacognition course. There were also fewer participants in this portion of the study.

Score on Major Metacognition Assignment and Course Grade

There was a significant correlation between scores on the major metacognition assignment and final course grades in biology. The relationship was a moderate one. This may be because students who demonstrated that they had learned metacognitive strategies in the metacognition course implemented them in their biology courses. The result agrees with Sletten (2017), who found that there was a strong correlation between study strategies and metacognition, self-talk, and effort.

Implications

This study has shown that engaging in online homework can improve academic performance in undergraduate biology courses, which had not been directly addressed in previous research. Overall, homework provides a means of engagement for students, which increases academic performance (Richards-Babb et al., 2015; Garrison et al., 2015). Motivation and feedback are two primary factors in completing homework (Gutarts and Bains, 2010). However, traditional homework presents the problem of providing only limited feedback

(Diegelman-Parente, 2011), often going ungraded (Richards-Babb et al., 2011). Planchard et al. (2015) demonstrated that a strong factor in students completing homework was motivation, which came primarily from grades. Therefore, a lack of grading homework can prevent its efficacy from being realized. There have been few studies regarding grading homework at the undergraduate level (Galyon et al., 2015), and evaluation of the use of homework, online or otherwise, in biology is seldom addressed in the literature. This study showed that use of online homework in undergraduate biology courses does increase academic performance.

This study furthered previous findings, where engagement with course material is critical to success. This study focused on this effect in biology classes, for students must understand the material that they are required to memorize. Building new schemata, as is necessary in such a course, is difficult without substantial engagement. Meyer (2014) demonstrated that when students are engaged with course material, they are constructing knowledge. Online homework provides this engagement along with automatic feedback that students need for motivation to complete assignments. Ideally, this feedback will result in a stronger sense of satisfaction, leading to more motivation to complete homework, ultimately resulting in a positive feedback loop that leads to greater academic achievement, as described by Planchard et al. (2015).

Overall, increased time spent on homework was a predictor for slightly lower course grades. Students in this study who spent a great deal of time on homework tended to have lower course grades and likely affected the overall variable. In contrast, many who spent a very small amount of time on homework tended to do poorly, but those in the middle had better grades. A certain minimum amount of time is necessary to complete assignments (Babaali & Gonzalez, 2015), and more successful students may be able to complete assignments in less time. Looking for students who are performing poorly on exams and are also spending a great deal of time on homework might be a way to point out those who may need extra attention or tutoring help. In this way online homework can not only be a source of engagement and feedback—it can also potentially be used as a measure for finding at-risk students early and getting them any help they might need.

Since females slightly outperformed males in this study, it may be worth exploring any reasons for this discrepancy. In addition, perceptions of online homework have been shown to be correlated with its use and with course grades (Parker & Loudon, 2013). A more highly structured course or one with a higher sense of community might also be beneficial for course grades (Eddy & Hogan, 2014). Interest in the course material or self-efficacy may differ among students in STEM courses (Singha et al., 2013; Farland-Smith, 2015). Any of these factors could be attributed differently to males and females. Online homework systems can be used to design effective pedagogy that might overcome these differences in order to be beneficial to both sexes equally. As demonstrated in this study, metacognitive training should also be employed, and if it can occur within an online homework system, students will benefit, and professors will save time.

Limitations

This study was correlational and non-experimental in nature. Archival data was used and the population was non-random and comprised a convenience sample. In addition, all students were from one small private university in the Southeast. Though there was a sufficient number of participants to insure validity, studying these variables in an experimental study or in a broader population might yield different results. Additionally, the study used final course grades in undergraduate biology as the criterion variable, where the study of exam grades might have been more reflective of the immediate efficacy of completing online homework assignments.

Also, the biology courses are taken by both biology majors and by non-majors as an elective course, so there may be a difference in performance between these groups. Therefore, the findings of the study should not be generalized beyond this population.

A metacognition course was introduced at the university after the semester in which the earliest data was collected. This course was required of most entering students, including all true freshmen and some transfer students, which left mainly early participants in the study not having the course. There may have been uncontrolled-for changes in the biology courses in general or the online homework assignments specifically that could have affected the results in relation to those who did not take the course in metacognition. There was also no control for performance in that metacognition course; there was only participation noted. It is quite possible that low performers in the biology courses were likewise low performers in the metacognition course and failed to adopt the strategies taught in that course.

Recommendations for Future Research

1. Study a broader population. This study was from one private Christian university in the Southeast. Studying at a research institution, for example, might be a worthy endeavor.
2. Study efficacy of doing online homework on immediate exam scores. This study utilized a model where online homework scores and time spent correlated with final course grades, but it may be beneficial to do a study where those predictor variables are compared against exam scores that immediately follow the homework assignments.
3. Study students who spend a large amount of time on homework. Those students who spent time that fell more than one standard deviation from the mean seemed to do more poorly than those near the mean. This could be indicative of ability and may be a predictor for students who are at risk.

4. Study predictors from high school in addition to the predictor variables in this study. High school GPA, ACT or SAT scores, number of AP courses taken, AP exam scores, or whether students take certain courses such as calculus may be predictors of success in undergraduate biology and other STEM courses.
5. Study the role of gender further, using biology courses. There may be gender-specific means in which students can be reached that improve academic performance. Incorporate high school predictors as stated in the previous recommendation.
6. Study metacognition by a more robust method. Some way of measuring metacognitive training as compared to academic achievement in STEM courses would be a valuable addition to the literature.

REFERENCES

Abd-El-Fattah, S.M., & AL-Nabhani, H.Z. (2012). From self-theories of intelligence to academic delay of gratification: The mediating role of achievement goals. *Australian Journal of Educational and Developmental Psychology, 12*, 93-107.

Ackerman, P.L., Kanfer, R., & Beier, M.E. (2013). Trait complex, cognitive ability, and domain knowledge predictors of baccalaureate success, STEM persistence, and gender differences. *Journal of Educational Psychology, 105*(3), 911-927.

Ali, M., Abd-Talib, C., Ibrahim, N.H., Surif, J., & Abdullah, A.H. (2016). The importance of monitoring skills in physics problem solving. *European Journal of Educational Studies, 1*(3), 1-10.

Allain, R., & Williams, T. (2006). The effectiveness of online homework in an introductory science class. *Journal of College Science Teaching*, *35*(6), 28-35.

Allen, D., Karanasios, S., & Slavova, M. (2011). Working with activity theory: Context, technology, and information behavior. *Journal of the American Society for Information Science and Technology, 62*(4), 776-788. doi:10.1002/asi.21441

Arasasingham, R. D., Martorell, I., & McIntire, T. M. (2011). Online homework and student achievement in a large enrollment introductory science course. *Journal of College Science Teaching*, *40*(6), 70.

Arora, M. L., Rho, Y. J., & Masson, C. (2013). Longitudinal study of online statics homework as a method to improve learning. *Journal of STEM Education: Innovations and Research, 14*(1), 36-44.

Ausubel, D. P. (2000). *The acquisition and retention of knowledge: A cognitive view*. Niger: Kluwer Academic Publishers.

Babaali, P., & Gonzalez, L. (2015). A quantitative analysis of the relationship between an online homework system and student achievement in pre-calculus. *International Journal of Mathematical Education in Science and Technology, 46*(5), 687-699.

Bailey, M.J., & Dynarski, S.M. (2011). Gains and gaps: Changing inequality in US college entry and completion. (No. w17633). Cambridge, MA: National Bureau of Economic Research.

Barthlow, M.J., & Watson, S.B. (2014). The effectiveness of process-oriented guided inquiry learning to reduce alternative conception in secondary chemistry. *School Science and Mathematics, 114*(5), 246-255. doi:10.1111/ssm.12076

Bateson, G. (1972). *Steps to an ecology of mind.* (New York: Ballantine Books).

Bembenutty, H. (2009). Test anxiety and academic delay of gratification. *College Student Journal, 43*(1), 10-12.

Blas, N. D., & Paolini, P. (2014). Multi-user virtual environments fostering collaboration in formal education. *Journal of Educational Technology & Society, 17*(1), 54-69.

Block, J. H. (1971). *Mastery learning: Theory and practice.* New York: Holt, Rinehart, & Winston.

Bloom, B. S. (1968). Learning for mastery: Instruction and curriculum. *Evaluation Comment UCLA-CSIEP, 1*(2), 1-12.

Bloom, B. S. (1974). Time and learning. *American Psychologist, 29,* 682-688.

Borich, G. D. (2014). *Effective teaching methods: Research-based practice.* Boston: Pearson.

Bowman, C. R., Gulacar, O., & King, D. B. (2014). Predicting student success via online homework usage. *Journal of Learning Design, 7*(2), 47-61.

Bransford, J., National Research Council (U.S.). Committee on Developments in the Science of Learning, NetLibrary, I., & National Research Council (U.S.). Committee on Learning Research and Educational Practice. (2000). How people learn: Brain, mind, experience, and school (Expand ed.). Washington, D.C: National Academy Press.

Bromley, R., & Huang, Z. (2015). Algorithmic case pedagogy, learning, and gender. *Journal of Educational Issues, 1*(2), 48-69.

Brooker, R. (2014). *Principles of Biology* (2nd ed.). McGraw-Hill Higher Education.

Brownell, S. E., & Tanner, K. D. (2012). Barriers to faculty pedagogical change: Lack of training, time, incentives, and …tensions with professional identity? *CBE – Life Sciences Education, 11*(4), 339-346.

Burch, K. J., & Kuo, Y. (2010). Traditional vs. online homework in college algebra. *Mathematics and Computer Education, 44*(1), 53-63.

Capobianco, B. M., Diefes-Dux, H. A., Mena, I., & Weller, J. (2011). What is an engineer? Implications of elementary school student conceptions for engineering education. *Journal of Engineering Education, 100*(2), 304-328.

Carroll, J. B. (1963). A model of school learning. *Teachers College Record, 64*: 723-733.

Chen, S., Yang, S.J.H., & Hsiao, C. (2016). Exploring student perceptions, learning outcome, and gender differences in a flipped mathematics course. *British Journal of Educational Technology, 47*(6), 1096-1112. doi: 10.1111/bjet.12278.

Cornell, L. P., & Odafe, V. U. (2008). The effect of grading homework on student performance in college chemistry classes. *Journal of the Association for University Regional Campuses of Ohio, 14*, 143-149.

Cuadros, J., Yaron, D., & Leinhardt, G. (2007). One firm spot: The role of homework as lever in acquiring conceptual and performance competence in college chemistry. *Journal of Chemical Education, 84*(6), 1047-1052.

Davies, R. S., Dean, D. L., & Ball, N. (2013). Flipping the classroom and instructional technology integration in a college-level information systems spreadsheet course. *Educational Technology Research and Development, 61*(4), 563-580.

Diegelman-Parente, A. (2011). The use of mastery learning with competency-based grading in an organic chemistry course. *Journal of College Science Teaching, 40*(5), 50-58.

Dweck, C. (1999). *Self-theories: Their role in motivation, personality, and development*. Philadelphia, PA: Psychology Press.

Eddy, S. L., & Hogan, K. A. (2014). Getting under the hood: How and for whom does increasing course structure work? *CBE Life Sciences Education, 13*(3), 453-468.

Eichler, J. F., & Peeples, J. (2013). Online homework put to the test: A report on the impact of two online learning systems on student performance in general chemistry. *Journal of Chemical Education, 90,* 1137-1143.

Engeström, Y. (1999). Activity theory and transformation. In Y. Engeström, R Miettinen, & R.L. Punamaki-Gitai (Eds.), Perspectives on activity theory. Learning in doing: Social, cognitive and computational perspectives. Cambridge, United Kingdom: Cambridge University Press.

Engeström, Y. (2001). Expansive learning at work: toward an activity theoretical reconceptualization. *Journal of Education & Work, 14*(1), 133-156. doi:10.1080/13639080020028747

Farland-Smith, D. (2015). Struggles of underrepresented girls as they become women: Understanding how race & gender that impact personal science identity construction. *Journal of Educational Issues, 1*(1), 114-127.

Folami, L. B., & Simons, K. (2012). Students' perceptions of online homework software in accounting courses. *International Journal of Education Research*, *7*(2), 56+.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences of the United States of America, 111*(23), 8410-8415.

Gabel, D. (1999). Improving teaching and learning through chemistry education research: A look to the future. *Journal of Chemical Education, 76*(4), 548-554.

Gall, M. D., Gall, J. P., & Borg, W. R. (2007). *Educational research: An introduction* (8th ed.). New York, NY: Allyn and Bacon.

Galyon, C. E., Voils, K. L., Blondin, C. A., & Williams, R. L. (2015). The effect of randomized homework contingencies on college students' daily homework and unit exam performance. *Innovative Higher Education, 40*(1), 63-77. doi:http://dx.doi.org/10.1007/s10755-014-9296-1

Garrison, R., McDaniel, K., & Daday, J. (2015). The effects of introducing e-texts and e-materials in 100-200 level college biology courses on teaching pedagogy. *Proceedings of the National Association of Biology Teachers Biology Education Research Symposium, Providence, RI.* Retrieved from https://nabt.org/files/galleries/Paper2_Garrison.pdf

Gebru, M. T., Phelps, A. J., & Wulfsberg, G. (2012). Effect of clickers versus online homework on students' long term retention of general chemistry course material. *Chemistry Education Research and Practice, 13*(1), 325-329.

Gershenson, S., & Holt, S.B. (2015). Gender gaps in high school students' homework time. *Educational Researcher, 44*(8), 432-441. doi: 10.3102/0013189X15616123

Griff, E. R., & Matter, S. F. (2013). Evaluation of an adaptive online learning system. *British Journal of Educational Technology, 44*(1), 170-176.

Gutarts, B., & Bains, F. (2010). Does mandatory homework have a positive effect on student achievement for college students studying calculus? *Mathematics & Computer Education, 44*(3), 232-244.

Halcrow, C., & Dunnigan, G. (2012). Online homework in calculus I: Friend or foe? *Primus: Problems, Resources, and Issues in Mathematics Undergraduate Studies, 22*(8), 664-682.

Heron, P.R.L., (2015). Effect of lecture instruction on student performance on qualitative questions. *Physical Review Special Topics – Physics Education Research, 11*(1), 010102.

Hsiung, C. (2014). The effectiveness of cooperative learning. *Journal of Engineering Education, 101*(1), 119-137.

Johnston, T. C. (2004). Online homework assessments: benefits and drawbacks to students. *Academy of Educational Leadership Journal, 8*(3), 29+.

Johnstone, A. H. (1982). Macro and microchemistry. *School Science Review, 64*, 377-379.

Johnstone, A. H. (1997). Chemistry teaching—science or alchemy? *Journal of Chemical Education, 74*(3), 262-268.

Johnstone, A. H. (2010). You can't get there from here. *Journal of Chemical Education, 87*(1), 22-29.

Jonasson, D.H. (2000). Revisiting activity theory as a framework for designing student-centered learning environments. In: Jonasson DH, Land SM (eds) Theoretical foundations of leaning environments. Lawrence Erlbaum, Mahwah, pp 89–121.

Kackar, H.Z., Shumow, L., Schmidt, J.A., Grzetich, J. (2011). Age and gender differences in adolescents' homework experiences. *Journal of Applied Developmental Psychology (32)*2, 70-77.

Knight, C. C., & Sutton, R. E. (2004). Neo-Piagetian theory and research: Enhancing pedagogical practice for educators of adults. *London Review of Education, 2*(1), 47-60. doi:10.1080/1474846042000177474

Kontur, F. J., de la Harpe, K., & Terry, N. B. (2015). Benefits of completing homework for students with different aptitudes in an introductory electricity and magnetism course. *American Physical Society, 11*(1), 010105.

Kozma, R. B., & Russell, J. (1997). Multimedia and understanding: Expert and novice responses to different representations of science phenomena. *Journal of Research in Science Teaching, 34*(9), 949-968.

Lazarova, K. (2015). The role of online homework in low-enrollment college introductory physics courses. *Journal of College Science Teaching, 44*(3), 17-21.

Lewthwaite, B., & Wiebe, R. (2014). Responding to students' learning preferences in chemistry. *Journal of Science Teacher Education, 25*(3), 263-287.

Mathai, E., & Olsen, D. (2013). Studying the effectiveness of online homework for different skill levels in a college algebra course. *Primus: Problems, Resources, and Issues in Mathematics Undergraduate Studies, 23*(8), 671-682.

Matthews, M. R. (2002). Constructivism and science education: A further appraisal. *Journal of Science Education and Technology, 11*(2), 121-134.

McLaren, H. J., & Kenny, P. L. (2015). Motivating change from lecture-tutorial modes to less traditional forms of teaching. *Australian Universities' Review, 57*(1), 26-33.

McLaughlin, J. E., Griffin, L. M., Esserman, D. A., Davidson, C. A., Glatt, D. M., Roth, M. T., Gharkholonarehe, N., & Mumper, R. J. (2013). Pharmacy student engagement, performance, and perception in a flipped satellite classroom. *American Journal of Pharmaceutical Education, 77*(9), 1-8.

Meyer, K. A. (2014). Student engagement in online learning: What works and why. *ASHE Higher Education Report, 40*(6), 37-66.

Mulford, D. R., & Robinson, W. R. (2002). An inventory for alternate conceptions among first-semester general chemistry students. *Journal of Chemical Education, 79*(6), 739-744.

Nakhleh, M. B. (1992). Why some students don't learn chemistry. *Journal of Chemical Education, 69*,191-196.

Nicol, D. J., & Macfarlane-Dick, D., (2006). Formative assessment and self-regulated learning: A model and seven principles of good feedback practice. *Studies in Higher Education, 31*(2), 199-218.

Orr, R., & Foster, S. (2013). Increasing student success using online quizzing in introductory (majors) biology. *CBE - Life Sciences Education 12*(3), 509-514.

Parker, L. L., & Loudon, G. M. (2013). Case study using online homework in undergraduate organic chemistry: Results and student attitudes. *Journal of Chemical Education, 90,* 37-44.

Patrick, L. E., Howell, L. A., & Wischusen, W. (2016). Perceptions of active learning between faculty and undergraduates: Differing views among departments. *Journal of STEM Education: Innovations and Research, 17*(3), 55-63.

Perdian, D. C. (2012). Early identification of student performance and effort using an online homework system: A pilot study. *Journal of Science Education and Technology, 22,* 697-701.

Phillips, F., & Johnson, B.G. (2011). Online homework versus intelligent tutoring systems: Pedagogical support for transaction analysis and recording. *Issues in Accounting Education, 26*(1), 87-97. doi:10.2308/iace.2011.26.1.87

Piaget, J. (1973). *The child and reality.* (Arnold Rosen, Trans.) New York: Grossman.

Planchard, M., Daniel, K.L., Maroo, J., Mishra, C., & McLean, T. (2015). Homework, motivation, and academic achievement in a college genetics course. *Bioscene: Journal of College Biology Teaching, 41*(2), 11-18.

Revell, K. D. (2014). A comparison of the usage of tablet PC, lecture capture, and online homework in an introductory chemistry course. *Journal of Chemical Education, 91,* 48-51.

Richards-Babb, M., Curtis, R., Georgiva, Z., & Penn, J. H. (2015) Student perceptions of online homework use for formative assessment of learning in organic chemistry. *Journal of Chemical Education, 92,* 1813-1819.

Richards-Babb, M., Drelick, J., Henry, Z., & Robertson-Honecker, J. (2011). Online homework, help or hindrance? What students think and how they perform. *Journal of College Science Teaching*, *40*(4), 81.

Rosenblatt, L. M. (1994). *The reader, the text, the poem: The transactional theory of the literary work.* Carbondale: Southern Illinois University Press.

Sandall, L., Mamo, M, Speth, C., Lee, D., & Kettler, T. (2014). Student perception of metacognitive activities in entry-level science courses. *Natural Sciences Education* (43), 25-32. doi:10.4195/nse2013.06.0021

Schroeder, N., Gladding, G. Gutmann, B., & Stelzer, T. (2015). Narrated animated solution videos in a mastery setting. *American Physical Society, 11*(1), 010103.

Singha, A., Bhadauraib, V., Jainc, A., & Gurungd, A. (2013). Role of gender, self-efficacy, anxiety, and testing formats in learning spreadsheets. *Computers in Human Behavior, 29*(3), 739-746.

Sletten, S.R. (2017). Investigating flipped learning: Student self-regulated learning, perceptions, and achievement in an introductory biology course. *Journal of Science Education & Technology, 26*(3), 347-358. doi:10.1007/s10956-016-9683-8

Tanner, K. D. (2012). Promoting student metacognition. *CBE – Life Sciences Education, 11*(2), 113-120.

Tasker, R. (2014). Research into practice. *Teaching Science: The Journal of The Australian Science Teachers Association, 60*(2), 16-27.

Thadani, V., & Bouvier-Brown, N.C. (2016). Textbook-bundled metacognitive tools: A study of LearnSmart's efficacy in general chemistry. *Journal on Excellence in College Teaching, 27*(2), 77-95.

Theodoraki, X., & Plakitsi, K. (2013). Analyzing activities in the course of science education, according to activity theory: The case of sound. *US-China Education Review, 3*(6), 353-364.

Thomas, G.P., & McRobbie, C.J. (2013). Eliciting metacognitive experiences and reflection in a year 11 chemistry classroom: An activity theory perspective. *Journal of Science Education Technology, 22*(3), 300-313. Retrieved from http://www.jstor.org/stable/23442251

Titard, P. L., DeFranceschi, J. E., & Knight, E. (2014). Using online homework to improve exam scores. *Journal of Business and Educational Leadership, 5*(1), 58-63.

Wang, X., Yuan, W, Guo, W., & Liu, X. (2013). Research on the design and implementation of online homework review and similarity comparison system. *Journal of Applied Sciences*, *13*: 2774-2780.

Warner, R. M. (2013). *Applied statistics: From bivariate through multivariate techniques* (2nd ed.). Thousand Oaks, CA: Sage Publications.

Wood, W. B. (2009). Innovations in teaching undergraduate biology and why we need them. *Annual Review of Cell and Developmental Biology*, (25), 93-112. doi:10.1146/annurev.cellbio.24.110707.175306

Woolley, D. J. (2015). Which helps accounting students learn more: traditional homework, online homework, or clickers? *Academy of Educational Leadership Journal*, *19*(3), 337-343.

Wright, L. K., Newman, D. L., Cardinale, J. A., & Teese, R. (2016). Web-based interactive video vignettes create a personalized active learning classroom for introducing big ideas in introductory biology. *Bioscene 42*(2), 32-43.

Zhao, N., Wardeska, J.G., McGuire, S.Y, & Cook, E. (2014). Metacognition: An effective tool to promote success in college science learning. *Journal of College Science Teaching, 43*(4), 48-54.

APPENDIX

IRB APPROVALS

May 17, 2018

Donnie Cook
Researcher
Liberty University
1508 N 4th Ave
Lanett, AL 36863

Dear Mr. Cook:

It is my pleasure to inform you that the Institutional Research Board at (redacted) has reviewed and approved your request to conduct your research proposal entitled The Impact of Online Homework, Gender, and Metacognition in Improving Student Achievement in Undergraduate Biology Courses at [redacted]

Please note the following:

☒ [Data will be provided to the researcher stripped of any identifying information.]

☒ [I/We are requesting a copy of the results upon study completion and/or publication.]

Best wishes for a successful research project.

Respectfully,

[redacted]

[redacted]
Chief Academic Officer

LIBERTY UNIVERSITY
INSTITUTIONAL REVIEW BOARD

June 1, 2018

Donnie Cook
IRB Application 3356: The Impact of Online Homework, Time on Homework, Gender, and Metacognition in Improving Student Achievement in Undergraduate Biology Courses

Dear Donnie Cook,

The Liberty University Institutional Review Board has reviewed your application in accordance with the Office for Human Research Protections (OHRP) and Food and Drug Administration (FDA) regulations and finds your study does not classify as human subjects research. This means you may begin your research with the data safeguarding methods mentioned in your IRB application.

Your study does not classify as human subjects research because it will not involve the collection of identifiable, private information.

Please note that this decision only applies to your current research application, and any changes to your protocol must be reported to the Liberty IRB for verification of continued non-human subjects research status. You may report these changes by submitting a new application to the IRB and referencing the above IRB Application number.

If you have any questions about this determination or need assistance in identifying whether possible changes to your protocol would change your application's status, please email us at irb@liberty.edu.

Sincerely,

[redacted]

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UNIVERSITY.
Liberty University | Training Champions for Christ since 1971