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THE EFFECTS OF LECTURE CAPTURE DESIGN ON STUDENT PERFORMANCE IN AN ONLINE, ASYNCHRONOUS NONMAJORS BIOLOGY COURSE

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by

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ABSTRACT

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Lecture capture technology, the ability to provide multimedia recordings of instructional content, has become an essential technology for online learning. One of the ways online courses have tried to appeal to the digital lifestyle of today's students is providing different lecture capture styles, such as audio (podcasts), video, or interactive videos, due to the popularity of mobile media players providing anytime and anywhere learning. Although lecture capture technology provides educators with a diverse set of tools on how content is delivered, studies have shown mixed results on the impact of lecture capture styles on learning.

For this study, the main purpose was to determine when students use lecture captures, and if they used a lecture capture, how the lecture capture affected exam scores. More specifically, is there a particular style of lecture capture that has a higher impact on student assessment score? Analyses considered retention of biological concepts presented to students without the use of technology (reading the textbook), auditory information (audio podcast), video (graphic and auditory information combined), and interactive video (signaled, graphic information). Data were collected from 80 students using pre-test surveys, viewership records, and exam scores. By studying the broad use and benefits of lecture captures, the data supported that lecture capture had a positive, significant effect on exam scores. When examined more closely, the impacts on student retention of information varied by the following three factors: lecture capture style, content presented, and level of difficulty of exam question.

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DEDICATION

I dedicate the following project to my family, my partner, my friends, and students. To my family, I know you are thankful to no longer have to ask me, “When will it be done?” To my friends, especially Angela Williams, your gentle encouragement and support kept me going. To my students, thank you for setting a high bar. You constantly are challenging me to continue to seek new ways to design a quality course.

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LIST OF ILLUSTRATIONS

LIST OF ABBREVIATIONS

GEC	General Education Curriculum
STEM	Science, Technology, Engineering, and Math

CHAPTER I

Introduction

Distance learning, an educational term used to describe instructional materials being provided to students across a geographic distance, has gone through several changes since its origins in the 1800s (Moore et al., 2010). In the beginning, learning materials were developed and mailed to learners (Schlosser & Simonsom, 2010; Dobbs et al., 2009; Casey, 2008; Spector, Merrill, Merrienboer, and Driscoll, 2008). One of the well-known examples occurred in 1911 when Anna Comstock built a series of biology lessons concerning the environment for elementary teachers to complete at home. By the 1950s, the materials available for at-home instruction via mail started to advance. First, audio recordings were played at home, then television screens became visual tools to enrich learning away from a classroom (Anderson, 2008).

In the 1960s, universities took advantages of these delivery methods and began to offer distance-based courses and degree programs, also known as correspondence courses. Unfortunately, the definition of distance learning in the literature became inconsistent after this time and was only further exacerbated when computers were introduced as a delivery method (Moore, 1990). In the 90s, computing and internet technology started to become available in homes, and by the end of the 90s, the term distance learning became an umbrella term that described other forms of learning such as online learning or internet-based learning (Conrad, 2006).

Today, there are still some challenges when describing online learning due to the current debate on how to define online learning and accessibility. Mobile computing devices have become more affordable and widely available, and the potential for learning from a mobile computing device has become much easier. This freedom to travel with educational materials has opened doors for a more flexible learning experience and more flexible definitions. Some consider online learning as an experience that is completed solely online (Oblinger and Oblinger, 2005) while others believe simply using online technology to deliver some information is still considered online learning (Caliner, 2004: Conrad, 2002). As more educators debate the definition, clarification has taken high priority. If some but not all learning takes place online, this style of learning is more appropriately termed a web-enhanced course. On the other hand, Singh and Thurman (2019) define online learning as specifically the delivery of information either synchronously or asynchronously through the Internet in which learning is not dependent on the student's location. While there continue to be disparities concerning the terms surrounding online learning, most authors agree that the Internet has become the dominant technology of this time, and online learning is considered the new and improved version of distance learning (Benson, 2002) by being able to distribute learning opportunities to students separate from the source of instruction via connection to the Internet.

Online Learning Growth

Since the early 2000s, students enrolled in an online class significantly increased (Muljana and Luo, 2019), and the idea of students completing courses on the computer was no longer considered a novel concept. In the United States, from 2003 to 2007, the number of students enrolled in online courses increased by 100% (Moore and Fetzner, 2009). By 2011, 89% of public universities were offering courses taught fully online and analysis showed that 32% of students in 2013 had taken at least one online course (Allen and Seaman, 2013). In 2018, a study by Seaman, Allen, and Seaman, found that 6,359,121 students in 2016 had taken at least one distance learning online course, and there was a 5.6% growth rate of students from the year prior (6,022,105 students enrolled in an online course in 2015). By 2019, the number of enrolled students in an online course or degree reached 7,313, 623 students (National Center for Education Statistics, 2020) suggesting that students enrolling in online classes was not slowing.

Unfortunately, in March 2020, COVID-19 disrupted traditional in person educational experiences. In the United States, institutions of higher education were forced to close and required all students to transition their courses to online learning in a phenomenon known as “emergence remote teaching” (Thurab-Nkhosi, Maharaj, and Ramadhar 2021; Olasile and Emrah, 2020). As the restrictions associated with the pandemic have lessened and students have returned to campus, preliminary reports show online courses are still being offered in higher numbers than before the pandemic (Lehrer-Small, 2022).

Advantages and Disadvantages in Online Learning

With no signs of slowing down, it is important to note that distance learning has both advantages and disadvantages compared to the traditional, face-to-face education.

Advantages: Online education has provided several advantages over traditional classrooms. First and foremost, students can attend class from anywhere and in both asynchronous, an online class with a flexible schedule in which students access the materials when their schedule permits and not restricted to a time to attend lecture, and synchronous courses, an online course occurring in real time in which a student is expected to log on and participate during that time (Zimmerman, 2012; Lee and Choi, 2011). The flexibility to choosing the path of course work, not commuting, and potential completing assignments when time is available has positive attributes for students that are looking to earn course credit to improve qualifications while being employed (Bijeesh, 2017; Brown 2017; Nagrale, 2013; Appana, 2008; Banathy, 1994; Hannum and Briggs, 1982). At the same time, employers can support employees' continued education since it helps reduce their own training costs and reduces the workers' time away during working hours (Appana, 2008). These advantages are not possible with traditional courses.

Within the classroom, face-to-face instruction has been reported as supporting a passive learning environment that fails to meet the needs of different types of learners (Banathy, 1994; Hannum and Briggs, 1982), whereas online learning environments have been reported as being accessible due to the growth of technology and providing programs to reach all types of learners (Lee and Choi, 2011). Online learning has been described as a friendlier environment to students, and students feel more comfortable providing their thoughts in online discussions than in face-to-face courses (Appana, 2008). Students also have reported a higher level of fairness due to the lack of visual cues that may occur in face-to-face courses in which implicit biases influence faculty treating some students differently (Appana, 2008).

In online classes, the ability to build diverse communities is higher than in face-to-face courses. Students from different areas can interact and collaborate within the course (An and Kim, 2006). With students working together, faculty can focus on higher order thinking through problem solving and collaborative learning, and build job-related skills (Katz and Associates, 1999; Hill, 1997; Webster and Hackey, 1997; Dolence and Norris, 1995).

Disadvantages: While there are many potential benefits to online learning, there are also limitations presenting their own unique challenge to educators. For example, as technology continues to advance, the utilization of this technology comes at a cost since many of these advancements are expensive and require training for both basic and effective use. These two requirements become barriers to effective online teaching (Conlon, 1997). These technological barriers, for example, lack of computers and training, along with other concerns make many educators resistant to online teaching since they do not believe online education solves any of the problems that teachers and learners face in a traditional classroom (Conlon, 1997), such as students completing assignments and low interactions between faculty and students. In fact, some faculty, especially in the Science, Technology, Engineering, and Mathematics (STEM) fields, believe that online instruction reduces the standards and value of education and threatens to commercialize education into isolated, passive, learning experiences for students, much like issues stated concerning traditional face-to-face classes (Hara and Kling, 2000; Gallick, 1998).

The resistance to online education does not stop at educators but also includes the students. While assumptions have been made about higher education students and their skilled technological competence, these assumptions are continually challenged. While students may live with technology comfort (Drab-Hudson et al., 2012), it has been shown that outside core skills, like accessing and reading emails, students are not at ease with more specialized technologies, are resistant to online learning (Kennedy et al., 2008; Kennedy et al., 2008), and prefer the structure and comfort of traditional, face-to-face courses.

Retention

Since the pandemic, universities have continued to expand their online course offerings, and students continue to enroll in these courses (Lehrer-Small, 2022). While both have increased, retention rates have remained low in online courses (Pekkarinen et al., 2023). When compared to traditional courses, the completion rate of an online course is 8–14% lower than its tradition counterpart (Xu and Jaggars, 2011a, 2011b). While the term online learning encompasses many different forms of learning, studies have confirmed that online-asynchronous self-paced courses specifically are the least effective, have high dropout rates, and are considered unsustainable by many educators (Liu, Gomez, and Yen, 2009; Willginig and Johnson, 2009). For students, such negative experiences often result in never registering for another online course (Poellhuber, Chomienne, and Karsenti, 2008).

But why do online courses have higher dropout rates? When considering the course curriculum or course relatedness to major, these two criteria also have become two key factors that influence student retention in an online course. Boston, Ice, and Gibson (2011) found when courses are not challenging or too challenging students readily drop the course. Also, the course content and relatedness to major (elective vs major requirement) can be predictable factors in student retention. For STEM fields, lower-level, service online courses often fall under the category of elective and high level of difficulty leading to higher risk of attrition (Wladis et al., 2014). Therefore, it is essential for online instructors in STEM fields to be able to bridge the gap and improve online learner satisfaction, popularity, and completion rate (Garratt-Reed, Roberts, & Heritage, 2016; Lee & Choi, 2011; Moore & Greenland, 2017; Murphy & Stewart, 2017; Wuellner, 2013) under this non-ideal situation.

Addressing Retention Problems: To address student retention in online education settings, institutes of higher education have considered the following three factors: institutional, instructor, and student level. For this study, the focus is on the instructional level. At the instructional level, course design and quality instruction have been linked to attrition rates (Garratt-Reed et al., 2016; Parkes et al., 2015; Stewart et al., 2013; Ice et al., 2011). In both traditional and online classrooms, the dominant form of distributing content is through lecture which is described as the vehicle for teachers to deliver large quantities of complex information to their learners (McGarr, 2009; Biggs and Tang, 2007; Williams and Fardon, 2007; Behr 1988). When designed properly, lectures have the ability to increase engagement in a course, for example, supporting problem solving when a teacher models how to approach a task (Covill 2011; Feldon 2010; Behr 1988). Lectures are also able to connect materials and build links that students typically cannot do by just reading the textbook (Kirkpatrick, 1990). Unfortunately, the most common type of lecture capture is an unedited video of streaming content which has been known to impose large amounts of extraneous load on the learner (Mayer, 2009). Using technology is one possible way for instructors to edit and make their lecture captures more conducive to learning.

Technology in the Classrooms

Technology and the entertainment industry have heavily influenced higher education (Renes and Strange 2010; Ellis et al. 2009; Owens et al. 2009; Zhao et al. 2009; Appana 2008; Dykman and Davis 2008; Salinas 2008; Ozdemir and Abrevaya 2007). For as long as the entertainment industry has used innovative technology to create films and video for audiences to view and listen, educators have utilized these resources as teaching supplements in their classrooms (Danielson et al., 2014). Today, advancements in computer technology have not only expanded the quality and number of available audio and visual tools, but they have also increased the ability for educators to create their own. Since the early 2000s, it has become a common practice for teachers to use some form of lecture-capturing technologies to either capture audio or audio plus a video of a classroom available to students (Danielson et al., 2014). By utilizing this type of technology, education is no longer restricted to an instructor standing in front of a classroom but is readily available to students who want to review content prior to an assessment (Brady et al. 2013; Gorissen et al. 2012; Gosper et al. 2010; Groen et al. 2016) or to students that previously may not have access to these opportunities (Ke and Xie 2009; Owens et al. 2009; Talbert 2009; Chaney et al. 2008; Crow 2008; Majeski and Stover 2007; McMurry 2007; Ozdemir and Abrevaya 2007; Spaniol et al. 2006; McNab 2005; Carnevale 2002; Musick 2001).

Although this approach of providing recorded lectures to students is popular among students and thought to be an imperative and required component in distant learning classrooms (Soong et al. 2006; Boling and Robinson, 1999), deviations in the type, style, and use of lecture-captures in undergraduate education have provided mixed results on the relationship between learning and lecture capture use in both traditional classrooms and in online classrooms. In the following studies (Franklin et al., 2011; Bacro, Gebregziabher, and Fitzharris, 2010; Brotherton and Abowd, 2004; Solomon et al., 2004; Spickard et al., 2002), the results reported no discernable relation between the use of lecture recordings and their impact on student's academic performance (Leadbeater et al., 2013). Studies conducted by the following (Fernandes, Moira, and Cruickshank, 2012; Franklin et al., 2011; McNulty et al., 2009, 2011; Owston, Lupshenyuk, and Wideman, 2011) reported a negative relationship, but studies by Bridge, Jackson, and Robinson, 2009; Dey, Burn, and Gerdes, 2009; Elsasser et al., 2009; Shaw and Molnar, 2011; von Konsky, Ivins, and Gribble, 2009, found a positive relationship. Whether the relationship is positive, negative, or unclear, each of the following studies (Franklin et al., 2011; Holbrook and Dupont, 2011; Bacro et al., 2010; Heilesen, 2010; Scutter et al., 2010; Dey et al., 2009; Lovell and Plantegenest, 2009; Von Konsky et al., 2009; Cardall, Krupat, and Ulrich, 2008; Pilarski et al. 2008; Yudko, Hirokawa, and Chi, 2008; Mattick, Crockr, and Bligh, 2007; Brotherton and Abowd, 2004; Solomon et al., 2004; Spickard et al., 2002) reported that students valued the lecture captures and believed having access to these tools improved learning since they were able to review lectures if a class is missed or if the information was difficult to understand.

Styles of Lecture Captures

With the development of the Internet, the ability to upload materials and disperse the information quickly to individuals has changed the way educators communicate with students. As technology and software become freely available, instructors are incorporating online lecture content in their courses. The type of lecture captures available vary from simple productions (audio only or audio recording accompany a separate presentation) to elaborate videos (audio and video representations combined) (Osborn, 2010). Below is a general overview of the two types of lecture-captures and their current impacts on learning.

Audio Lectures. Audio lecture captures, also known as podcasts, are the simplest form of lecture capture. They are audio recordings files that provide a narrative style learning experience where the individual listens to the continuous streaming content (Evans 2008). Since the file may be downloaded or streamed through a computer or mobile device, the resource is considered a flexible and an easily accessible style of e-learning and mobile learning (Evans 2008). It can be useful for students who prefer to listen to lectures and/or have difficulty with paying attention and taking notes during a lecture.

When examining the effects of audio-only lectures on learning, the research is limited to studies concerning lectures used as supplements to traditional lectures learning (Morris, 2010; McKinney, Dycka, and Lubera, 2009; Abt and Barry, 2007; Cramer et. Al., 2007; Spickard et al. 2004) and one study by McKinney, Dycka, and Lubera, 2009 on using an audio-only recordings (podcast) to replace a missed lecture. Each of the studies designs are variable, but they all showed a slight increase on academic performance concerning the use of audio-only lectures (Morris, 2010; McKinney, Dycka, and Lubera, 2009; Abt and Barry, 2007; Cramer et. Al., 2007; Spickard et al. 2004). The slight increase in performance has been attributed to students that use this type of academic tool were more likely to take personal notes (McKinney et al. 2009). This phenomenon of notetaking is an integral part of learning and has been shown to result in higher scores on assessments (Titsworth and Kiewra, 2004; Kiewra, 1985). When concerned with students' attitudes and learning from podcasts, most students preferred and believed a recorded lecture rather than reading the textbook was more effective to revisit and revise their notes on the course materials (Evans, 2008). It is speculated that the learner's ability to control the recordings pace encourages students to reflect, revise, and facilitate more detailed notes (Bassili and Joordens, 2008).

Video Lectures. Videos are a multimedia resource that incorporates both visual elements (text, images, and graphics) and sound/audio (speech and hearing cues) media to provide content information to students (Pan et al., 2012). Videos are thought to be the most effective and preferred (common) form of lecture captures (Mayer 1993; Levie and Lentz, 1982), and many courses, both online and face-to-face, use video lectures because their overall ease of simply uploading a recording (Osborn, 2010; Rose, 2009; Branigan 2005). When designed effectively, a video covers difficult concepts with images, cues, and explanation of difficult content presented in the textbook by two modes of learning: visual and auditory (Rose, 2009; Branigan, 2005; Vasu and Howe, 1989). Especially for online students, videos are able to enrich the students' learning experience because they are able to see the concepts in action and are able to construct mental models for processes that are difficult to describe, similarly to those students that are in a face-to-face classroom (Pan et al., 2012; Bonk, 2011; Schönborn and Anderson, 2006; Klass, 2003; Michelich, 2002; Brown, Collins, and Duguid, 1989; Paivio, 1986).

In studies conducted on the use and overall importance of lecture videos, students enrolled in courses with unlimited access to lecture videos deemed the video captures important for not only retaining the course content but also improving their test scores because of their ability to review concepts for clarity (Veeramani and Bradley, 2008; Yudko et al., 2008; Simpson, 2006; Winer and Cooperstock, 2002; Wilson and Weiser, 2001). Studies have also found that students with access to unlimited video captures also outscored students without access to videos (Kim and Chen, 2011; Hove and Corcoran, 2008). In each of the studies, students provided feedback on the value of the lecture videos and expressed their hope that other instructors would adopt the use of videos in their courses.

Learning from PowerPoints in Video Lectures. In the online environment, today's video lecture capture generally includes two types of information: a) non-persistent (speech) and 2) persistent information (e.g., PowerPoint presentation slide) (Alley and Neeley, 2005; Brotherton and Abowd, 2004). Microsoft PowerPoint software not only organize information but also includes features such as bullets and animations that are used to capture students' attention.

Focus

As the use of lecture recordings increases in both online and face-to-face classrooms and with much research focusing on how lecture recordings improve student performance, the focus of this study is to determine the most effective design of lecture capture to motivate learners and the impact of the use of lecture recordings on the learner in an online classroom. When comparing the two types of lecture captures, some argue that video content along with audio is preferred due to the personalized nature of the presentation compared to the audio only lecture. Others argue that video is timely, costly, and not necessary to effectively cover the content of a course. Given the importance of lecture captures to online education, it is important to design a study that addresses whether there is a difference in learning so that instructors are able to make executive decisions on data rather than opinions.

This study examined the different types of learning cues, clicking (segmentation) and signaling, and whether or not these techniques fulfill the role of a direct approach to aid a learner while viewing an interactive video lecture capture (Driver, 2001). By providing different types of learning cues, this study determined whether or not a particular type of cue reduces the amount of cognitive resources a learner uses. In reducing the cognitive load, the cue may increase comprehension by limiting the number of external stimuli the learner may experience when a lecture capture is on. This, in turn, is expected improve an individual's learning experience by providing a scaffold approach to sustain the attention of the learner (Cook, 2006; Driver, 2001). With limited studies on the impact of the various styles of lecture captures, the results would provide a valuable reference for video lecture design in terms of effectiveness for students in a self-directed learning environment (Hartsell and Yuen, 2006).

Statement of the Problem

When examining the format of a biology course, a typical introductory biology college course covers large amounts of information concerning complex topics. To avoid reducing the content presented and depriving students that have higher levels of preparedness, instructors should develop a pedagogical structure in which all learners are engaged and are able to acquire knowledge (Rayner, 2008). As stated previously, lectures are still considered the dominant teaching method and have been consistently used as the delivery method of complex materials to large number of students (Behr 1988). Today, advancements in computer technology have expanded the number of available materials to instructors and students, which in turn, has increased the overall use of multimedia content available to students (Rundgren and Tibell, 2010).

For this study, various styles of lecture captures were recorded, and students had the option to select which type of lecture capture they would utilize to review the content. The type of lecture capture selected was used as the independent variable to determine whether the selected lecture capture style had an influence on the dependent variable, the scores on summative assessments (exam scores). By assessing the following mechanism, it was determined whether or not using a lecture capture increased retention of information for students that used a lecture capture compared to students that did not (Cook, 2006).

Research Questions and Hypotheses

For the following investigation, the study has two general research questions. The researcher intended to determine if lecture capture design affects retention and comprehension of biological concepts covered in an online nonmajors biology course.

Specific Research Questions: “Will using a lecture capture influence learning (exam scores) in an online nonmajors biology course?” and “When comparing lecture styles, how does lecture capture design influence learning?” These questions were subdivided into several hypotheses.

Research Hypothesis One: When comparing exam scores, there will be a significant difference in the means of the exams between students who used a lecture capture than students who did not use a lecture capture.

Research Hypothesis Two: Across exams, students who used an available lecture capture will score higher on challenging concepts, as defined by Bloom’s level and identified as historical challenging, than students that chose not to utilize any lecture capture available.

Research Hypothesis Three: For each exam, students who used an available lecture capture will score higher on challenging concepts, as defined by Bloom’s level and identified as historical challenging, than students that chose not to utilize any lecture capture available.

Assumptions, Limitations, and Delimitations

For the following research project, the subjects were students enrolled in a nonmajors biological sciences asynchronous online course. It was assumed that students in the experimental group (students selecting a particular type of lecture capture) were watching the assigned lecture captures prior to completing any assignment. It was also assumed that students would answer any assessment (questionnaire and assessments) to the best of their abilities and without any assistance. Because of the nature of online courses, it is possible that students may have another person answer assessment questions or use additional materials to answer questions. It is also possible that with no risk assessments like the questionnaire, students would not take the assessment seriously and answer the questions unthoughtfully. In such a case, it could lead to an incorrect indication of whether a topic is unfamiliar to the test subject.

The results of this study are limited to students enrolled in a four-year university in southern Mississippi during the Spring 2019 semester. With such limitation to study population, this study and the data presented may not be universally applicable to all student populations.

Since the following course is a General Education Course (GEC) lab-based, nonmajors course, it can be taken at any point during a student's academic pursuit. Therefore, the participants of this study varied in majors, academic year, and age in addition to ethnicity, sex, and gender and not distributed evenly in the semester. The results of the project would have been different, for example, if the sample of student groups differed, students were enrolled in a face-to-face course, or students previously were enrolled in a majors biological sciences course.

Because the students were online students, there was no data collected on whether the students explored other resources, such as reading an article or watching any other available online resource to study the content prior to the assessment. Therefore, it was assumed when students were asked to complete a task, they were only using the resources provided to them by the instructor.

All assessments, readings, lecture captures, animations, etc., were part of the online class design and were not adjusted between semesters.

Justification

While most research supports the use of lecture captures as a way to improve students learning and perception of either a face-to-face course or an online course, research fails to clarify the effects of different styles of lecture captures have on learning. It is necessary to realize that the types of content used by the instructor should be sensitive to the cognitive load demand necessary to interpret the information (Mayer et al., 2003). The degree of anxiety a learner experiences during a particular learning activity greatly influences a learner's performance. When instructional content, such as a lecture capture, is overloaded with content, the chance of a learner not understanding the concept being presented greatly increases. The strain from the extraneous cognitive overload prevents the learner from focusing on the important information being presented, and the overall success of the learner interpreting the information is not achieved. This poses the question: how much of students' knowledge gain comes from merely listening to an audio lecture capture compared to how much knowledge is gained when navigating through a video lecture capture?

Summary

This quantitative research study explores the experiences of students using lecture captures in an online, asynchronous nonmajors biology course at four-year, public university in south Mississippi. Chapter 1 provides a discussion of how content delivery in a classroom affects learning, and the problem, purpose, and significance of the following study. This chapter also includes the primary research questions and hypotheses. Limitations and delimitations close the chapter.

CHAPTER II – REVIEW OF THE LITERATURE

For the following study, the literature review summarizes background research related to distance learning, learning with online materials, and factors influencing the usefulness of online materials. The literature review includes the pros and cons of using the different types of lecture captures, a form of delivery of information to students. It also highlights that no form of lecture capture is useful unless it is well designed and centers around the principles of the following conceptual frameworks: the dual coding theory, multiple intelligences, cognitive load, and cognitive load theory, multimedia learning and media richness theories (Mayer 1997).

Introduction

The idea of distance learning education in which a student does not attend a campus for class has been traced back to 1840 in which Englishman Isaac Pitman offered learning by mail (Bower & Hardy, 2004). By 1852, the Phonographic Institute in Cincinnati, OH, offered a training program by Pitman to those interested in providing distance learning, and in 1892, the first distance college level program was offered at the University of Chicago (Casey, 2008). Since that time, distance learning has flourished and has become popular to a) people unable to make the commute to a geographically distant university due to other commitments, b) for those that otherwise could not afford the time or expense of a full-time education, c) students with disabilities, and d) professionals looking to review the latest advancements in their field.

Due to the technological advancements from mail to radio to television to multimedia materials today, the current trend for universities to offer online courses and materials continues to increase (Bower & Hardy, 2004). Universities are seeking strategies to reduce cost but maintain effective learning. Online classrooms provide educational interventions that require little funding and are becoming the common adopted strategy to reduce cost. How? Improvements in technology, such as the online learning management systems and free recording software, are providing the tools to help faculty to do so. Online management systems can increase the availability of a course and reduce the cost to deliver course materials since students are able to enjoy the flexible instruction and assignment at home. Enhanced ability to record and distribute instructional materials has allowed the instruction in online classes to mimic face-to-face classes and challenges the traditional styles of teaching and learning (Somenarain et al. 2010; Swan 2006; McIsaac & Gunawardena, 1996).

Statement of the Problem

When it comes to online education, there are disagreements about the quality of online programs, materials available in online classrooms, students learning passively through online lectures, learning in isolation (Hara and Kling, 2000), the importance of online education (Allen & Seaman, 2014), transferability of online courses (Allen & Seaman, 2012), and online retention (Allen & Seaman, 2014). Still online education is a prevalent feature of attracting students to higher education.

For this study, various styles of lecture captures were included in the course learning management systems, and students had the ability to select which type of lecture capture they would utilize to review the content. By assessing the different types of lecture captures, the study would be able to determine whether a lecture capture, more specifically an edited lecture capture, reduced cognitive resources a learner used while trying to learn a complex biological concept and increased retention and comprehension for students using a lecture capture (Cook, 2006).

Why observe different styles? Historically, lectures, whether online or face-to-face, are a continuous stream of information and tend to bore students. The lack of engagement between the instructor providing the information and the students listening ultimately undermines academic achievement because students are not able to focus on what they are supposed to learn (Mann & Robinson, 2009; Moreno, 2007). One way to address the problem is to edit an audio recorded lecture by adding features, such as words, pictures, segmenting, and signaling. Based on the Cognitive Theory of Multimedia Learning, if an instructor applies some of the principles of the CTML stated above to their lecture, students have a higher chance of learning due to the application of instructional design (Mayer, 2009). Thus, the following investigation has the potentially to fill in the gaps concerning the effects of changing the format of a lecture capture through editing and how editing may influence students' ability to recall biological concepts on an exam.

Learning from Lecture Captures

Along with reinforcing concepts, lecture captures motivate learning by keeping students' attention and providing learners both flexibility and control (Pan et al., 2012; Mackey & Ho, 2008; Choi & Johnson, 2007; Koumi, 2006; Choi & Johnson, 2005). By having the ability to open the materials when, where, and on various devices, the student ultimately controls the course speed by working at their own pace (Evan, 2008). They also have the option to pause, skip, stop, and replay any materials to target materials which they deem difficult and skip over content they deem easy (Davis, Connolly, & Linfield, 2009; Kawka and Larkin, 2011; Soong et al., 2006). Especially when examining students that are non-native language learners and learning gains, lecture captures provide considerable learning gains presumably because they had the opportunity to repeat difficult content that most likely would have been lost in a fast-paced course (Scutter et al., 2010; Shaw & Molnar, 2011; Simpson, 2006).

Issues with Learning with Lecture Captures

Despite the successful reports on the use of unlimited lecture captures access, these instructional materials used for educational purposes do have disadvantages. Below are some examples of disadvantages to learning by audio and visual displays as reported in the literature.

Negative: Audio Lecture. While studies have reported a small increase in grades for students that used audio only lectures (McKinney, Dycka, & Lubera, 2009; Morris, 2010), the findings are controversial. In a follow-up study concerning learning from audio-only podcast, the results showed a negative effect. Based on data, students that were pausing the audio had adopted a surface learning approach by attempting to memorize course content instead of using the materials to achieve a deeper understanding. In the course, the new tool supported a non-effective learning strategy since most students who learned using audio recordings had lower scores (Le et al., 2010).

Negative: Video Lecture. Issue 1: With any type of instructional method, the length of the available lecture capture can be a significant problem. When content is made available, most content tends to exceed 40 minutes. These lengthy lecture captures make it difficult for the viewer to dedicate the time to view the content. Instead, students may lose interest and zone out, missing important parts of the lecture capture (Rose, 2009).

Issue 2: In most instances, lecture captures are generic, focusing on vocabulary and basic concepts they could learn reviewing the textbook, and do not assist in furthering comprehension of complex materials (Coleman, Bradley, and Donovan, 2012). Because of the lack of tailoring of the content, the viewer is expected to sort through multiple layers of information and mentally shift through the content to deem what is important, imposing large cognitive demands on the student (Goldstein, 2010; Ormrod, 2008; Baddeley, 1992). Students attempting to understand fundamental scientific concepts instead of focusing on vocabulary and basic concepts become frustrated and tune out information, potentially missing vital concepts.

Issue 3: Often students do not associate learning with videos because the term "video" is thought of as entertainment (Salomon 1984). With videos, students become overconfident in their ability to understand the content being presented, have an illusion of understanding, and do not spend as much time studying the learning materials (Son and Metcalfe 2000; Salomon 1984). By relying on the illusion of understanding, less time is spent reading the text or studying notes.

Issue 4: Most students have good intentions and plan on using the digital materials available, but Dev et al. (2000) found that the number of students that actually viewed the materials was much lower than anticipated. The study also concluded when students did view the content they did not treat the lecture as a primary source of material but thought of the lectures as review.

Issue 5: On the technology front, video-lecture captures can be difficult to upload or view due to Internet connections, and the quality of the materials is often low due to the equipment used to record the content (Goldstein, 2010; Ormrod, 2008; Baddeley, 1992).

Negative: Learning from Visual Displays (PowerPoint Presentations). In humans, visual perception, a sense involved in collecting and analyzing data from the surrounding environment to make decisions, is the most developed sense (Sekular and Blake, 1985). This same sense is essential for learning because humans learn by forming concepts and understanding from collecting data from our environment and manipulating them into a mental model (Sekular and Blake, 1985). In education, this information should be essential in how educators assist students in understanding complex processes by providing students with visual aids (PowerPoints) during a video lecture. A well-designed PowerPoint slide should provide a specific visual object in which a student can process and develop their own personal understanding of a process or content in a short time frame (Kraidy, 2002; Linn et al., 1996). From the research on representations, Mayer, Bove, Bryman, Mars, and Tapangco (1996) found that students are able to develop a higher level of conceptual knowledge from a representation (PowerPoint presentation) (Cook, 2008); therefore, PowerPoint presentations are crucial components in display concepts especially in science courses with learners that have little to no prior knowledge

(Cook 2008; Ametller & Pinto, 2002). Not only do PowerPoint presentations attract students' attention, but they help organize complex conceptual ideas that are often too difficult to understand from just reading the text (Cook, 2006).

But the degree in which a PowerPoint may improve understanding and retention varies calling into question the value of a visual representations (Cook, 2008). For a PowerPoint to improve learning and aid in retention, the learner must overcome a cognitive hurdle of understanding the concepts being written or depicted. If the PowerPoint is not thoughtfully designed and merely a decorative presentation or an outline specifically for the lecturer to keep pace during class time, the PowerPoint presentation does not illicit a cognitive responsive (Mayer 1993).

If the PowerPoint presentation is too complex, the learning experience is hindered because the learner is unable to overcome the cognitive hurdle (Cook 2008). For example, when Renkl (2017) studied learning from visual representation, such as a PowerPoint presentation, the researcher found some visual representations pose substantial demands on learners and students experience problems when trying to learn from the visual display. Some believe that the problem may be due to learners focusing on what is on the slide and not on what the instructor is saying (Driessnack 2005).

From a different viewpoint, some researchers believe that such issues with learning from visual displays arise not from the actual design of the representation but from students with low prior knowledge (scientific literacy) and representational competence (Kozma and Russell 1997). When comparing students with below average prior scientific knowledge to students with high level of prior scientific knowledge, Reid and Beveridge (1986) found that a lecture with pictures was beneficial for those with high scientific knowledge. On the other hand, visual displays (PowerPoint presentation) become meaningless and difficult to interpret for students with low scientific knowledge (Reid and Beveridge 1986). Similarly, when students have low representational competence, a set of skills for interpreting representations for a specific discipline, a visual representation is nothing more than points and dots (Kozma and Russell 1997). Instead of focusing on pertinent information, the novice student becomes distracted and is unable to grasp the relevant information (Canham and Hegarty 2010; Hegarty et al. 2010; Lowe 2004).

Why use audio lectures?

Data collected on expectations in an online course showed that students expect and prefer PowerPoint presentations to accompany a lecture (Amare 2006; Alley and Neeley, 2005). The same could be said for faculty (Alley and Neeley, 2005). But critics of PowerPoint label this tool as a crutch. Why? Studies have shown the traditional design of a PowerPoint does not communicate the content effectively; instead, it oversimplifies and fragments the content (Alley and Neeley, 2005). There are also issues with the bulleted format. The bullets create a false sense of hierarchy, order, and connection among facts (Alley and Neeley, 2005). In a study by Amare (2006), the researcher found that while PowerPoint presentations are the best tool for making presentations, students' performance in the absence of PowerPoint presentation was much higher than in a class with PowerPoint presentations.

With data supporting higher learning from audio only compared to lectures with PowerPoint presentation in a face-to-face class, it is important to see if similar results would be determined in an online classroom. In the absence of PowerPoint, both faculty and students would have to be more knowledge able a subject matter. It would also mean that students would need to rely on other means (office hours, reading the text, watching videos or animations) to acquire the proper knowledge (Alley and Neeley, 2005).

Optimizing Video Lecture Captures with PowerPoint Presentation

From the literature, the relationship between the use of video lecture captures and its influence on learning is variable. Therefore, clarification on how lecture captures influence performance is an important pedagogical consideration in an online classroom since it is often the dominant form of lecture capture. The traditional design of a lecture capture with PowerPoint is inherently flawed. Focusing on facts and conveying concepts, the traditional lecture fails to stimulate engagement or deep thoughts concerning the content and is a passive form of learning (Bligh 1998). To deviate from the traditional style, instructors need to incorporate methods in which students learn by doing and move away from one-way passive presentation of an instructor continually providing information (Bligh 1998). Previous studies have shown that scaffold items, such as arrows or pointing to a particular item, often lead the learner to make incorrect conclusions about what is being depicted on the slide, and the lecture capture is ineffective (Coleman et al., 2012). Instead, a more direct approach is necessary to guide the learners' attention through the complex tool (PowerPoint presentation).

Educators have made changes to their presentations in response to criticisms of PowerPoint presentations, so there is a level of learning by doing rather than by listening

(Coleman et al., 2012). Below are two examples of direct approaches: segmenting (clicking) and signaling.

1. Interaction Modality: Segmenting/Clicking

   When the learner moves through the visualization, the learner decides when to move onto the next segment. Based on the study by Spanjers et al. (2010), the learner-controlled segmentation compared to a continuous streaming video resulted in higher? student achievements. Since the learner can decide when to continue, the potential pause between each segment allows the student to review the content, update their mental model, and consolidate information learned. The ability to create motion by clicking to the next slide distinguishes segmented video lectures from a passive, static flow of a continuously flowing lecture capture and may provide a better means for students to capture critical information as they process information being depicted in a video (Goldstein et al. 1982; Blake 1977).

2. Interaction Modality: Signaling

   Signaling a visual cue to reduce cognitive load breaks the content into smaller, meaningful parts and allows the learner to process the information presented before moving onto the next segment. Signaling allows the learner to learn the materials piece by piece without overusing the learner's working memory and leaving room for the learner to complete other cognitive tasks (Fong et al., 2012).

Conceptual Frameworks

Dual Coding Theory

The Dual Coding Theory, a theory of cognition, provides an explanation of learning in which an individual's memory and learning are supported by a verbal cue and/or a visual cue. According to dual coding theory, the verbal system processes and stores information in the form of words and language, while the visual system processes and stores information in the form of images and spatial relationships. When combined, there is an increased ability of remembering a concept since the individual is stimulated by two different methods of organizing incoming information (Palvio 1986; Palvio 1979; Clark and Palvio 1971). As such, audio style lecture captures are valuable aids by supporting the verbal aspect of long-term memory; furthermore, by combining both verbal and visual cues, video lecture captures provide two distinct channels for information processing and subsequently increase the chances of information retrieval (Mayer and Anderson, 1991).

Gardner's Multiple Intelligences Theory

The theory of multiple intelligences, developed by Howard Gardner, challenges the idea of a single type of intelligence, or general intelligence, that focuses on cognitive skills, but instead, believes learners are able to learn and comprehend information through a variety of mediums and exhibit multiple intelligences (Gardner, 2006). Gardner identifies seven multiple intelligences that guide students' grasp of information and are shaped by experiences and potentially genetics. The seven inclusion criteria are musical intelligence, visual-spatial intelligence, linguistic-verbal intelligence, bodily-kinesthetic intelligence, logical-mathematical intelligence, interpersonal intelligence, and intrapersonal intelligence (Gardner, 2006). By acknowledging the different types of multiple intelligences, teachers should recognize the various methods in which students learn instead of focusing on one or two modalities such as linguistic intelligence and logical intelligence (Gardner, 2006). By faculty being aware of these inclusion criteria, faculty may build course content and available resources around these characteristics to enhance learning (Yesil and Korkmaz, 2010). Based on Gardner's theory, video lecture captures use multiple intelligences (linguistic and visual intelligence) and should enhance the ability of students to recall and understand the lecture content being presented compared to listening to the spoken word alone (audio lecture captures).

Cognitive Load Theory

The cognitive load theory provides an explanation as to how information presented to an individual moves from their short-term memory into working memory and eventually into long-term memory (Bollmeier et al., 2010). For the purpose of this research project, the cognitive load theory described by Sweller, Merriënboer, and Paas (1998), has been selected to explain whether or not lecture capture style reduces a learner's cognitive load.

The cognitive load theory describes three types of cognitive load a learner experiences that affects their working memory: intrinsic load, extraneous load, and germane load (Lin and Atkinson, 2011). Intrinsic load is defined as the level of difficulty of the learning task (Lin and Atkinson, 2011). Since all tasks have an inherent difficulty and at the same time, each learner has a varying level of knowledge, this is not something that may be directly altered (Lin and Atkinson, 2011). On the other hand, how the material is designed and presented to the learner, or the extraneous load, may be altered (Lin and Atkinson, 2011). The final type of cognitive load, germane load, is highly dependent on both intrinsic and extraneous load. Germane load explains how the brain processes and organizes the information into a usable pattern that may be stored in the long term as schemas.

According to the cognitive load theory, for an individual to successfully interpret information from a lecture capture, the lecture must be well organized, and the learner must have the cognitive ability to accurately assess and mentally visualize the concepts being depicted (Lin and Atkinson, 2011; de Koning, Tabbers, Rikers, and Paas, 2010). More specifically, a learner can only learn from a lecture if a limited amount of information is being presented at a given time (Feldon, 2010).

Although faculty members desire students to absorb and comprehend lecture content after one viewing, the cognitive demand of the lecture overwhelms the learner's ability to process and comprehend the intended meaning of the lecture and the assimilation and transmission of information does not fully occur (de Koning et al., 2010). To aid students in learning, an instructor can change the style of the instructional presentation by promoting more opportunities to transit information from short-term to long-term memory by freeing up available cognitive resources and promote learning of specific course content (Lin and Atkinson, 2011; de Koning et al., 2010).

Cognitive Theory of Multimedia Learning

Compared to previous generations, many of the students today encounter and use multimedia digital technologies in the classroom (Blouin et al., 2009; Brazeau & Brazeau, 2009). With the increased connection to the digital world and the use of digital media in education, the following framework, Cognitive Theory of Multimedia Learning (Mayer, 2005), is an acceptable framework for the following study concerning student learning through online, video lecture captures (Owston et al., 2011; Scutter et al., 2010; Dey et al., 2009) since the conceptual framework provides an explanation as to how both visual and audio components weaved together increases student learning (Mayer, 2005). At the core of learning people are able to gather information and learn from both words either printed or spoken and from visualizations (includes illustrations, charts, animations, and/or videos) (Mayer, 2005).

The theory is based on three assumptions: 1) individuals possess dual channels (the dual channel assumption) for processing the two ways in which people learn: a channel for processing visual information (visual channel) and a channel for processing verbal information (auditory channel), 2) the channels in which people use for processing information have a limited capacity and can be overloaded because they can only process a few facts at a given time (the limited capacity assumption), and 3) there is no set pattern to which individuals select which information to process. When a student is presented with incoming information, the learner is actively try to make sense of the information, incorporate the information with previous knowledge, and sort and store the information as a memory (the active processing assumption) (Mayer & Moreno, 2003).

Based on these assumptions, instructional design of a multimedia tool, such as a video lecture capture, should be designed with each of these assumptions in mind (Mayer 2005). For this study, the researcher focused on the processing limiting factor (the limited capacity assumption) when designing a lecture capture. When reviewing the assumptions considering whether or not a lecture capture is helpful, lecture captures would likely be beneficial to students when the lecture capture is designed to reduce cognitive demands (Mayer & Moreno, 2003). Therefore, the following assumption is an adequate explanation to determine whether the lecture capture design and different cues (clicking/segmenting and signaling) used with the lecture captures benefit students when learning from a multimedia tool.

Purpose

In traditional and online classrooms, the availability of lecture captures to students is widespread (Alley and Neely, 2005). Studies have shown that students who use lecture captures are more frequently low achieving students (Owston et al., 2011; Le et al., 2010; McNulty et al., 2009), non-English speaking students, or students with disabilities (Leadbeater et al., 2013). For each of those populations, the ability to learn at their own pace and revisit information that was deemed difficult is creating inclusive learning experiences (Olofsson et al., 2012; Pearce & Scutter, 2010). Even so, the variability in the results on the benefits and the negative effects of type of lecture captures on students' performance are still topics of debate and warrant further investigation. Therefore, the purpose of this study is to provide a refined evaluation of the effects of different delivery styles of lecture captures and features associated with lecture captures on students' scores on summative assessments in an asynchronous, online nonmajors biology course (Susskind, 2005). More specifically, the study's purpose is to design and implement educational lecture captures to determine if there is a value to audio-video slide presentation (video and interactive video lecture captures) compared to audio only presentation (audio lecture captures). The primary goal is to improve the online experience for students in an online, nonmajors biology course by providing instructional content that increases students understanding of course materials in their class. With individuals seeking ways to return to school but limited to distance learning programs (Kadlubowski, 2000), information pertaining to asynchronous distance education methodologies, such as instructional methods best practices, need to be continually examined to ensure a quality learning experience. Moreover, with increasing educational cost, improved educational materials, such as lecture captures, would be a highly desirable attribute.

CHAPTER III - METHODOLOGY

With the lack of clear effects of the impact of the various styles of lecture captures on student performance in an online classroom, the following study provided an assessment on the effects of delivery styles of a lecture capture on student performance in an online, nonmajors biology course (Susskind, 2005). Therefore, the following study was designed to address whether lecture captures have an impact on students' performance in an online lecture nonmajors biology course and how does lecture capture design influence learning. This overarching idea was divided into three separate research hypotheses to address specific aspects of the study.

To address these specific aspects, the following conceptual frameworks were used: the dual coding theory, multiple intelligences, cognitive load, and cognitive load of multimedia learning. More specifically, the Cognitive Load Theory of Multimedia Learning was broadened so student performance can be compared to both exam scores and question scores of students that did not utilize lecture captures. The study also addressed scores of students based on the lecture capture delivery selected (audio only, video with audio and segmenting, and video with audio, segmenting, and signaling) and provide a clearer direction on which lecture capture delivery style, if any, improved student performance compared to students that did not utilize lecture capture.

Research Questions and Hypotheses

The data collected was analyzed using statistical evaluations to address the following research questions and hypotheses.

Comparison of exam scores between courses

First, the study addressed whether providing online lectures influences exam and questions scores. Therefore, the study attempted to answer the following two questions, "Will using a lecture capture influence student success in an online nonmajors biology course? And "When comparing lecture styles, how does lecture capture design influence learning?" These questions were subdivided into several hypotheses.

Hypothesis 1: When comparing exams, students who used available lecture captures (experimental group) will score higher on exams than students that choose not to utilize any lecture capture (control group).

Part A: Intervention vs. No Intervention: Does additional assistance (a lecture capture) to the textbook improve a students' ability to score higher on exams than students that do not use a lecture capture?

Null hypothesis: There is no difference between exams of the students who chose not to use lecture captures compared to students that used lecture captures.

Part B: Intervention Type vs No Intervention: Is there a specific type of lecture capture that improves test scores or are all lecture capture styles equivalent in assisting a student to recall information on the exam?

Null hypothesis: There is no difference between exams of students that used different lecture capture style.

Investigation: In this approach, students were able to choose whether they used a lecture capture provided by the instructor, and the scores of those that chose to review a captured lectures are compared with the scores of those chose not to use captured lectures (von Konsky et al. 2009, McNulty et al., 2009, McNulty et al., 2011). Since the exams were the same for every student, level of difficulty and content coverage were controlled for individual exams.

Data analysis: A two-way ANOVA test with a control (choosing not to use captured lectures) will be used to compare the following groups:

Test 1: Control group (Students that do not select a lecture capture) vs. Students that use lecture captures

Test 2: Control group (Students that do not select a lecture capture) vs. Audio only lecture capture (audio)

Control group (Students that do not select a lecture capture) vs. PowerPoint with audio and segmentation lecture capture (video)

Control group (Students that do not select a lecture capture) vs. PowerPoint with audio, segmentation, and signaling lecture capture (interactive video)

Comparison of question scores

Hypothesis 2: Across exams, students who used an available lecture capture will recognize and recall information and score higher on challenging concepts than students that choose not to utilize any lecture capture available.

Part A: Hypothesis 2A: Across all exams, **t**here is a statistical difference between students who use lecture captures on higher-level Bloom's taxonomy exam questions than students that choose not to utilize an available lecture capture.

Part A: Intervention vs. No Intervention: Does additional assistance (a lecture capture) to the textbook improve a students' ability to score higher on Bloom's questions than students that do not use a lecture capture?

Null hypothesis: There is no difference between exam questions of the students who chose not to use lecture captures compared to students that used lecture captures.

Part B: Intervention Type vs No Intervention: Is there a specific type of lecture capture that improves recall on higher level Bloom's questions or are all lecture capture styles equivalent in assisting a student to recall information on the exam?

Null hypothesis: There is no difference between exam questions of students that used different lecture capture style.

Investigation: The study investigated whether choosing to use one of the lecture-capture has an impact on students' high order thinking skills. In this approach, students can choose whether they will use captured lectures provided by the instructor or not, and scores of the question types will be compared between students that choosing to review captured lectures compared with the scores of those choosing not to use captured lectures (von Konsky et al. 2009, McNulty et al., 2009, McNulty et al., 2011). Stephenson et al.

2008 noted that different delivery styles affected on different questions depending on what level of Bloom's taxonomy was being evaluated.

Data analysis: A 3-Way ANOVA test with a control (choosing not to use captured lectures) was used to compare the following groups:

Test 1: Control group (Students that do not select a lecture capture) vs. Students that use lecture captures

Test 2: Control group (Students that do not select a lecture capture) vs. Audio only lecture capture (audio)

Control group (Students that do not select a lecture capture) vs. PowerPoint with audio and segmentation lecture capture (video)

Control group (Students that do not select a lecture capture) vs. PowerPoint with audio, segmentation, and signaling lecture capture (interactive video)

Part B: Hypothesis 2B: Across exams, there will be a statistical difference between students who use lecture captures in recognition of correct answers for historical challenging concept questions after viewing the lecture capture than students that choose not to utilize any lecture captures available.

> Part A: Intervention vs. No Intervention: Does additional assistance (a lecture capture) to the textbook improve a students' ability to score higher on historical challenging questions than students that do not use a lecture capture?
>
> Null hypothesis: There is no difference between exam questions of the students who chose not to use lecture captures compared to students that used lecture captures.

Part B: Intervention Type vs No Intervention: Is there a specific type of lecture capture that improves recall on historical challenging questions or are all lecture capture styles equivalent in assisting a student to recall information on the exam?

Null hypothesis: There is no difference between exam questions of students that used different lecture capture style.

Data analysis: A 3-Way ANOVA test with a control (choosing not to use captured lectures) was used to compare the following groups acoss exams:

Test 1: Control group (Students that do not select a lecture capture) vs. Students that use lecture captures

Test 2: Control group (Students that do not select a lecture capture) vs. Audio only lecture capture (audio)

Control group (Students that do not select a lecture capture) vs. PowerPoint with audio and segmentation lecture capture (video)

Control group (Students that do not select a lecture capture) vs. PowerPoint with audio, segmentation, and signaling lecture capture (interactive video)

Hypothesis 3: For each exam, students who used an available lecture capture will score higher on challenging concepts than students that chose not to utilize any lecture capture available.

Part A: Intervention vs. No Intervention: On each exam, members of the experimental group will perform significantly better in recognition of correct answers for higher level Blooms and historical challenging questions after viewing the lecture capture than will members of the control group.

Null hypothesis: There is no difference between exam questions of the students who chose not to use lecture captures compared to students that used lecture captures.

Part B: Intervention Type vs. No Intervention: On each exam, members that use video lecture captures will perform significantly better in recognition of correct answers for higher level Blooms and historical challenging questions after viewing the lecture capture than will members that used audio lecture captures.

Null hypothesis: There is no difference between scores of students that used different lecture capture style.

Data analysis: A 3-Way ANOVA test with a control (choosing not to use captured lectures) was used to compare the following groups for each exam:

Test 1: Control group (Students that do not select a lecture capture) vs. Students that use lecture captures

Test 2: Control group (Students that do not select a lecture capture) vs. Audio only lecture capture (audio)

Control group (Students that do not select a lecture capture) vs. PowerPoint with audio and segmentation lecture capture (video)

Control group (Students that do not select a lecture capture) vs. PowerPoint with audio, segmentation, and signaling lecture capture (interactive video)

Study Description

The population of interest was students enrolled in an online, nonmajors biology course at a university located in the Southern region of the United States. The following course implemented a first edition, online relevancy textbook along with the online resources associated with the textbook. In Spring 2019, the course was offered with three different styles of lecture captures with their complementary PowerPoint presentations and study guides found on the learning management site.

In the LMS, three different types of lecture captures were made available to students for each lecture relevancy unit: Option 1: Audio lecture capture; Option 2: Video Lecture Capture; and Option 3: Interactive Video Lecture Capture. For the audio component, the same audio recording was used for all three options for consistencies purposes. All three types of lecture captures were available to every student. Students were able to access the captured lectures by clicking links available on the course webpage. The audio recordings were linked to a YouTube account, and data on viewership was used to match access to the lecture capture and the survey completed. The lecture captures were linked to a Microsoft Office account. Data on viewership (students clicking on the file) was used to match access to the video lecture capture and the survey completed.

The lecture captures were opened at the beginning of the unit and made available for the students to either listen or view through the browser, YouTube, or through Microsoft OneDrive. Once the unit closed, the lecture captures were hidden from view to avoid students clicking on materials later in the semester. To avoid overlap in the type of lecture capture a student selected, students were told once they selected a type of lecture capture, they were not able to select a different type for the duration of that unit content. If they wanted to use a different lecture capture in the next unit, they were able to so. They were not constrained to a single type of lecture capture during the semester.

Besides availability of the different type of lecture captures, the course design and all assignments associated with the course were the same as the previous face-to-face and online nonmajors biology sections.

Participants

In the course, 80 students participated in the study during the Spring 2019 semester. The students within this classroom were not randomly selected. Instead, they fell into one of the two sections based on their preference (online vs. face-to-face) and when they selected to enroll in the course during the 2018-2019 school year.

59 students (73.8%) were female, and 21 students (26.3%) were males (Table 1). 55 students (68.8%) identified as white, 21 students (26.3%) identified as black, 2 students identified as Hispanic (2.5%), and 2 students identified as Asian (2.5%). Most of the students fell within the age 18-21 (53.8%), with the second largest group of students were within the 22-25 age group (26.3%) (Table 1).

Table 1. Demographic (gender and age group) Data for the Spring 2019 nonmajors course

		18-21	22-25	26-29	30-33	24-37	38-41	42-45	46-49	50-53	Total
Gender	Female	32	14	2	2	4	1	1	2	1	59
	Male	11	7	0	0	2	0	0	1	0	21
Total		43	21	2	2	6	1	1	3	1	80
Percent		53.8	26.3	2.5	2.5	7.5	1.3	1.3	3.8	1.3	100%

23 (28.7%) of the students were classified as freshmen, 20 (25%) were sophomores, 17 (21.3%) students were juniors, 16 (20%) students were seniors, and 4 (5%) students were graduate students (Table 2).

Table 2. Demographic (gender and level of education) Data for the Spring 2019 nonmajors course

		Freshman	Sophomore	Junior	Senior	Graduate	Total
Gender	Female	17	14	12	12	4	59
	Male	6	6	5	4	0	21
Total		23	20	17	16	4	80

Course Design

At the following university in 2019, the nonmajors biology course was offered as face-to-face course and as an online course. The course has been defined as a general education curriculum course (GEC). The course can be taken to meet one of the two GEC 02 Natural Science requirements. therefore, students enrolled in the course are required to complete this course. For this study, the section of interests was the online sections offered during the Spring 2019 term.

The nonmajors biology course was under re-designed in Spring 2019 with a theme-based approach by the instructor that teaches the online course. Prior to the redesign, the course followed a traditional nonmajors biology approach. During the Fall 2019 semester, the following five themes, Cancer, Energy and Diet, Influenza, Genetic Diseases, and Climate Change, were examined as current trends in biology. Across these topics, various biological concepts were addressed: atoms, organic molecules, cells, energy and cells, enzymes, DNA, genetics, cell division, evolution, and ecology. During the semester, each topic included assigned readings in an eBook and learning was expanded through various avenues (articles, surveys, and discussions). For the readings and additional materials, each topic was considered comparable in length and level of difficulty.

All students were required to access eBook and assignments through the textbook company, and any additional readings, surveys, and discussions through the learning management system, Canvas. For each unit covered, the unit would open and all assignments for the unit were made available for the students to complete over a three-weeks period. During the time the unit was opened, the students were expected to read the eBook, complete several assignments related to the unit (adaptive learning assignments and reading quizzes), a discussion, and an exam. In addition to these assignments, the students had available lecture captures they were able to watch, take notes, and reflect on the course content. Prior to the lecture captures being available, the students were given a description of the lecture captures via a video and transcript with instructions concerning how to pick the type of lecture capture that was the most appealing to their learning style. This was to ensure that students were able to access the course content and to become more familiar with the materials available to them.

Research Design

This study employed a quantitative research design. Specifically, a quasi-experimental research design to determine the usefulness of lecture captures to students' performance. This study used posttest instruments to compare students' scores on exams. It also utilized posttest instruments to compare with a within-group and between-groups comparison on students' responses to exam questions. The instructor, the materials used, and instruments to conduct the study were kept constant to ensure constancy of the research design. The assessments for the course were of similar lengths and level of difficulty since the same materials (question pools and questions author) were used to construct assessments.

Purposive sampling was used in this study. The participants were a nonrandom, convenience sample because they were purposefully selected based on their enrollment in an online nonmajors biology course available the Spring 2019 semester. Therefore, this study was unable to employ controls for gender, age, major, or ethnicity. To ensure confidential and prevent bias, student names were removed to examine the data and instead an assigned confidential number given to each student. This number was linked to their survey results and posttests. The participants that did not use an available lecture capture were considered the control group while the students that selected a lecture capture were considered the experimental group because the effects on the lecture capture materials on students were to be measured.

Three types of lecture captures were available to the Spring 2019 students: audio only format, video without segmentation (continuous streaming), and video with segmentation (interactive video) lecture capture. The lecture captures were made available to students at the opening of a Unit. Students were able to select only one of three type of lecture captures when made available to them and complete a survey as proof of using the type of resource available to them. The survey was made available on Canvas. Students that did not utilize a lecture capture were able to complete a similar survey on using the textbook as the only resource. Once the students completed the survey, they were able to access the exam.

Independent variable: Lecture capture delivery style. The three lecture capture styles used in this study were: audio only, PowerPoint and audio (video), and PowerPoint, audio, and segmentation (interactive video). In the audio only lecture capture, no PowerPoint slides were used. The lecturer presented the materials verbally and read a transcript describing and explaining the content covered in the Unit. The audio file was uploaded to YouTube, and students were able to play the following audio file for continuous streaming. In the PowerPoint and audio lecture capture (streaming video), the audio was used to match PowerPoint slides that included text and tables, diagrams, and/or images from the eBook. The following audio file was trimmed into smaller chunks and added to specific PowerPoint slides that matched the audio description. For each unit, there were three to four Modules. For each module within the unit, there was a single presentation. Each presentation was uploaded to Microsoft OneDrive. When students opened the file, the students were able to click on the slide and the audio would play per slide. The act of clicking was considered a form of interaction (Appendix A).

In the segmented PowerPoint and audio lecture capture, the text and graphics were segmented into smaller more, manageable pieces to match the same audio as the audio lecture capture and the PowerPoint and audio lecture capture. While the available text and the pictures remained the same, the text and graphics were separated into smaller pieces to provide further assistance to direct content to specific aspects of a graphic. For the segmented PowerPoint based lecture captures, the lectures were intended too also be interactive. Using Microsoft office, the audio file was inserted into the PowerPoint Slide and uploaded into Microsoft Office OneDrive. When the students opened the file, the students would have to click through each slide. When the slide opened, the audio that matched the slide content would play. After the audio was finished, the student was able to navigate to the next slide by the navigation bar at the bottom of the slide. As before, the act of clicking was considered a form of interaction. In addition to clicking, the act of segmenting the information into smaller and smaller content was a form of signaling to the student to pay attention to a specific component of the PowerPoint slide (Appendix B).

For all the lectures, the same instructor was used to write and present the materials for the audio component. The instructor was careful to make sure that the information presented was identical to minimize any potential variables that may affect scores. In the PowerPoint and audio lecture captures, the instructor was not visible. In both situations, this was to avoid any potential influence of the lecturer on student performance.

The lecture audio was recorded using an Apple MacBook Air computer and edited using Garage Band to create a continuous streaming file for the audio and video lecture captures. For the interactive video, Microsoft Word was used to insert specific parts of the audio to match specific slides (Appendix C).

*Dependent variable: Exam performance***.** For the dependent variable, information recalled on the exam assessment (scores) was measured. In study by Stephenson, Brown, and Griffin (2008), the researchers examined the effects of delivery mode on learning. While no significance affects were determined between delivery mode to overall exam scores, they did detect a significant difference pertaining to level of Bloom's taxonomy and delivery style. For this study, not only would overall exam scores be considered, but the question scores on topics covered on the exam and the question scores on the various Blooms taxonomy level were evaluated. Therefore, on each exam, the questions on the exam ranged in various Bloom's taxonomy with most of the questions from levels 1 (Remember) and 2 (Understand).

Instruments

Two instruments were used in this study. The first instrumentation used was a survey. A survey was opened at the beginning of the unit and remained open until the exam was posted. The students were asked to complete a 5 questions survey concerning whether the resource they made use of aided the student in their learning. For this specific study, the questions and answers on the survey were not used. The surveys were the first step to track students use and preference of the three available lecture captures.

The second instrument used were the five-test completed over the semester. The test assessed participant learning related to the type and amount of information retained with a given lecture capture style. The online tests were created using the McGraw Hill Connect test banks to measure student learning. Each assessment was composed of multiple choice, true or false, and matching style questions. Each exam was timed (1 minute per question). When students answer a question correctly, the correct answer was used a measurement of understanding for a given concept. If a question is answered incorrectly, the researcher concluded that this concept was not understood. All students enrolled were required to take each of the five exams during the semester. All students received a score out of 100 points after completion (Table 3).

Table 3. General description of each exam given during the Spring 2019 semester

	# of questions	**Bloom Taxonomy**	**Biological Concepts Addressed**	**# of students completed exam:**
Exam 1: Energy and Diet	48	Level 1 Remember: 8 Level 2 Understand: 29 Level 3 Apply: 3 Level 4 Analyze: 6 Level 5 Evaluate: 2	Atomic Structure, Macromolecules, Cell Structure, Metabolism, ATP, Enzymes, Membranes, Transport (Active and Passive), Cell Respiration, Digestive System	Spring 2019: 69 students
Exam 2: Cancer and the Cell Cycle	61	Level 1 Remember:15 Level 2 Understand: 37 Level 3 Apply: 6 Level 4 Analyze: 3	Cancer, Cell Cycle (Mitosis), DNA, Chromosome Structure, Enzymes, Homeostasis, Gene Expression (Transcription and Translation), Mutations	Spring 2019: 77 students
Exam 3: Genetics	55	Level 1 Remember: 14 Level 2 Understand: 28 Level 3 Apply: 4 Level 4 Analyze: 9	Genetics (Mendelian and Non-Mendelian), DNA Structure, DNA Replication, Chromosome Structure, Gene Expression (Transcription and Translation), Meiosis, Pedigrees, Sickle Cell Disease, Blood and Cardiovascular System	Spring 2019: 69 students

Table 3 continued.

Exam 4: Influenza (Evolution)	49	Level 1 Remember: 11 Level 2 Understand: 29 Level 3 Apply: 5 Level 4 Analyze: 3 Level 5 Evaluate: 1	Evolution, Evidence for Evolution, Natural Selection, Viruses, Viral Reproduction, Respiratory System, Immune System (Innate vs Adaptive)	Spring 2019: 62 students
Exam 5: Climate Change		Level 1 Remember: 10 Level 2 Understand: 29 Level 3 Apply: 11 Level 4 Analyze: 2	Climate Change, Energy and Chemical Cycling, Photosynthesis, Biomes and Ecosystems, Human Environmental Impacts (Community vs Ecosystem Ecology), Sustainability and Alternative Energy Sources	Spring 2019: 60 students

Data Collection

Treatments: For the following study, the subjects were able to select a treatment group for each exam (Appendix D).

Tracking Students Use of Lecture Captures: To track student use of lecture captures and to compare this information with exam scores, a survey in which students acknowledge they used a specific type of lecture capture was given for each unit. Students were able to select one of three lecture captures best suited to their learning (Appendix E). Once they accessed the lecture capture they preferred, the student was unable to select any other lecture capture available to them. After they either listened to or viewed the lecture capture, they provided feedback on the instructional materials. When reviewing the data, the instructor first collected the surveys than followed up by reviewing the viewing history of the audio and video files to ensure that the students survey matched the view history of the lecture capture selected (Appendix E).

Quantitative Data Analysis

A descriptive analysis was performed on data collected provided by SOAR. The level of learning achieved by each student was determined by data collected from exams. A two-way Analysis of Variance (ANOVA) was utilized to determine if a significant difference exist in student learning depending upon whether a student used a lecture capture, and if they did use a lecture capture, if the style of lecture capture the student selected on their exam affected their exam scores.

All statistical analyses were conducted using SPSS. Significance was be determined using an alpha of 0.05.

Summary

The purpose of this study was to evaluate the impact of lecture captures had on undergraduates in an online nonmajors introductory biology course ability to recall or recognize material on exams. By examining different lecture capture styles, this studying is attempting to determine whether there are differences in retention based on the style of lecture capture and if a particular style is an effective means to maximize students' retention of course materials. In doing so, the hope is that the following tools (lecture captures) can be created or improved to aid diverse learner, and ultimately, result in improved student retention rates in the online nonmajors biology course.

CHAPTER IV – ANALYSIS OF DATA

The purpose of this study was to determine the effects of lecture capture use and design on exam scores. More specifically, the study wanted to determine if there was a relationship between lecture capture design and scores on the various Blooms level (difficulty of the exam) questions and/or a relationship between lecture capture design and scores on various biological concepts. Data were collected from students in one online nonmajors biology class. The results of this study were used to determine whether a difference in exam scores and exam question scores existed based on the lecture capture use and lecture capture style: audio, video, and interactive video. The students that did not use an intervention (only reviewed the eBook) were treated as the control group, while the students that used an intervention were treated as the experimental group.

Findings

Data for this study was collected from students answers on five pre-exam surveys and five-unit exam scores. The pre-exam surveys were used to categories students into a respective group in the course: students that did not use a lecture capture, students that used audio, students that used video, and students that used interactive video. The unit exam scores were used to determine student knowledge on material covered in each of the specific units.

Data were quantitatively collected using SPSS (Version 28.0) to gather descriptives for participants in each of the instruments listed above. Additional descriptive data for the following participants were collected but not present in these findings below. Not all participants participated in every instrument (pre-exam surveys and exams). Table 4 and Table 5 show the overall participation for this study and the mean scores on the assessments.

Table 4. Total Participation for Unit Exams (Intervention Vs No Intervention)

Exam #	Intervention	Mean	Std. Deviation	N
1	**No intervention**	60.67	20.95	24
	Intervention	74.39	11.44	45
Total		69.62	16.32	69
2	**No intervention**	60.43	17.97	34
	Intervention	65.76	11.34	43
Total		63.41	14.77	77
3	**No intervention**	72.66	16.94	34
	Intervention	71.26	15.70	35
Total		71.95	16.22	69
4	**No intervention**	69.27	16.64	38
	Intervention	79.31	7.17	24
Total		73.16	14.55	62
5	**No intervention**	80.27	13.54	31
	Intervention	81.1	9.10	29
Total		80.67	11.52	60
Average Exams	**No intervention**	68.96	18.46	161
	Intervention	73.44	12.72	176
Total		71.30	15.86	337

Table 5. Total Participation for Unit Exams (Intervention Type Vs No Intervention)

Exam Number	**Intervention**	**Mean**	**Std. Deviation**	**N**
1	**No intervention**	60.67	20.95	24
	Audio	72.41	10.88	12
	Video	77.97	11.24	26
	Interactive Video	75.60	1.87	7
Total		69.62	16.32	69
2	**No intervention**	60.43	17.97	34
	Audio	63.94	13.95	16
	Video	67.76	9.08	15
	Interactive Video	65.70	10.5	12
Total		63.41	14.77	77
3	**No intervention**	72.66	16.94	34
	Audio	65.51	15.56	22
	Video	80.57	12.27	6
	Interactive Video	78.24	14.06	7
Total		71.95	16.22	69
4	**No intervention**	69.27	16.64	38
	Audio	79.02	5.75	10
	Video	80.31	5.13	5
	Interactive Video	78.35	9.96	9
Total		73.16	14.55	62
5	**No intervention**	80.28	13.54	31
	Audio	73.04	11.31	6
	Video	83.13	7.19	13
	Interactive Video	83.30	7.94	10
Total		80.67	11.52	60
Total Exams	**No intervention**	68.96	18.46	161
	Audio	69.36	13/34	56
	Video	77.13	10.55	75
	Interactive Video	75.63	12.43	45
Total		71.30	15.86	337

Hypothesis 1: Part 1: Intervention Vs No Intervention Across Exams

Research hypothesis one stated that over the semester, students who accessed and used an available lecture capture will score higher on exam scores than students that choose not to utilize any lecture capture available. A two-way ANOVA was conducted to examine the effects of the use of an intervention and exam number on exam scores during the semester. When comparing exam scores and intervention use, there was a statistically significant interaction between unit exams and intervention use on exam, $F(4,327)= 2.971$, $p=.020$, partial $\eta 2=.035$ (Table 6).

Table 6. Intervention Use: 2-Way ANOVA Summary for Mean Exam Scores Across All Exams.

	Type III Sum of Squares	**Degrees of freedom**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Intervention vs No Intervention	2630.838	1	2630.838	12.463	<.001	.037
Exam Number	11825.439	4	2956.360	14.005	<.001	.146
Intervention vs No Intervention *Exam Number	2508.570	4	627.142	2.971	.020	.035
Error	69027.959	327	211.095			

Mean Comparison Across Exams

A univariate analysis of main effects showed a statistically significant difference in mean exam score for students across each exam ($F(4,327)=14.005$, $p<.001$, partial $\eta 2=.146$). The unweighted marginal means of exam scores across all exams for all students were Exam 1 mean=67.532 ± 1.836, Exam 2 mean= 63.095± 1.667, Exam 3 mean=71.961 ± 1.749, Exam 4 mean=74.294 ± 1.894, and Exam 5 mean=80.688 ± 1.877 (Figure1).

Comparing Means: Intervention vs No Intervention Across Exams

When examining intervention use on each exam, a univariate analysis of main effects showed a statistically significant difference in mean exam score for students that did not use an intervention ($F(4,327)=10.141$, $p<.001$, partial $\eta 2=.110$) compared to students that used an intervention, ($F(4,327)= 6.243$, $p<.001$, partial $\eta 2=.071$), within each exam. The unweighted marginal means of exam scores across all exams for students that used an intervention was (74.366 ± 1.126, n=176) compared to students that did not use an intervention (68.662 ± 1.159, n=161). When conducting a pairwise comparison between intervention use across exams, students that used an intervention (mean difference= 5.705 ± 1.616, CI 95% [2.526 to 8.884], $p<.001$) scored significantly higher than students that did not use an intervention (Figure2).

Comparing Means: Intervention vs No Intervention Within Exams

Mean exams scores for no intervention were 60.67 ± 2.966 for exam 1, 60.429 ± 2.492 exam 2, 72.66 ± 2.492 for exam 3, 69.28 ± 2.36 for exam 4, and 80.28 ± 2.61 exam 5. Respectfully, mean exams scores for an intervention used were 74.39 ± 2.166 for exam 1, 65.761 ± 2.216 for exam 2, 71.265 ± 2.50 for exam 3, 79.313 ± 2.96 for exam 4, and 81.10 ± 2.70 for exam 5. For exam 1, students that did not use an intervention scored statistically significant lower mean exam scores than students that used an intervention, (13.72 points lower ($F(1,327)=13.964$, CI 95% [6.499 to 20.948], $p<.001$, partial η2=.041). For exam 4, students that did not use an intervention score statistically significant lower mean exam scores than students that used an intervention, (10.04 points lower, (F(1,327)=7.020, (CI 95% [2.585 to 17.490], p= .008, partial η2=.021). For exam 2 (mean difference= 5.333, CI 95%[1.227 to 11.892]) and 5 (mean difference= .823, CI 95%[6.561 to 8.207)], students that did not use an intervention scored lower than students that used an intervention, but it was not deemed significant. For exam 3, students that used an intervention scored slightly higher than students that used an intervention (mean difference= 1.392, CI 95%[5..491 to 8.274) (Figure3).

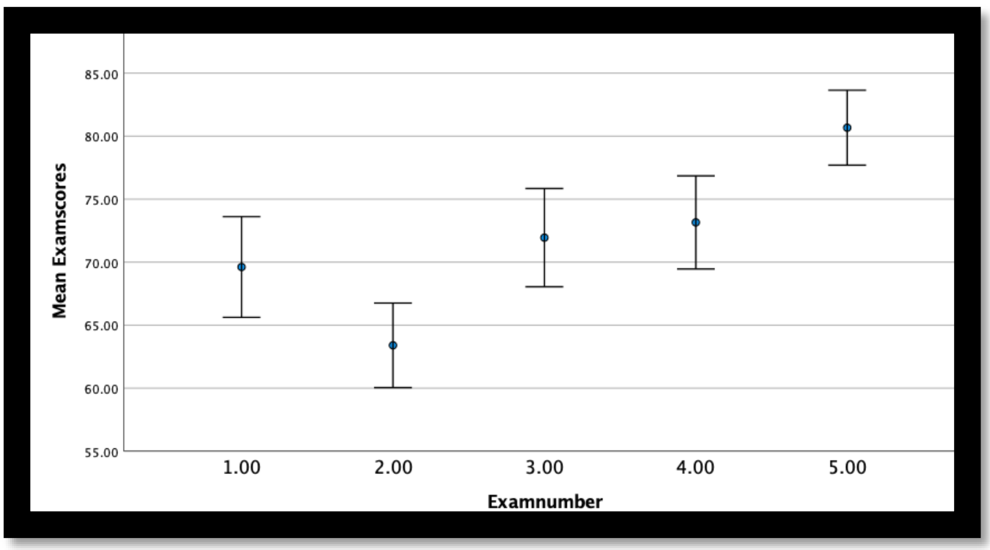


Figure 1. The mean exam scores across the five exams.

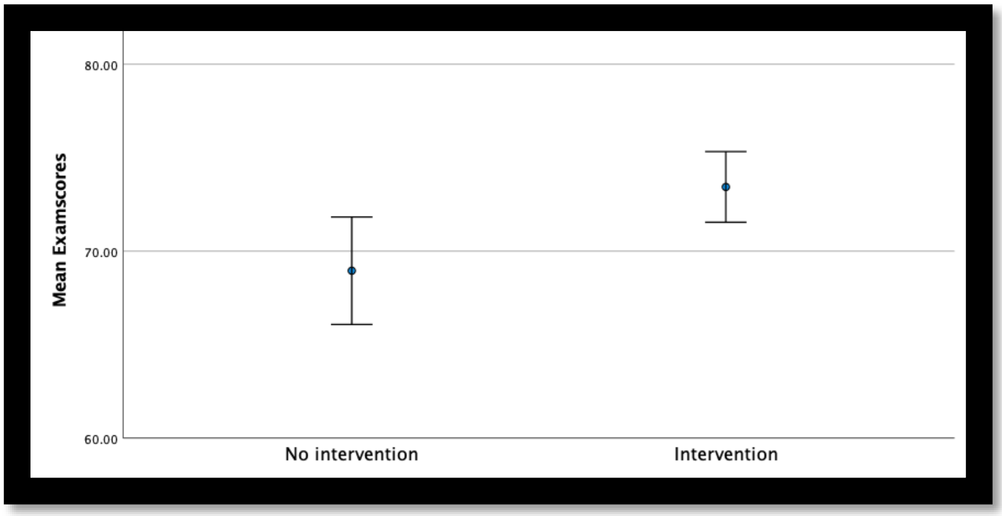


Figure 2. *Comparison of mean exam scores between students that used an intervention and students that did not use an intervention.*

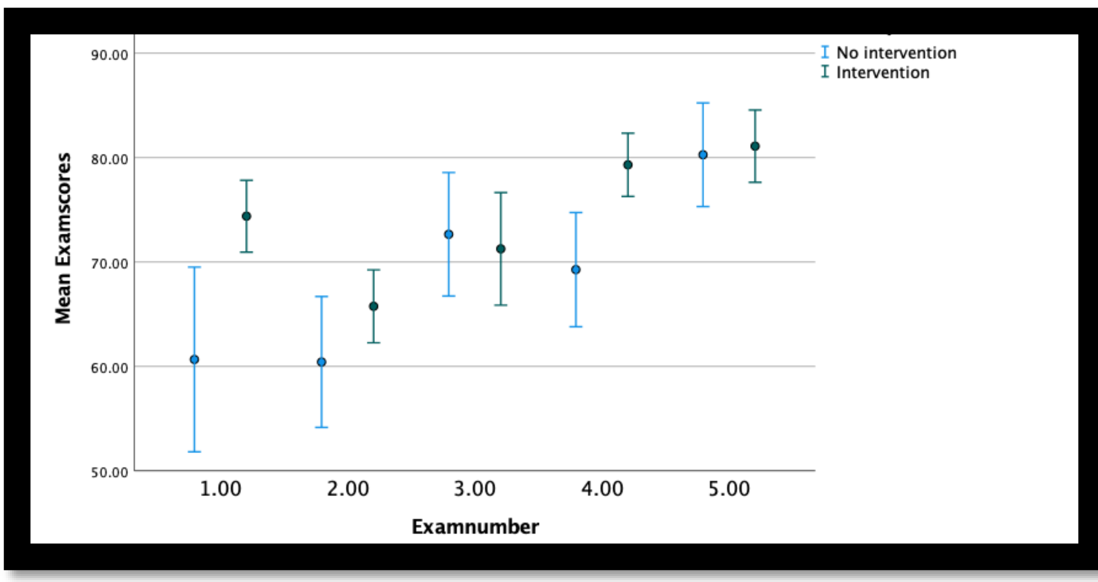


Figure 3. *Comparison of mean exam scores across all five exams between students that used an intervention and students that did not use an intervention.*

Hypothesis 1: Part 2: Audio, Video, and Interactive Video Use Across Exams

A two-way ANOVA was conducted to examine the effects of the intervention type and exam number on exam scores during the semester. When comparing exam scores and intervention type, there was no statistically significant interaction between exam number and intervention type on exam scores, $F(12, 317)= 1.298$, $p=.218$, partial $\eta 2=.047$ (Table 7).

Table 7. Intervention Type: 2-Way ANOVA Summary for Mean Exam Scores Across All Exams.

	Type III Sum of Squares	**Degrees of freedom**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Audio, Video, Interactive Video vs No Intervention	4342.387	3	1447.462	6.871	<.001	.061
Exam Number	7493.085	4	1873.271	8.892	<.001	.101
Audio, Video, Interactive Video*Exam Number	3282.036	4	273.503	1.298	.218	.047
Error	66779.393	317	210.661			

Mean Comparison Across Exams

A univariate analysis of main effects showed a statistically significant difference in mean exam score for students across each exam ($F(4,317)=8.892$, $p<.001$, partial $\eta 2=.101$). The unweighted marginal means of exam scores across all exams for all students were

Exam 1 mean=71.665 ± 2.008, Exam 2 mean= 64.455± 1.785, Exam 3 mean=74.494 ± 2.250, Exam 4 mean=76.744 ± 2.400, and Exam 5 mean=79.935 ± 2.225.

Pairwise Comparison of Intervention Type Across Exams

The unweighted marginal means of exam scores across all exams were audio (70.984 ± 2.08), video (77.951 ± 2.039), and interactive video (76.238 ± 2.211) compared to students that did not use an intervention (68.662 ± 1.159). When examining intervention type between exam, there was a statistically significant difference in mean exam score for the intervention type compared to students that used an intervention, ($F(3,317)$= 6.871, $p<.001$, partial $\eta2$=.061), across all exams (Figure4).

When conducting a pairwise comparison between intervention type across exams, students that used video (mean difference= 9.289, CI 95%[4.675 to 13.903] $p<.001$) and interactive videos (mean difference= 7.576, CI 95%[2.666 to 12.487] $p=.003$) scored significantly higher than students that did not use an intervention. While not significant, students that used audio (mean difference= 2.323, CI 95% [2.360 to 7.005] $p=.330$) scored slightly higher than students that did not use an intervention. A pairwise comparison also indicated that students that used video (mean difference= 6.966, CI 95% [1.236 to 12.697] $p=.017$) scored significantly higher than students that used audio. While not significant, students that used interactive videos (mean difference= 5.254, CI 95% [.718 to 11.225], $p=.102$) scored higher than students that used audio.

Pairwise Comparisons of Intervention Type within an Exam

An analysis of main effects for the use of interventions within an exam found statistical significance receiving a Bonferroni adjustment and being accepted at the $p<.05$ level. There was a statistically significant difference in mean exam score for students on exam 1 ($F(3,317)=5.086$, $p=.002$, partial $\eta 2= .046$) and exam 4 ($F(3,317)= 2.374$, $p=.05$, partial $\eta 2=.024$) when comparing interventions use within the exam. Mean exam scores were approaching significance for exam 3 ($F(3,317)= 2.202$, $p= .088$, partial $\eta 2= .020$).

Exam 1 pairwise comparison indicated that students that used audio (mean= 72.41±13.87), video (mean= 77.98, ± 11.24), and interactive videos (mean= 75.60 ± 13.87) had a significantly higher average exam score than students that used no intervention (mean= 60.67 ± 20.95).

Exam 2 pairwise comparison did not indicate any significance in intervention type and exam scores. Even so, the comparison indicated that students that used video (mean= 67.75 ± 9.08), segmented video (mean= 65.70 ± 10.50), and audio (mean= 63.94 ± 13.95) had higher average exam score than students that used no intervention (mean= 60.42 ± 17.96).

Exam 3 pairwise comparison indicated that students that used video (mean= 80.57 ± 12.27) and segmented video (mean= 78.24 ± 14.05) had significantly higher average exam score than students that selected audio (mean= 66.51 ± 15.55).

Exam 4 pairwise comparison indicated that students that used video (mean= 80.31 ± 5.13), interactive video (mean= 78.35 ± 9.95), and audio (mean= 79.026 ±6.491) had significantly higher average exam score than students that used no intervention (mean= 69.27 ± 16.64).

Exam 5 pairwise comparison indicated that there was no determined significant occurred between students that used videos, interactive video, and audio compared to students that did not use an intervention. Even so, the comparison indicated that students that used video (mean= 83.13 ± 7.19) and segmented video (mean= 83.30 ± 7.94) had higher average exam score than students that used no intervention (mean= 80.28 ± 13.54). Students that used audio (mean= 73.03 ± 11.31) had lower scores than students that used video, segmented video, and no intervention (Figure 5).

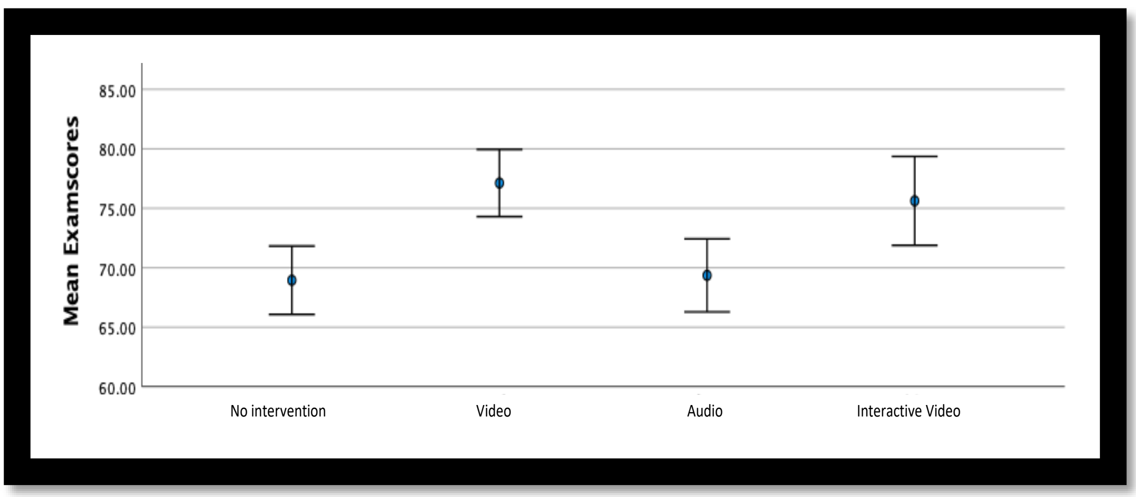


Figure 4. Comparison of mean exam scores between intervention types.

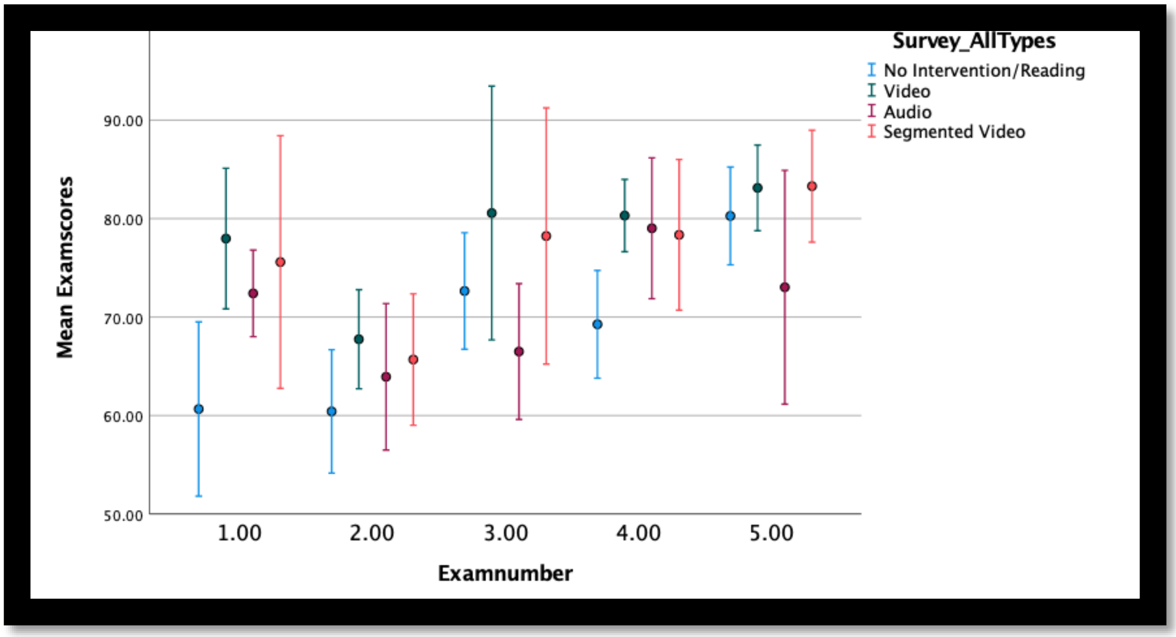


Figure 5. Comparison of mean exam scores between intervention types across the five exams.

Hypothesis 2: Part 1A: Across Exams, The Effect of Intervention Vs No Intervention, Level of Difficulty, and Exam Number On Exam Question Scores

A Three-Way ANOVA was conducted to compare the effects of intervention use, level of difficulty, and exam number on question scores (Table 8). There was no significant three-way interaction, $F(12, 17248) = 1.184$, $p = .287$, partial $\eta 2 = .001$. There was a statistically simple two-way interaction between the four levels of difficulty and the exam number and a two-way interaction between intervention use and exam number (Table 8). There were also statistically significant simple main effect of intervention use, level of difficulty, and exam number (Table 8).

Table 8. 3-Way ANOVA Summary for Mean Questions Scores, Blooms Level, and Intervention Use Across All Exams.

	Type III Sum of Squares	Degrees of freedom	Mean Square	F	Sig.	Partial Eta Squared
Intervention vs No Intervention	8.054	1	8.054	46.757	<.001	.003
Level of Difficulty (Blooms)	22.419	3	7.473	43.386	<.001	.007
Exam Number	22.773	4	6.943	40.310	<.001	.009
Intervention vs No Intervention *Blooms	.160	3	.053	.311	.818	.000
Intervention vs No Intervention *Exam Number	8.180	4	2.045	11.873	<.001	.003
Intervention*Blooms	26.073	12	2.173	12.614	<.001	.009
Intervention vs No Intervention *Blooms*Exam Number	2.448	12	.204	1.184	.287	.001
Error	2970.901	17248				

Mean Question Scores and Use of Intervention Across Exams

An univariate-test performed for question scores and intervention use indicated that the effect was statistically significant for students that used an intervention compared to students that did not use an intervention for Exam 1 (univariate test), $F(1, 17248)= 46.757$, $p<.001$, partial $\eta 2 = .003$. The modified population marginal means of question scores across all questions for students that used an intervention (.770± .006) compared to students that did not use an intervention (.708 ± .007).

When conducting a pairwise comparison between intervention and no intervention use on questions on Exam 1, students that used an intervention (mean difference= .062 ± .009, CI 95% [.045 to .080], $p<.001$) scored significantly higher on all questions than students that did not use an intervention (Figure 6).

Mean Question Scores and Level of difficulty (Blooms Taxonomy)

An univariate-test performed for Blooms Level found a statistically significant interaction between student scores and level of difficulty, $F(3, 17248)= 43.386$, $p<.001$, partial $\eta2= .007$. Across all exams, the modified population marginal means of question scores across all level 1 questions (.781 ± .007), level 2 questions (.690 ± .004), level 3, (.739 ± .011), and level 4/5 questions (.745 ± .012) (Figure 7).

Mean Question Scores and Exam Number

An univariate-test performed for Exam number found a statistically significant interaction between student scores and exam number, $F(4, 17248)= 40.310$, $p<.001$, partial $\eta2=.009$. The modified population marginal means of question scores across the following five exams are exam 1 mean question scores (.695 ± .011), exam 2 mean question scores (.658 ± .009), exam 3 mean question scores (.738 ± .009), exam 4 mean question scores (.778 ± .010) and exam 5 mean question scores (.825 ± .012) (Figure 8).

Intervention No Intervention vs Exam Number

An univariate-test performed for Exam Number*Intervention found a statistically significant interaction between level of difficulty and intervention use: no intervention ($F(3, 17248)= 17.899$, $p<.001$, partial $\eta2=.003$) and intervention ($F(3, 17248)= 26.075$, $p<.001$, partial $\eta2=.005$) when compared across the exams. In addition, there were a significant interaction between level of difficulty and intervention use within exams: Exam 1(F(1, 17248)= 47.505, p<.001, partial η2=.003), Exam 2(F(1, 17248)= 8.292, p=.004, partial η2=.000), and Exam 4(F(1, 17248)= 28.456, p<.001, partial η2=.002 (Figure 9). The modified population marginal means of question scores across the following five exams are found in the following Table (9).

Table 9. Comparison of mean exam scores in relation to intervention use and exam number.

	No Intervention		**Intervention**	
Exam Number	Mean	Std. Error	Mean	Std. Error
Exam 1	.619	.018	.772	.013
Exam 2	.631	.014	.684	.012
Exam 3	.746	.012	.730	.012
Exam 4	.723	.013	.833	.016
Exam 5	.819	.016	.831	.017

*Blooms Level*Exam Number*

An univariate-test performed for Blooms Level*Exam found a statistically significant interaction between level of difficulty within exams: Level 1 (F(4, 17248)= 14.902, p<.001, partial η2=.003), Level 2 (F(4, 17248)= 66.938, p<.001, partial η2=.015), Level 3 (F(4, 17248)= 38.626, p<.001, partial η2=.009), and Level 4 (F(4, 17248)= 10.363, p<.001, partial η2=.002), (Figure 9). In addition, there were a significant interaction between level of difficulty and intervention across exams: Exam 1(F(1, 17248)= 47.505, p<.001, partial η2=.003), Exam 2(F(1, 17248)= 8.292, p=.004, partial η2=.000), and Exam 4(F(1, 17248)= 28.456, p<.001, partial η2=.002 (Figure 2).

*Pairwise Comparison between Exams (Intervention Use*Blooms)*

Next, an analysis of the main effect for Blooms level was performed, which indicated that the effect was statistically significant for Level 1 Blooms questions and the use of an intervention $F(1,17342)= 11.543$, $p<.001$, partial $\eta 2 = .001$, and Level 2 Blooms questions and the use of an intervention $F(1,17342)= 26.545$, $p<.001$, partial $\eta 2 = .002$. For Level 4 Blooms questions, the scores were approaching significance ($F(1,17342)= 3.181$, $p=.075$, partial $\eta 2 = .000$.

All pairwise comparisons were run reported 95% confidence intervals and p-values are Bonferroni-adjusted. The unweighted marginal means of questions scores for students that used an interventions compared to students that did not use an intervention on the varying levels of Blooms taxonomy were: Level 1/no intervention .756 ±.010, Level 1/ intervention .803 ±.010, Level 2/no intervention .658 ±.006, Level 2/intervention .701 ±.006, Level 3/no intervention .710 ±.014, Level 3 intervention .734 ±.014, Level 4/no intervention .700 ±.016, Level 4/intervention .738 ±.015, respectively.

A student that used an intervention scored .047 (CI 95% [.020 to .074]) points higher than students that did not use an intervention on Blooms Level 1 questions, a statistically significant difference, $p<.001$. A student that used an intervention scored .043 (CI 95%[.027 to .060]) points higher than students that did not use an intervention on Blooms Level 2 questions, a statistically significant difference, $p<.001$. While not deemed significant, students scored slightly higher on level 3 (.024 points) and 4/5 Blooms (.038 points) question than students that did not use an intervention (Figure10).

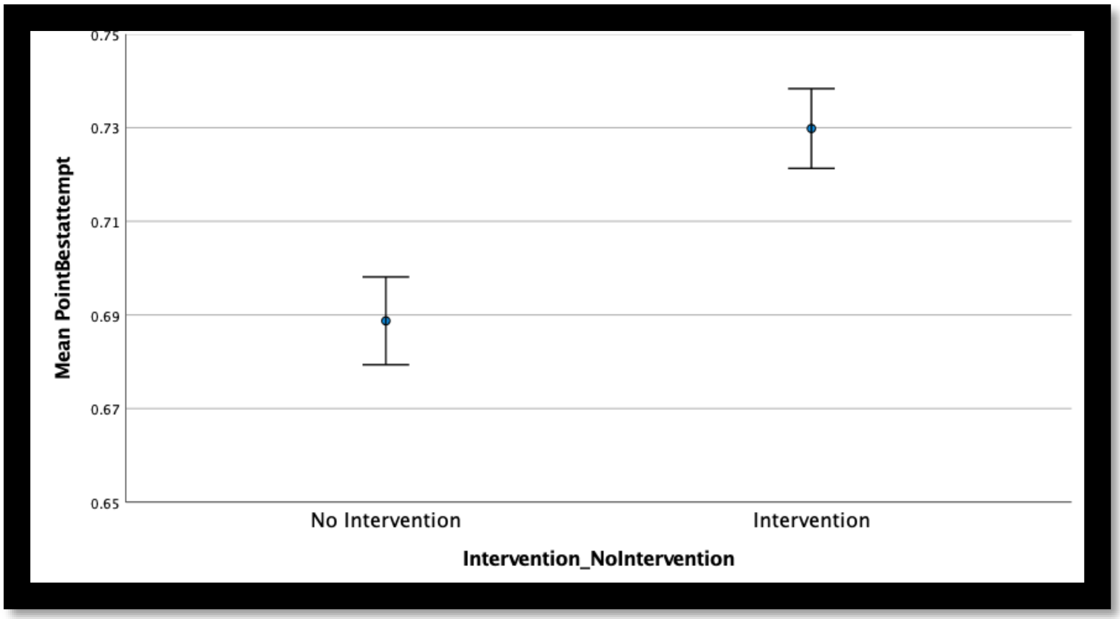


Figure 6. Comparison of mean questions scores between students that used an intervention and students that did not use an intervention.

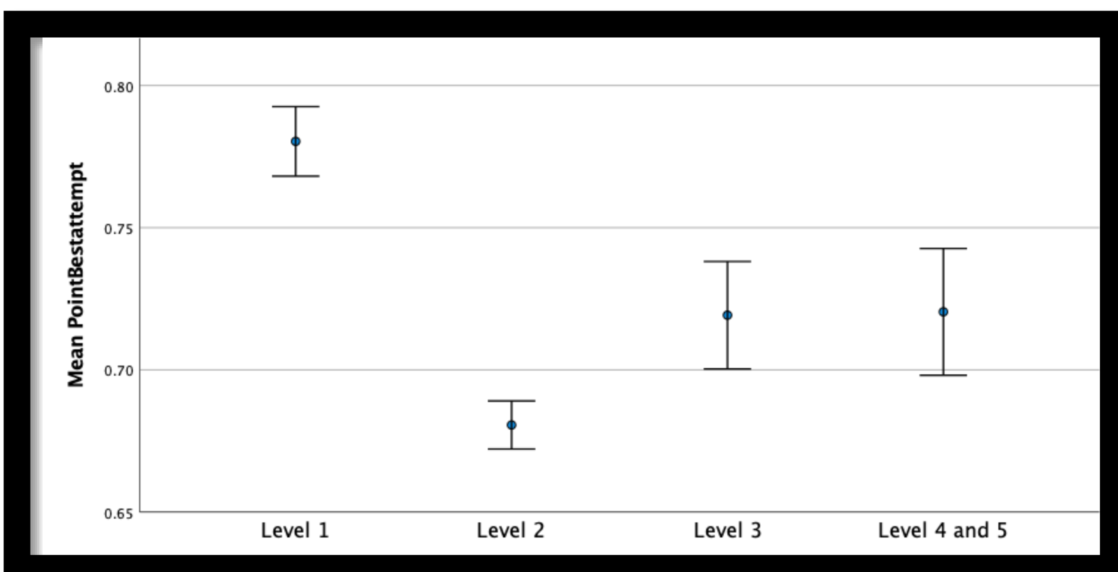


Figure 7. The mean question scores across the four Blooms Levels.

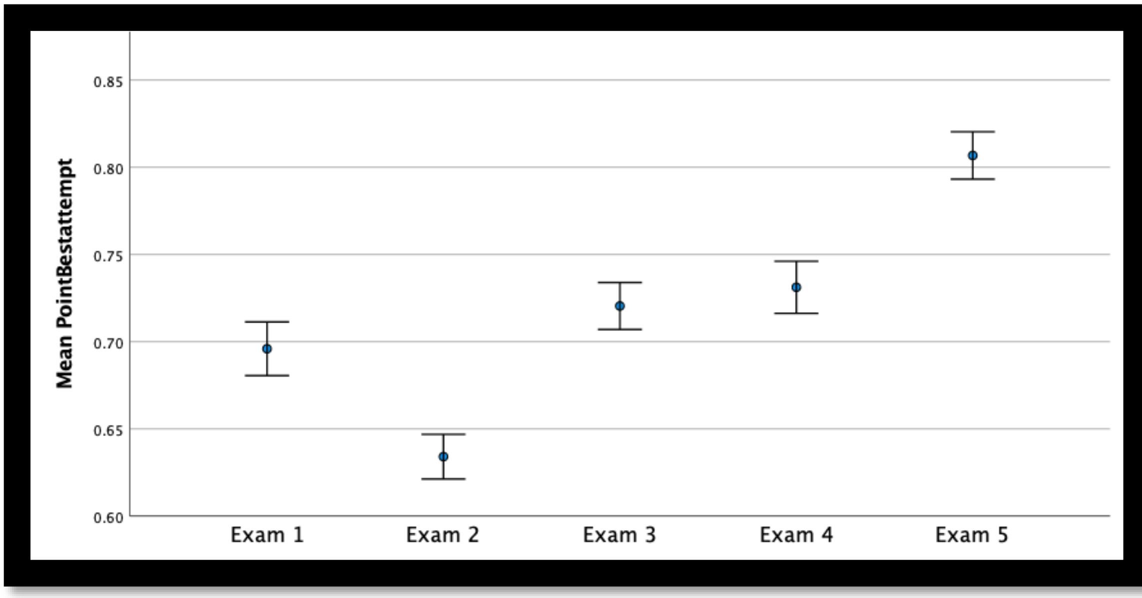


Figure 8. The mean question scores across the five exams.

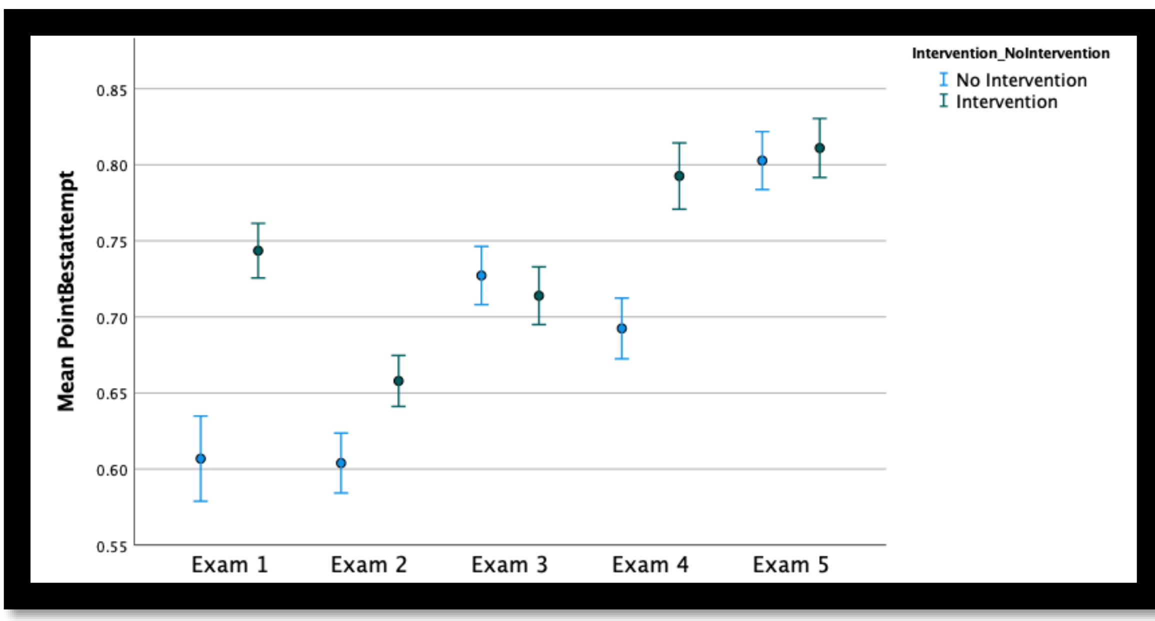


Figure 9. The mean question scores across the five exams depending on whether the student used an intervention or not.

Figure 10 a.

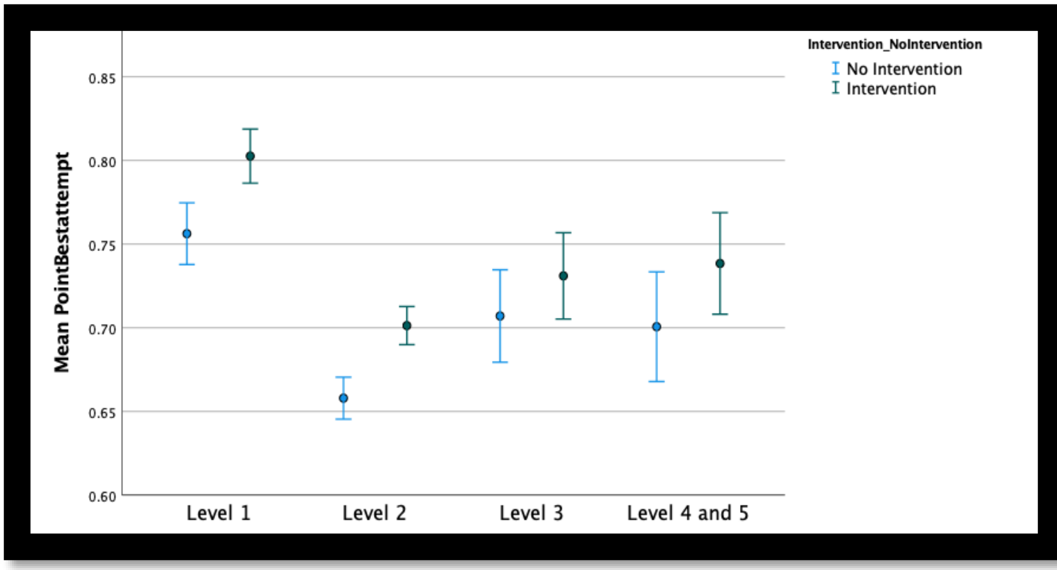


Figure 10 b.

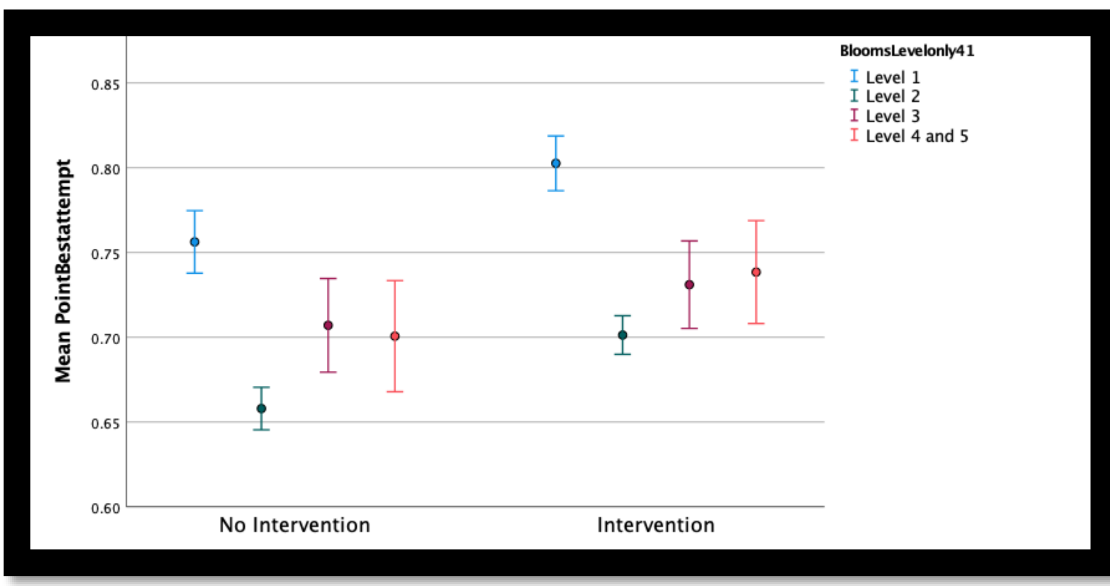


Figure 10 a and b. The mean question scores across the 4 Blooms Level depending on whether the student used an intervention or not.

Hypothesis 2: Part 1B: Across All Exams, The Effect of the Intervention Type, Level of Difficulty, and Exam Number On Exam Question Scores

A Three-Way ANOVA was conducted to compare the effects of intervention type, level of difficulty, and exam number on question scores (Table 10). There was no significant three-way interaction, $F(36, 17208) = .869$, $p = .692$, partial $\eta 2=.002$. There was a statistically simple two-way interaction between the four levels of difficulty and the exam number and a two-way interaction between intervention type and exam number (Table 10). There were also statistically significant simple main effect of intervention type, level of difficulty, and exam number (Table10).

Table 10. 3-Way ANOVA Summary for Mean Questions Scores, Blooms Level, and Intervention Type Across All Exams.

	Type III Sum of Squares	**Degrees of freedom**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Audio*Video*Interactive Video*No Intervention	13.950	3	4.650	27.072	<.001	.005
Level of Difficulty (Blooms)	16.622	3	5.541	32.259	<.001	.006
Exam Number	17.935	4	4.484	26.105	<.001	.006
Intervention Type*Blooms	.742	9	.082	.480	.889	.000
Intervention Type*Exam Number	10.202	12	.850	4.950	<.001	.003
Blooms*Exam Number	22.443	12	1.870	10.889	<.001	.008
Intervention Type *Blooms*Exam Number	5.374	36	.149	.869	.692	.002
Error	2955.625	17208				

Pairwise Comparison Use of Intervention Across Exams and Question Scores (Intervention Type)

An univariate-test performed for question scores and intervention type indicated that the effect was statistically significant for students that used an intervention compared to students that did not use an intervention (univariate test), $F(3, 17208) = 27.072$, $p<.001$, partial $\eta 2 = .005$. The modified population marginal means of question scores across all questions for students that used intervention video (.814 ± .011), intervention audio (.731 ± .012), and intervention interactive video (.784 ± .012) compared to students that did not use an intervention (.708 ± .007).

When conducting a pairwise comparison between intervention type and no intervention on across exams, students that used an intervention video scored significantly higher on all questions than students that did not use an intervention (mean difference= .107 ± .013, CI 95% [.081 to .131], $p<.001$) and intervention audio (mean difference= .084 ± .016, CI 95% [.052 to .116], $p<.001$). Students that used an intervention interactive video scored significantly higher on all questions than students that did not use an intervention (mean difference= .076 ± .014, CI 95% [.049 to .104], $p<.001$) and intervention audio (mean difference= .053 ± .017, CI 95% [.020 to .087], $p=.002$).

Exam Scores and Level of difficulty (Blooms Taxonomy)

A univariate-test performed for Blooms Level found a statistically significant interaction between student scores and level of difficulty, $F(3, 17208) = 32.259$, $p<.001$, partial $\eta 2 = .006$. Across all exams, the modified population marginal means of question scores across all level 1 questions ($.802 \pm .009$), level 2 questions ($.709 \pm .005$), level 3, ($.760 \pm .012$), and level 4/5 questions ($.765 \pm .014$).

Mean Question Scores and Exam Number (Exam Number)

A univariate-test performed for Exam number found a statistically significant interaction between student scores and exam number, $F(4, 17208) = 26.105$, $p < .001$, partial $\eta 2 = .006$. The modified population marginal means of question scores across the following five exams are exam 1 mean question scores ($.746 \pm .012$), exam 2 mean question scores ($.671 \pm .010$), exam 3 mean question scores ($.760 \pm .011$), exam 4 mean question scores ($.805 \pm .013$) and exam 5 mean question scores ($.813 \pm .014$).

Intervention No Intervention vs Exam Number

A univariate-test performed for Intervention Type* Exam Number found a statistically significant interaction between intervention type and exam number: no intervention ($F(4, 17208) = 28.716$, $p < .001$, partial $\eta 2 = .007$), intervention video ($F(4, 17208) = 9.136$, $p < .001$, partial $\eta 2 = .002$), intervention audio ($F(4, 17208) = 5.401$, $p < .001$, partial $\eta 2 = .001$), and intervention interactive video ($F(4, 17208) = 6.759$, $p < .001$, partial $\eta 2 = .002$) when compared across the exams Figure 1. In addition, there were a significant interaction between exam number and intervention type within exams: Exam 1($F(3, 17208) = 8.547$, $p < .001$, partial $\eta 2 = .001$), Exam 2($F(3, 17208) = 47.471$, $p < .001$, partial $\eta 2 = .008$), Exam 3 ($F(3, 17208) = 10.899$, $p < .001$, partial $\eta 2 = .002$), Exam 4 (F(2, 17208)= 11.129, $p<.001$, partial $\eta2=.002$) and Exam 5 ($F(3, 17208)= 7.115$, $p<.001$, partial $\eta2=.001$) (Figure 2).

*Blooms Level*Exam Number*

A univariate-test performed for Blooms Level*Exam found a statistically significant interaction between level of difficulty within exams: Level 1 ($F(4, 17208)= 6.973$, $p<.001$, partial $\eta2=.002$), Level 2 ($F(4, 17208)= 45.376$, $p<.001$, partial $\eta2=.010$), Level 3 ($F(4, 17208)= 37.259$, $p<.001$, partial $\eta2=.009$), and Level 4 ($F(4, 17208)= 4.706$, $p<.001$, partial $\eta2=.002$), Figure 1. In addition, there were a significant interaction between level of difficulty and intervention across exams: Exam 1($F(3, 17208)= 8.547$, $p<.001$, partial $\eta2=.001$), Exam 2($F(3, 17208)= 47.471$, $p<.001$, partial $\eta2=.008$), Exam 3 (3, 17208)=10.899 ($p<.001$, partial $\eta2=.001$), Exam 4($F(3, 17208)= 11.129$, $p<.001$, partial $\eta2=.002$), and Exam 5 ($F(3, 17208)= 7.115$, $p<.001$, partial $\eta2=.001$) (Figure 2).

Pairwise Comparison Use of Intervention and Blooms Level

A analysis of the main effect for Blooms level was performed, which indicated that the effect was statistically significant for Level 1, Level 2, and Level 4 Blooms questions and the type of intervention used. For Level 1, $F(3,17334)= 6.611$, $p<.001$, partial $\eta2 = .001$, Level 2 $F(3,17334)= 21.829$, $p<.001$, partial $\eta2 = .004$, and Level 4 $F(3,17334)= 7.300$, $p<.001$, partial $\eta2 = .001$. For Level 3, the questions scores were approaching significance ($F(3,17334)= 2.253$, $p=.080$, partial $\eta2 = .000$). All pairwise comparisons run was reported 95% confidence intervals and p-values are Bonferroni-adjusted. The unweighted marginal means of questions scores for students that used an intervention compared to students that did not use an intervention on the varying levels of Blooms taxonomy were Level 1/no intervention .756 ±.010, Level 1/intervention video .833 ±.017, Level 1/intervention audio .772 ±.014, Level 1/intervention interactive video .818 ±.019. Level 2/no intervention .658 ±.006, Level 2/intervention video .736 ±.010, Level 2/intervention audio .659 ±.009, Level 2/intervention interactive video .726 ±.011. Level 3/no intervention .710 ±.014, Level 3/intervention video .771 ±.023, Level 3/intervention audio .699 ±.022, Level 3/intervention interactive video .732 ±.025. Level 4/no intervention .700 ±.016, Level 4/intervention video .816 ±.028, Level 4/intervention audio .674 ±.021, Level 4/intervention interactive video .781 ±.031.

Level 1: Through a pairwise comparisons, a student that used intervention video scored .077 95% (CI, .025 to .129) points higher than students that did not use an intervention on Blooms Level 1 questions, a statistically significant difference, $p<.001$. A student that used the intervention interactive video scored .061 95% (CI, .006 to .117) points higher than students that did not use an intervention on Blooms Level 1 questions, a statistically significant difference, $p=.022$. A student that used the intervention video scored .061 95% (CI, .002 to .120) points higher than students that used the intervention audio on Blooms Level 1 questions, a statistically significant difference, $p=.039$.

Level 2: Through a pairwise comparisons, a student that used intervention video scored .078 95% (CI, .047 to .109) points higher than students that did not use an intervention on Blooms Level 2 questions, a statistically significant difference, $p<.001$. A student that used the intervention interactive video scored .068 95% (CI, .034 to .102) points higher than students that did not use an intervention on Blooms Level 2 questions, a statistically significant difference, $p<.001$. A student that used the intervention video scored .077 95%

(CI, .041 to .112) points higher than students that used the intervention audio on Blooms Level 2 questions, a statistically significant difference, p<.001. A student that used the intervention interactive video scored .067 95% (CI, .029 to .105) points higher than students that used the intervention audio on Blooms Level 2 questions, a statistically significant difference, p<.001.

Level 4/5: Through a pairwise comparisons, a student that used intervention video scored .116 95% (CI, .031 to .201) points higher than students that did not use an intervention on Blooms Level 4 questions, a statistically significant difference, p=.002. A student that used the intervention video scored .142 95% (CI, .049 to .236) points higher than students that used the intervention audio on Blooms Level 4 questions, a statistically significant difference, p<.001. A student that used the intervention interactive video scored .108 95% (CI, .009 to .206) points higher than students that used the intervention audio on Blooms Level 4 questions, a statistically significant difference, p=.023 (Figure 14).

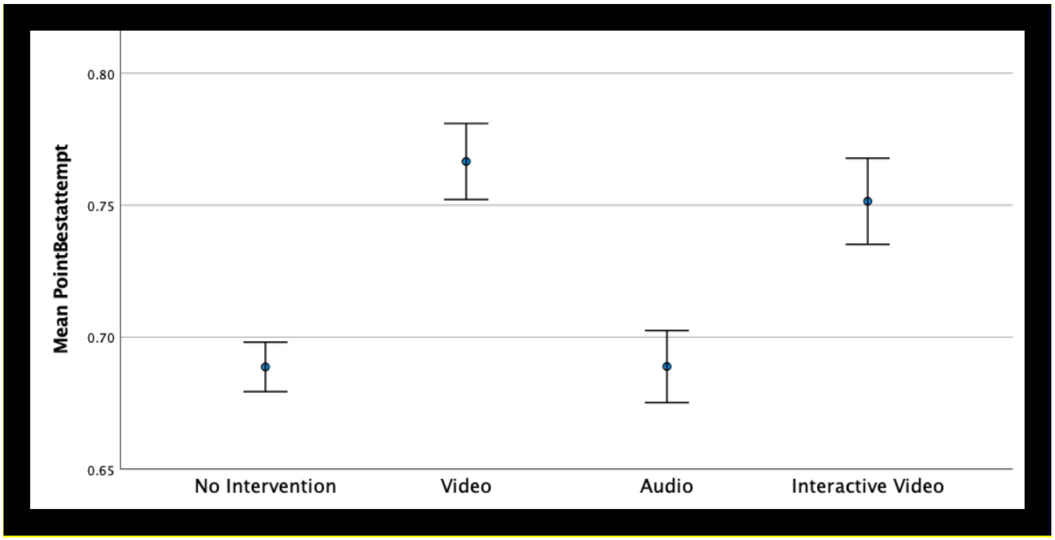


Figure 11. The mean question scores for the three different intervention types across exams.

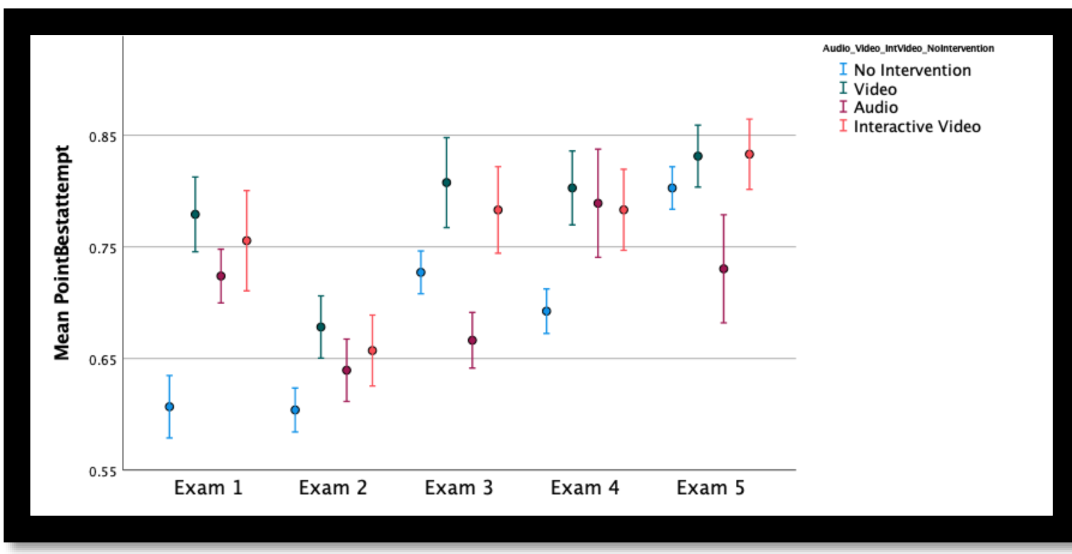


Figure 12. The mean question scores across the five exams depending on intervention type.

Figure 13 a.

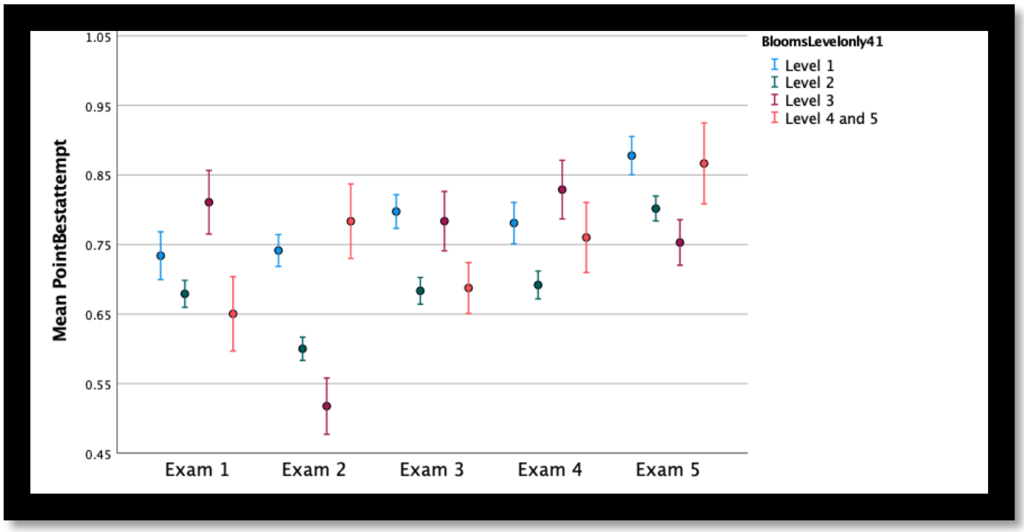


Figure 13 b.

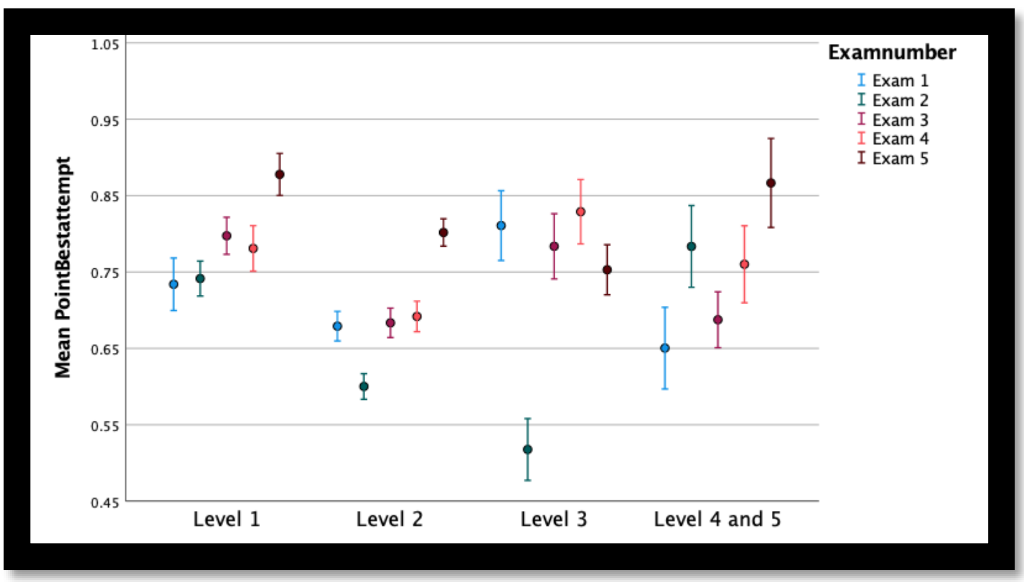


Figure 13 a and b. The mean question scores across the five exams depending on Blooms Level.

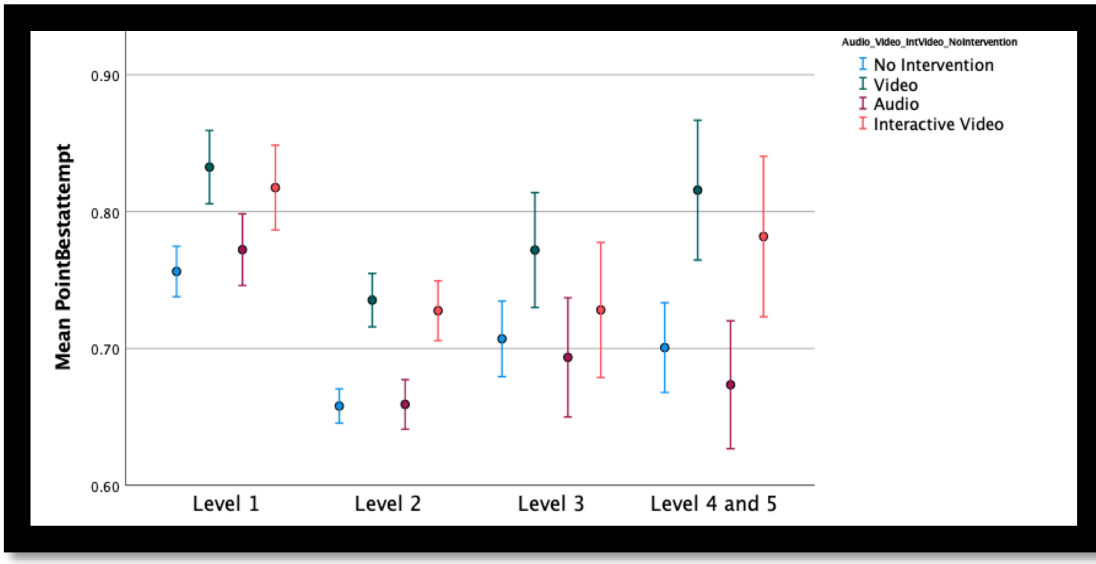


Figure 14. The mean question scores across the four Blooms Levels depending on intervention type.

Hypothesis 2: Part 2A: Across Exams, The Effect of Intervention Vs No Intervention on Exam Question Scores Concerning Different Categories of Biological Concepts

A two-way ANOVA was conducted to examine the effects of the use of an intervention and 25 categories of biological concepts on question scores across the five exams. When comparing questions scores, there was a statistically significant interaction between categories and intervention use on question scores, $F(24, 17238)= 3.568$, $p<.001$, partial $\eta 2=.005$ (Table 11).

Table 11. 2-Way ANOVA Summary for Mean Questions Across All Historically Challenging Concepts

	Type III Sum of Squares	**Degrees of freedom**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Intervention vs No Intervention	9.580	1	9.580	55.638	<.001	.003
Category	119.404	24	4.975	28.894	<.001	.039
Intervention vs No Intervention *Category	14.743	24	.614	3.568	<.001	.005
Error	2968.152	17238	.172			

Pairwise Comparison Use of Intervention Across Exams and Question Scores

An analysis of the main effect for question scores and intervention use indicated that the effect was statistically significant for students that used an intervention compared to students that did not use an intervention $F(1,17238)= 55.638$, $p<.001$, partial $\eta 2 = .003$. The unweighted marginal means of question scores across all categories for students that used an intervention ($.688 \pm .010$) were compared to students that did not use an intervention (.742 ± .011). When conducting a pairwise comparison between intervention across all categories on all exams, students that used an intervention (mean difference=.054, CI 95% [.040 to .068], $p<.001$) scored significantly higher on all questions than students that did not use an intervention.

Pairwise Comparison between Use of Intervention and Categories

Next, an analysis of the main effect for categories was performed, which indicated that the effect was statistically significant for the following categories: category 1, category 2, category 3, category 4, category 5, category 6, category 7, category 10, category 14, category 17, category 18, and category 20 (Table 12). All pairwise comparisons were run reported 95% confidence intervals and p-values are Bonferroni-adjusted. The unweighted marginal means of questions scores for students that used an intervention compared to students that did not use an intervention on the different categories have been reported in Table 12 and Figure 15.

Table 12. Comparison of mean exam scores in relation to intervention use and category.

	No Intervention		**Intervention**		**Mean Difference**	**Sign.**	**CI Interval**
Cat.	**Mean**	**Std. Error**	**Mean**	**Std. Error**			
1	.648	.023	.747	.017	.099*	<.001	.042-.156
2	.609	.028	.751	.021	.142*	<.001	.074-.211
3	.640	.035	.817	.025	.176*	<.001	.092-.260
4	.605	.027	.722	.020	.116*	<.001	.051-.181
5	.423	.042	.659	.031	.237*	<.001	.134-339
6	.643	.016	.690	.014	.047*	.022	.007-.088
7	.580	.027	.652	.024	.072*	.045	.002-.143
8	.603	.029	.666	.026	.063		
9	.719	.029	.769	.026	.050		
10	.538	.016	.591	.014	.053*	.013	.011-.095
11	.743	.036	.714	.035	-.028		
12	.708	.029	.731	.029	.023		
13	.668	.023	.661	.022	-.056		
14	.799	.029	.719	.029	-.081*	.048	.001-.118
15	.771	.023	.771	.017	.000		
16	.683	.029	.708	.020	.025		
17	.570	.017	.667	.022	.097*	<.001	.042-.152
18	.777	.022	.913	.028	.136*	<.001	. 065-.206
19	.731	.034	.777	.042	.046		
20	.738	.015	.836	.019	.098*	<.001	.050-.145
21	.805	.028	.813	.029	.008		
22	.809	.024	.822	.024	.013		
23	.838	.021	.861	.021	.023		
24	.725	.025	.720	.026	-.005		
25	.818	.022	.815	.023	-.003		

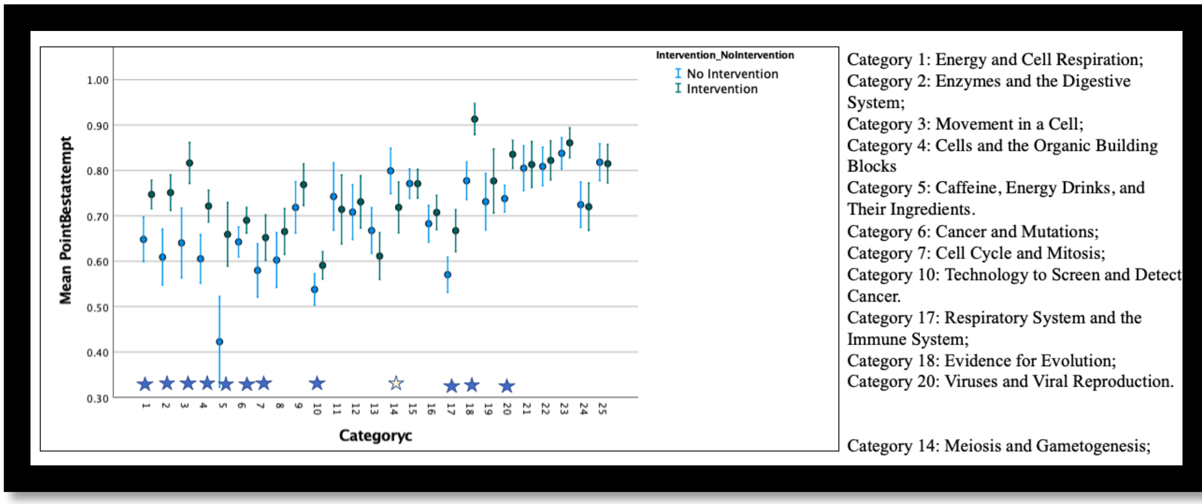


Figure 15. Reviewing the effects of Intervention Use and Categories on Question Scores on All Exam

Hypothesis 2: Part 2B: Across Exams, The Effect of Intervention Type on Exam Question Scores Concerning Different Categories of Biological Concepts

A two-way ANOVA was conducted to examine the effects of the use of an intervention type and categories of biological concepts on question scores. When comparing questions scores, there was a statistically significant interaction between categories and intervention type on question scores, $F(72, 17188)= 1.951$, $p<.001$, partial $\eta2=.008$ (Table 13).

Table 13. 2-Way ANOVA Summary for Mean Questions Across All Historically Challenging Concepts and Intervention Type

	Type III Sum of Squares	**Degrees of freedom**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Audio*Video*Interactive vs No Intervention	18.439	3	6.146	35.803	<.001	.006
Category	81.198	24	3.383	19.707	<.001	.027
Audio*Video*Inter. V vs No Intervent. *Category	24.120	72	.335	1.951	<.001	.008
Error	2950.726	17188	.172			

Pairwise Comparison of Intervention Type Across Exams and Question Scores

An analysis of the main effect for question scores and intervention use indicated that the effect was statistically significant for students that used an intervention compared to students that did not use an intervention $F(3,17188) = 35.803$, $p<.001$, partial $\eta2 = .006$. The unweighted marginal means of question scores across all categories for students that used no intervention (.688 ± .005) were compared to students that used intervention video (.786 ± .009), intervention audio (.703 ± .009), and intervention interactive video (762 ± .010).

When conducting a pairwise comparison between all intervention across all categories on all exams, students that used an intervention video (mean difference=.098, CI 95% [.077 to .119], $p<.001$) and interactive video (mean difference=.074, CI 95% [.052 to .097], $p<.001$) scored significantly higher on overall category questions compared to students that did not use an intervention. Students that used audio (mean difference=.016, CI 95% [.036 to .057], $p=.129$) scored slightly higher than students that did not use an intervention. Students that used an intervention video (mean difference=.083, CI 95% [.057 to .108], $p<.001$) and interactive video (mean difference=.059, CI 95% [.033 to .085], $p<.001$) also scored significantly higher on overall category questions compared to students that used audio.

Pairwise Comparison Intervention Type and Categories

An analysis of the main effect for the different categories was performed, which indicated that the effect was statistically significant for category 1, category 2, category 3, category 4, category 5 question, category 12, category 13, category 14, category 15, category 16, category 17, category 18, category 20, category23, and category 24 (Table 14).

Table 14. Results of univariate test for each category depending on intervention use.

Category	**Degree of Freedom**	**F**	**Sig.**	**Partial Eta Squared**
1	3,17188	4.688	.003	.001
2	3,17188	5.789	<.001	.001
3	3,17188	5.688	<.001	.001
4	3,17188	4.731	.003	.001
5	3,17188	8.471	<.001	.001
12	3,17188	3.245	.021	.001
13	3,17188	4.438	.004	.001
14	3,17188	2.955	.031	.001
15	3,17188	2.717	.043	.001
16	3,17188	5.169	.001	.001
17	3,17188	4.243	.005	.001
18	3,17188	4.907	.002	.001
20	3,17188	5.680	<.001	.001
23	3,17188	3.219	.022	.000
24	3,17188	3.866	.009	.001

All pairwise comparisons were run reported 95% confidence intervals and p-values are Bonferroni-adjusted. The unweighted marginal means of questions scores for intervention type compared to students that did not use an intervention on the varying levels of Blooms taxonomy have been reported in Table 15.

Table 15. Comparison of mean exam scores in relation to intervention type and category.

	No Intervention		Video		Audio		Interactive Video	
Cat.	**Mean**	**Std. Error**	**Mean**	**Std. Error**	**Mean**	**Std. Error**	**Mean**	**Std. Error**
1	.648	.023	.787	.033	.726	.023	.760	.043
2	.609	.028	.779	.040	.737	.027	.758	.052
3	.640	.035	.804	.049	.821	.033	.823	.064
4	.605	.027	.760	.038	.700	.026	.738	.050
5	.423	.042	.766	.060	.606	.041	.679	.078
6	.643	.016	.702	.023	.669	.023	.703	.026
7	.580	.027	.689	.040	.614	.039	.657	.045
8	.603	.029	.696	.044	.667	.042	.625	.049
9	.719	.029	.801	.044	.743	.042	.764	.049
10	.538	.016	.607	.024	.579	.023	.586	.027
11	.743	.036	.833	.085	.659	.044	.786	.078
12	.708	.029	.813	.069	.665	.036	.869	.064
13	.668	.023	.633	.053	.564	.028	.743	.050
14	.799	.029	.849	.069	.678	.036	.736	.064
15	.771	.023	.861	.041	.736	.021	.804	.038
16	.683	.029	.849	.049	.651	.026	.767	.045
17	.570	.017	.861	.034	.695	.048	.648	.036
18	.777	.022	.846	.044	.936	.063	.887	.046
19	.731	.034	.671	.066	.730	.093	.726	.069
20	.738	.015	.925	.029	.806	.042	.850	.031
21	.805	.028	.867	.043	.679	.064	.824	.050
22	.809	.024	.812	.036	.779	.053	.861	.041
23	.838	.021	.909	,032	.740	.047	.871	.036
24	.725	.025	.767	.038	.549	.056	.762	.044
25	.818	.022	.787	.035	.856	.051	.827	.040

Category 1: Through a pairwise comparisons, students that used the following interventions (video (mean difference= .138, CI 95%(.059 to .218), p<.001), audio (mean difference=.077, CI 95%(.014 to .141), p=.017) and interactive video (mean difference=.112, CI 95%(.015 to .209), p=.023)) scored higher on category 1 questions than students that did not use an intervention.

Category 2: Through a pairwise comparisons, students that used the following interventions (video (mean difference= .170, CI 95%(.074 to .265), p<.001), audio (mean difference=.128, CI 95%(.051 to .204), p=.001) and interactive video (mean difference=.149, CI 95%(.033 to .265), p=.012)) scored higher on category 2 questions on than students that did not use an intervention.

Category 3: Through a pairwise comparisons, students that used the following interventions (video (mean difference= .164, CI 95% (.046 to .281), p=.006), audio (mean difference=.180, CI 95%(.086 to .274), p<.001) and interactive video (mean difference=.182, CI 95%(.040 to .325), p=.012)) scored higher on category 3 questions on than students that did not use an intervention.

Category 4: Through a pairwise comparisons, students that used the following interventions (video (mean difference= .155, CI 95% (.064 to .246), p<.001), audio (mean difference=.094, CI 95%(021 to .167), p=.011) and interactive video (mean difference=.132, CI 95%(.022 to .242), p=.019)) scored higher on category 4 questions on than students that did not use an intervention.

Category 5: Through a pairwise comparisons, students that used the following interventions (video (mean difference= .343, CI 95% (.199 to .488), p<.001), audio (mean difference=.183, CI 95%(.068 to .298), p=.011) and interactive video (mean difference=.256, CI 95%(.082 to .430), p=.019)) scored higher on category 5 questions on than students that did not use an intervention. Students that used the following intervention video (mean difference= .160, CI 95% (.017 to .202), p<.001) also scored higher on category 5 questions on than students that used intervention audio.

Category 6: Through a pairwise comparisons, students that used the following interventions (video (mean difference= .060, CI 95% (.005 to .115), p=.033) and interactive video (mean difference=.061, CI 95%(.001 to .120), p=.045) scored higher on category 6 questions on than students that did not use an intervention.

Category 7: Through a pairwise comparisons, students that used intervention video (mean difference= .109, CI 95% (.014 to .205), p=.024) scored higher on category 7 questions on than students that did not use an intervention.

Category 10: Through a pairwise comparisons, students that used intervention video (mean difference= .069, CI 95% (.013 to .125), p=.016) scored higher on category 10 questions on than students that did not use an intervention.

Category 12: Through a pairwise comparisons, students that used intervention interactive video scored higher on category 12 questions on than students that did not use an intervention (mean difference= .161, CI 95% (.023 to .298), p=.022) and students that used intervention audio (mean difference= .204, CI 95% (.060 to .348), p=.005).

Category 13 Through a pairwise comparisons, students that used intervention audio scored lower on category 13 questions on than students that did not use an intervention (mean difference= .104, CI 95% (.034 to .174), p=.004) and students that used intervention interactive video (mean difference= .179, CI 95% (.068 to .291), p=.002).

Category 14 Through a pairwise comparisons, students that used intervention video scored higher on category 14 questions on than students that did not use an intervention (mean difference= .122, CI 95% (.031 to .212), p=.009) and students that used intervention video (mean difference= .172, CI 95% (.019 to .325), p=.027).

Category 15 Through a pairwise comparisons, students that used intervention video scored higher on category 15 questions on than students that did not use an intervention (mean difference= .089, CI 95% (.002 to .177), p=.045) and students that used intervention video (mean difference= .124, CI 95% (.034 to .215), p=.007).

Category 16 Through a pairwise comparisons, students that used intervention video scored higher on category 16 questions on than students that did not use an intervention (mean difference= .163, CI 95% (.059 to .267), p=.002) and students that used intervention audio video (mean difference= .195, CI 95% (.087 to .303), p<.001). Students that used intervention interactive video scored higher on category 16 questions on than students that used intervention audio (mean difference= .117, CI 95% (.015 to .218), p=.025).

Category 17 Through a pairwise comparisons, students that used the following interventions (video (mean difference= .101, CI 95% (.026 to .175), p=.008) and audio (mean difference=.125, CI 95%(.025 to .225), p=.014) scored higher on category 17 questions on than students that did not use an intervention.

Category 18 Through a pairwise comparisons, students that used the following interventions (video (mean difference= .148, CI 95% (.052 to .244), p=.003), audio (mean difference=.158, CI 95%(.029 to .287), p=.016), and interactive video (mean difference= .110, CI 95% (.009 to .210), p=.032)) scored higher on category 18 questions on than students that did not use an intervention.

Category 20 Through a pairwise comparisons, students that used the following interventions (video (mean difference= .100, CI 95% (.035 to .164), p=.002) and interactive video (mean difference= .112, CI 95% (.044 to .179), p=.001)) scored higher on category 20 questions on than students that did not use an intervention.

Category 21 Through a pairwise comparisons, students that used the following intervention video (mean difference= .188, CI 95% (.036 to .339), p=.015) scored higher on category 21 questions on than students that used intervention audio.

Category 23 Through a pairwise comparisons, students that used the following intervention video (mean difference= .170, CI 95% (.058 to .281), p=.003) and intervention interactive video (mean difference= .131, CI 95% (.015 to .248), p=.027) scored higher on category 23 questions on than students that used intervention audio.

Category 24 Through a pairwise comparisons, students that used the following intervention audio scored lower on category 24 questions on than students that did not use an intervention (mean difference= .175, CI 95% (.055 to .296), p=.004), intervention video (mean difference= .218, CI 95% (.084 to .351), p=.001), and intervention interactive video (mean difference= .212, CI 95% (.073 to .352), p=.003) (Figure 16).

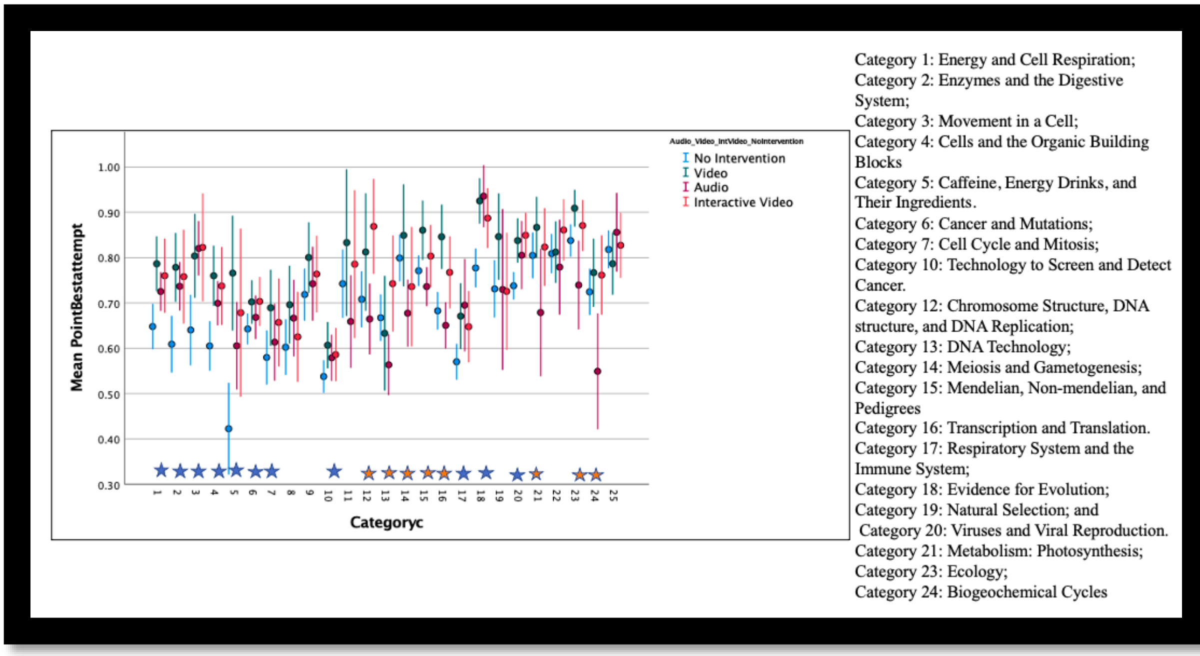


Figure 16. Reviewing the effects of Intervention Type and Categories on Question Scores on All Exam

Hypothesis 3: Within Each Exam, Intervention Use and Type Will Affect Question Scores Concerning Different Levels of Blooms Taxonomy and Categories of Biological Concepts

Exam 1: Comparing Question Scores_ Intervention Vs. No Intervention

The 48 questions on Exam 1 fell under the following 5 categories: Category 1: Energy and Cell Respiration; Category 2: Enzymes and the Digestive System; Category 3: Movement in a Cell; Category 4: Cells and the Organic Building Blocks; and Category 5: Caffeine, Energy Drinks, and Their Ingredients. The 48 questions were further divided into Blooms Level: Blooms Level 1: 8 questions; Blooms Level 2: 29 questions; Blooms Level 3: 3 Questions; Blooms Level 4&5: 8 questions.

A Three-Way ANOVA was conducted on a sample of 69 participants scores on exam 1 to compare the effects of intervention use, level of difficulty, and different biological concepts covered on question scores (Table 16). There was no significant three-way interaction, $F(6, 2870) = .841$, $p = .538$. There was a statistically simple two-way interaction between the four levels of difficulty and the five categories (Table 16). The main effect indicated that scores across different level of bloom between the categories yield significant differences. There were also statistically significant simple main effect of intervention use, level of difficulty, and category (Table 16).

Table 16. 3-Way ANOVA Summary for Intervention Use, Blooms Level, and Categories for Exam 1

	Type III Sum of Squares	Degrees of freedom	Mean Square	F	Sig.	Partial Eta Squared
Intervention vs No Intervention	7.153	1	7.153	42.585	<.001	.015
Level of Difficulty (Blooms)	2.074	3	.691	4.116	.006	.004
Category	9.118	4	2.279	4.116	<.001	.019
Intervention vs No Intervention *Blooms	1.074	3	.358	2.132	.094	.002
Intervention vs No Intervention *Category	1.375	4	.344	2.047	.085	.003
Blooms*Category	11.189	6	1.865	11.103	<.001	.023
Intervention vs No Intervention *Blooms*Category	.848	6	.141	.851	.538	.002
Error	482.058	2870	.168			

Intervention no intervention

An univariate-test performed for question scores and intervention use indicated that the effect was statistically significant for students that used an intervention compared to students that did not use an intervention for Exam 1 (univariate test), $F(1, 2870)= 43.940$, $p<.001$, partial $\eta 2 = .015$. The modified population marginal means of question scores across all questions for students that used an intervention (.745± .013) compared to students that did not use an intervention (.601 ± .018) (Figure 17).

When conducting a pairwise comparison between intervention and no intervention use on questions on Exam 1, students that used an intervention (mean difference= .144 ± .022, CI 95% [.101 to .187], p<.001) scored significantly higher on all questions than students that did not use an intervention.

Level of difficulty (Blooms Taxonomy)

An univariate-test performed for Blooms Level found a statistically significant interaction between student scores and level of difficulty, F(3, 2870)= 12.525, p<.001. The modified population marginal means of question scores across all level 1 questions (.702 ± .019), level 2 questions (.612 ± .015), level 3, (.794 ± .030), and level 4/5 questions (.625 ± .027).

Category

An univariate-test performed for Blooms Level found a statistically significant interaction between student scores and category, F(4, 2870)= 20.778, p<.001. The modified population marginal means of question scores across the following five categories are category 1 (.774 ± .022), category 2 questions (.677 ± .021), category 3 questions (.735 ± .024), category 4 questions (.551 ± .027) and level 5 questions (.515 ± .027).

Blooms Level and Category

An univariate-test performed for Blooms Level*Category found a statistically significant interaction between level of difficulty and category on categories and Level 2

(F(4, 2870)= 10.728, p<.001), Level 3 (F(2, 2870)= 6.632, p<.001), and Level 4/5 (F(2, 2870)= 17.275, p<.001).

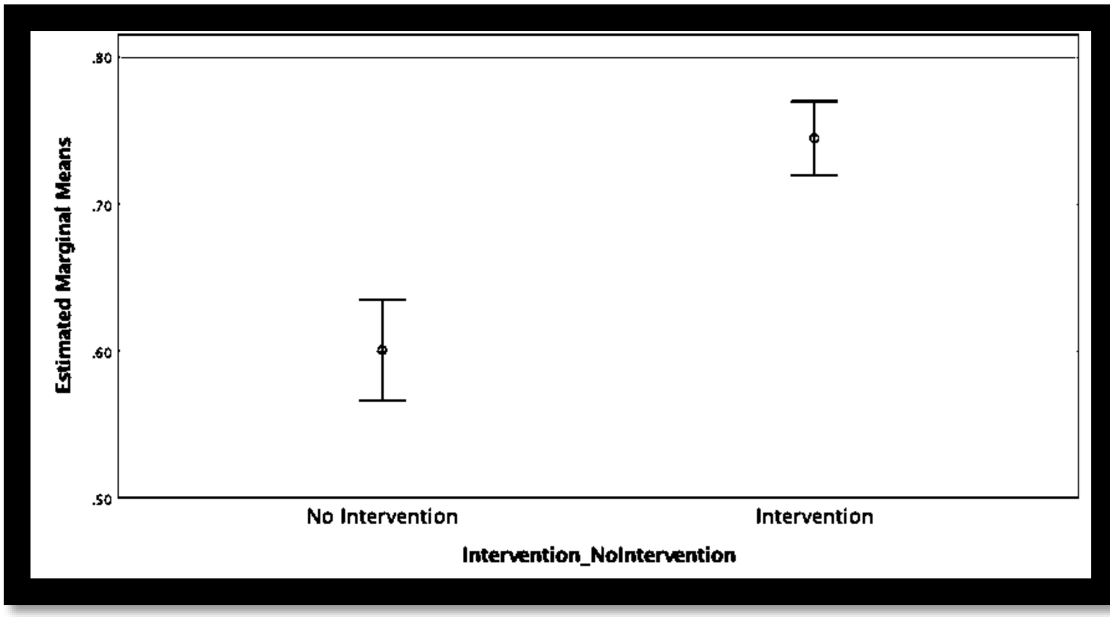


Figure 17. The mean question scores for the intervention vs. no intervention on Exam 1.

Exam 1: Comparing Question Scores_ Intervention Type Vs. No Intervention

A Three-Way ANOVA was conducted on a sample of 73 participants scores on exam 1 to compare the effects of intervention type, level of difficulty, and different biological concepts covered on question scores (Table 17). There was no significant three-way interaction, F(18, 2842) = .782, p = .723. There was a statistically simple two-way interaction between the four levels of difficulty and the five categories (Table 17). The main effect indicated that scores across different level of bloom between the categories yield significant differences. There were also statistically significant simple main effect of intervention use, level of difficulty, and category (Table 17).

Table 17. 3-Way ANOVA Summary for Intervention Type, Blooms Level, and Categories for Exam 1.

	Type III Sum of Squares	**Degrees of freedom**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Intervention (Audio, Video, Interactive Video) vs No Intervention	8.223	3	2.741	16.287	<.001	.017
Level of Difficulty (Blooms)	3.049	3	1.016	6.040	<.001	.006
Category	4.749	4	1.187	7.056	<.001	.010
Intervention Type *Blooms	2.057	9	.229	1.358	.202	.004
Intervention Type *Category	2.059	12	.172	1.020	.427	.004
Blooms*Category	8.556	6	1.426	8.474	<.001	.018
Intervention Type*Blooms*Category	2.370	18	.132	.782	.723	.005
Error	478.265	2842	.168			

Intervention type compared to no intervention

An univariate-test performed for question scores and intervention use indicated that the effect was statistically significant for students that used an intervention compared to students that did not use an intervention for Exam 1 (univariate test), $F(3, 2702)= 16.056$, $p<.001$, partial $\eta 2 = .017$. Comparing means, all students that used the interventions (audio .723 ± .017 (mean difference=.122 p<.001), video .782 ± .025 (mean difference= .181 p<.001), and interactive video .765 ± .033 (mean difference= .164 p<.001)) scored higher than students that did not use an intervention (.601 ± .018). Comparing within interventions, students that used video (mean difference=.059, p=.05) significantly scored higher than students that used the intervention audio (Figure 18).

Level of difficulty (Blooms Taxonomy)

An univariate-test performed for Blooms Level found a statistically significant interaction between student scores and level of difficulty, $F(3, 2842)= 14.143$, $p<.001$. The modified population marginal means of question scores across all level 1 questions (.758 ± .020), level 2 questions (.639 ± .017), level 3 (.849 ± .033), and level 4/5 questions (.677 ± .029).

Category

An univariate-test performed for Blooms Level found a statistically significant interaction between student scores and category, $F(4, 2842)= 13.621$, $p<.001$. The modified population marginal means of question scores across the following five categories are category 1 (.803 ± .024), category 2 questions (.729 ± .023), category 3 questions (.776 ± .026), category 4 questions (.593 ± .030) and level 5 questions (.583 ± .031).

Blooms Level and Category

An univariate-test performed for Blooms Level*Category found a statistically significant interaction between level of difficulty and category on categories and Level 2 ($F(4, 2870)= 10.728$, $p<.001$), Level 3 ($F(2, 2870)= 6.632$, $p<.001$), and Level 4/5 ($F(2, 2870)= 17.275$, $p<.001$).

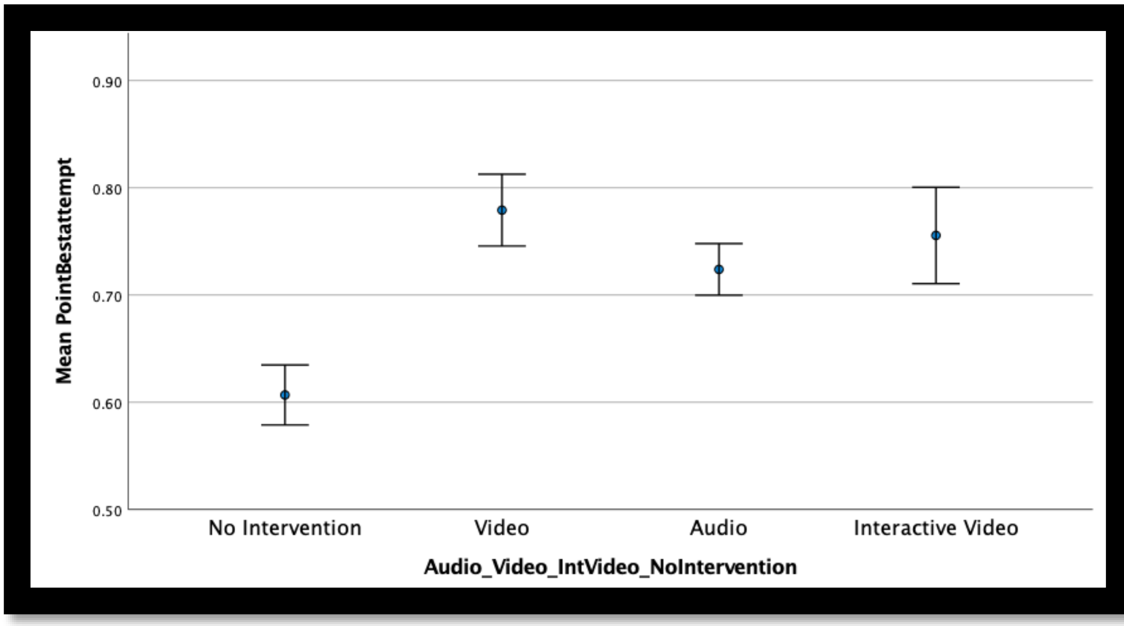


Figure 18. The mean question scores across intervention types on Exam 1.

Exam 2: Comparing Question Scores_ Intervention Vs. No Intervention

On Exam 2, there were 61 questions that fell under 5 categories: Category 1: Cancer and Mutations; Category 2: Cell Cycle and Mitosis; Category 3: Enzymes and Protein Synthesis; Category 4: Homeostasis; and Category 5: Technology to Screen and Detect Cancer. The 61 questions were further divided into Blooms Level: Blooms Level 1: 15 questions; Blooms Level 2: 37 questions; Blooms Level 3: 6 Questions; Blooms Level 4: 3 questions.

A Three-Way ANOVA was conducted on a sample of 77 participants scores on exam 2 to compare the effects of intervention use, level of difficulty, and different biological concepts covered on question scores (Table 18). There was no statistically significant three-way use of intervention, Blooms level, and category, $F(7,4560) = 1.496$, p= .164, partial η2 = .002. There was a statistically simple two-way interaction between the four levels of difficulty and the five categories (Table 18). There were also statistically significant simple main effect of intervention use, level of difficulty, and category (Table 18).

Table 18. 3-Way ANOVA Summary for Intervention Use, Blooms Level, and Categories for Exam 2.

	Type III Sum of Squares	Degrees of freedom	Mean Square	F	Sig.	Partial Eta Squared
Intervention vs No Intervention	1.773	1	7.153	42.585	.002	.002
Level of Difficulty (Blooms)	24.884	3	.691	4.116	<.001	.028
Category	8.114	4	.691	4.116	<.001	.009
Intervention vs No Intervention *Blooms	.521	3	.358	2.132	.421	.001
Intervention vs No Intervention *Category	.646	4	.344	2.047	.480	.001
Blooms*Category	13.440	7	1.865	11.103	<.001	.016
Intervention vs No Intervention *Blooms*Category	1.941	7	.141	.851	.164	.002
Error	850.567	4560				

Intervention no intervention

An univariate-test performed for question scores and intervention use indicated that the effect was statistically significant for students that used an intervention compared to students that did not use an intervention for Exam 2 (univariate test), F(1, 4950)=

9.094, p=.003, partial $\eta 2$ = .002. The modified population marginal means of question scores across all questions for students that used an intervention (.678± .011) compared to students that did not use an intervention (.627 ± .013).

When conducting a pairwise comparison between intervention and no intervention use on questions on Exam 2, students that used an intervention (mean difference= .052 ± .017, CI 95% [.018 to .085], p=.003) scored significantly higher on all questions than students that did not use an intervention (Figure 18).

Level of difficulty (Blooms Taxonomy)

An univariate-test performed for Blooms Level found a statistically significant interaction between student scores and level of difficulty, F(3, 4560)= 41.399, $p<.001$, partial $\eta 2$=.026. The modified population marginal means of question scores across all level 1 questions (.765± .015), level 2 questions (.608 ± .010), level 3, (.535 ± .021), and level 4/5 questions (.778 ± .028).

Category

An univariate-test performed for Blooms Level found a statistically significant interaction between student scores and category, F(4, 4560)= 12.073, $p<.001$, partial $\eta 2$=.010. The modified population marginal means of question scores across the following five categories are category 1 (.636 ± .013), category 2 questions (.597 ± .021), category 3 questions (.748 ± .027), category 4 questions (.731 ± .022) and level 5 questions (.587 ± .016).

Blooms Level and Category

An univariate-test performed for Blooms Level*Category found a statistically significant interaction between level of difficulty and category. Within the following categories, Category 1 ($F(3, 4560)= 6.984$, $p<.001$, partial $\eta2=.024$), Category 2 ($F(2, 4560)= 12.678$, $p<.001$, partial $\eta2=.005$), Category 3 ($F(1, 4560)= 39.792$, $p<.001$, partial $\eta2=.009$), and Category 4 ($F(2, 4560)= 4.298$, $p=.014$, partial $\eta2=.002$), there was significance difference in mean scores across the various Blooms levels within each category. At the following levels, Level 1 ($F(4, 4560)= 10.294$, $p<.001$, partial $\eta2=.009$), Level 2 ($F(4, 4560)= 12.928$, $p<.001$, partial $\eta2=.011$), and Level 3 ($F(3, 4560)= 11.690$, $p<.001$, partial $\eta2=.008$), there was significance difference in mean scores across categories within each Blooms level.

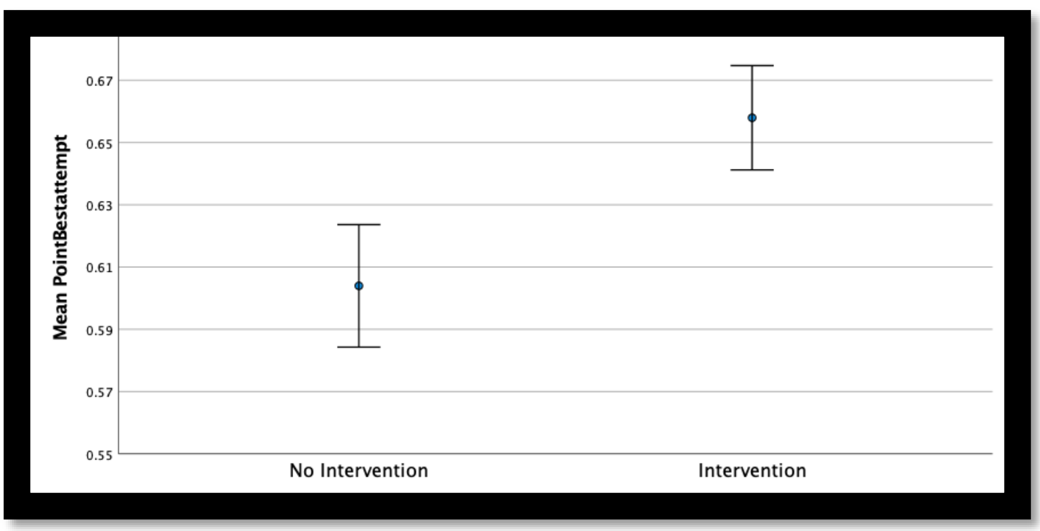


Figure 19. The mean question scores for the intervention vs. no intervention on Exam 2.

Exam 2: Comparing Question Scores_ Intervention Type Vs. No Intervention

A Three-Way ANOVA was conducted on a sample of 77 participants scores on exam 2 to compare the effects of intervention type, level of difficulty, and different biological concepts covered on question scores (Table 17). There was no significant three-way interaction, $F(21, 4560) = .830$, $p = .685$, partial $\eta 2=.004$. There was a statistically simple two-way interaction between the four levels of difficulty and the five categories (Table 17). There were also statistically significant simple main effect of intervention use, level of difficulty, and category (Table 17).

Table 19. 3-Way ANOVA Summary for Intervention Type, Blooms Level, and Categories for Exam 2.

	Type III Sum of Squares	**Degrees of freedom**	**Mean Square**	**F**	**Sig.**	**Partial Eta**
Intervention (Audio, Video, Interactive Video) vs No Intervention	2.245	3	.748	4.024	.007	.003
Level of Difficulty (Blooms)	24.710	3	8.237	44.298	<.001	.028
Category	7.696	4	1.924	10.348	<.001	.009
Intervention Type *Blooms	.768	9	.085	.459	.902	.001
Intervention Type *Category	1.151	12	.096	.516	.906	.001
Blooms*Category	15.112	7	2.159	11.611	<.001	.018
Intervention Type*Blooms*Category	3.240	21	.154	.830	.685	.004
Error	847.892	4560	.186			

Intervention type compared to no intervention

An univariate-test performed for question scores and intervention use indicated that the effect was statistically significant for students that used an intervention compared to students that did not use an intervention for Exam 2 (univariate test), $F(3, 4560)= 3.957$, $p=.008$, partial $\eta 2 = .003$. Comparing means, all students that used the interventions (audio .662 ± .019 (mean difference=.040), video .704 ± .019 (mean difference= .077 $p<.001$), and interactive video .667 ± .022 (mean difference= .040) scored higher than students that did not use an intervention (.627 ± .013) (Figure 20).

Level of difficulty (Blooms Taxonomy)

An univariate-test performed for Blooms Level found a statistically significant interaction between student scores and level of difficulty, $F(3, 4560)= 39.987$, $p<.001$, partial $\eta 2$=..026. The modified population marginal means of question scores across all level 1 questions (.783 ± .016), level 2 questions (.621 ± .011), level 3 (.538 ± .023), and level 4 questions (.801 ± .031).

Category

An univariate-test performed for categories found a statistically significant interaction between student scores and category, $F(4, 4560)= 10.668$, $p<.001$, partial $\eta 2$= .009. The modified population marginal means of question scores across the following five categories are category 1 (.641 ± .014), category 2 questions (.614 ± .023), category

3 questions (.767 ± .029), category 4 questions (.743 ± .024) and level 5 questions (.602 ± .017).

Blooms Level and Category

An univariate-test performed for Blooms Level*Category found a statistically significant interaction between level of difficulty and category. Within the following categories, Category 1 ($F(3, 4560)= 6.917$, $p<.001$, partial $\eta2=.024$), Category 2 ($F(2, 4560)= 14.468$, $p<.001$, partial $\eta2=.006$), Category 3 ($F(1, 4560)= 38.182$, $p<.001$, partial $\eta2=.008$), and Category 4 ($F(2, 4560)= 4.539$, $p=.011$, partial $\eta2=.002$), there was significance difference in mean scores across the various Blooms levels within each category. At the following levels, Level 1 ($F(4, 4560)= 9.667$, $p<.001$, partial $\eta2=.008$), Level 2 ($F(4, 4560)= 12.587$, $p<.001$, partial $\eta2=.011$), and Level 3 ($F(3, 4560)= 13.159$, $p<.001$, partial $\eta2=.009$), there was significance difference in mean scores across categories within each Blooms level.

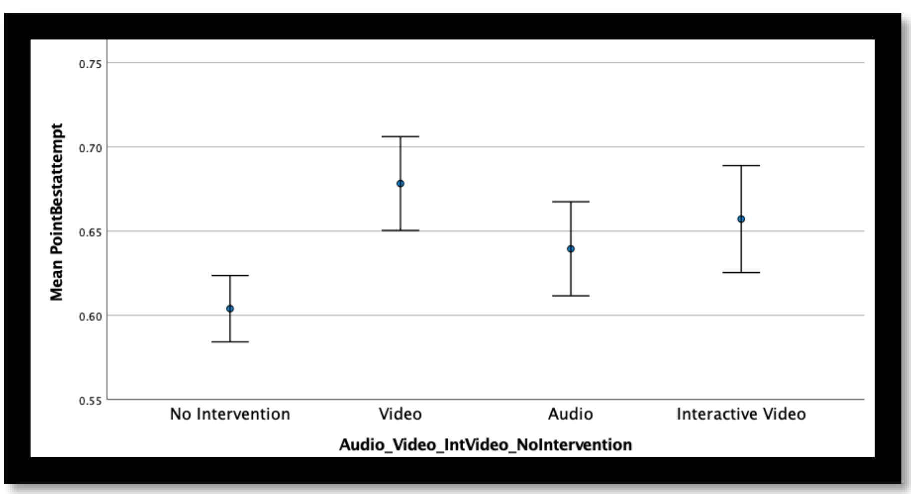


Figure 20. The mean question scores across intervention types on Exam 2.

Exam 3: Comparing Question Scores_ Intervention Vs. No Intervention

On Exam 3, there were 55 questions that fell under 6 categories: Category 1: Blood, Cardiovascular and Circulatory System; Category 2: Chromosome Structure, DNA structure, and DNA Replication; Category 3: DNA Technology; Category 4: Meiosis and Gametogenesis; Category 5: Mendelian, Non-mendelian, and Pedigrees, and Category 6: Transcription and Translation. The 55 questions were further divided into Blooms Level: Blooms Level 1: 14 questions; Blooms Level 2: 28 questions; Blooms Level 3: 4 Questions; and Blooms Level 4: 9 questions.

A Three-Way ANOVA was conducted on a sample of 69 participants scores on exam 3 to compare the effects of intervention use, level of difficulty, and different biological concepts covered on question scores (Table 20). There was no statistically significant three-way use of intervention, Blooms level, and category, $F(8,3761) = 1.219$, $p = .283$, partial $\eta 2 = .003$. There was a statistically simple two-way interaction between the four levels of difficulty and the six categories (Table 20). There were also statistically significant simple main effect of level of difficulty and category (Table 20).

Table 20. 3-Way ANOVA Summary for Intervention Use, Blooms Level, and Categories for Exam 3.

	Type III Sum of Squares	**Degrees of freedom**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Intervention vs No Intervention	.530	1	.530	3.121	.077	.001
Level of Difficulty (Blooms)	20.274	3	6.758	39.788	<.001	.031
Category	15.938	5	3.188	18.766	<.001	.024
Intervention vs No Intervention *Blooms	.204	3	.068	.400	.753	.000
Intervention vs No Intervention *Category	1.563	5	.313	1.840	.102	.002
Blooms*Category	14.504	8	1.813	10.674	<.001	.022
Intervention vs No Intervention *Blooms*Category	1.657	8	.207	1.219	.283	.003
	638.813	3761				

Intervention no intervention

While not significant, the modified population marginal means of question scores across all questions for students that used an intervention (.701± .011) compared to students that did not use an intervention (.730 ± .011).

When conducting a pairwise comparison between intervention and no intervention use on questions on Exam 3, students that used an intervention (mean difference= .029 ± .016, CI 95% [.002 to .059], p=.068) scored significantly lower on all questions than students that did not use an intervention.

Level of difficulty (Blooms Taxonomy)

An univariate-test performed for Blooms Level found a statistically significant interaction between student scores and level of difficulty, $F(3, 3761) = 37.696$, $p < .001$, partial $\eta2 = .029$. The modified population marginal means of question scores across all level 1 questions (.831± .014), level 2 questions (.664 ± .010), level 3, (.784 ± .025), and level 4 questions (.647 ± .018).

Category

A univariate-test performed for Blooms Level found a statistically significant interaction between student scores and category, $F(5, 3761) = 19.440$, $p < .001$, partial $\eta2 = .025$. The modified population marginal means of question scores across the following five categories are category 1 (.728 ± .025), category 2 questions (.753 ± .021), category 3 questions (.557 ± .020), category 4 questions (.754 ± .022), category 5 questions (.788 ± .014), and category 6 questions (.704 ± .016).

Blooms Level and Category

A univariate-test performed for Blooms Level*Category found a statistically significant interaction between level of difficulty and category. Within the following categories, Category 1 ($F(1, 3761) = 29.049$, $p < .001$, partial $\eta2 = .008$), Category 2 ($F(1, 3761) = 22.269$, $p < .001$, partial $\eta2 = .006$), Category 3 ($F(2, 3761) = 24.098$, $p < .001$, partial $\eta2 = .013$), Category 4 ($F(2, 3761) = 22.299$, $p < .001$, partial $\eta2 = .012$), and Category 5($F(3, 3761) = 38.871$, $p < .001$, partial $\eta2 = .007$), there was significance difference in mean scores across the various Blooms levels within each category. At the following levels, Level 1 ($F(4, 3761)= 13.989$, $p<.001$, partial $\eta2=.015$), Level 2 ($F(5, 3761)= 6.234$, $p<.001$, partial $\eta2=.008$), and Level 4 ($F(3, 3761)= 19.194$, $p<.001$, partial $\eta2=.020$), there was significance difference in mean scores across categories within each Blooms level.

Exam 3: Comparing Question Scores_ Intervention Type Vs. No Intervention

A Three-Way ANOVA was conducted on a sample of 69 participants scores on exam 3 to compare the effects of intervention type, level of difficulty, and different biological concepts covered on question scores (Table 21). There was no significant three-way interaction, $F(24, 3727) = .714$, $p = .842$, partial $\eta2=.005$. There was a statistically simple two-way interaction between the four levels of difficulty and the six categories (Table 21). There were also statistically significant simple main effect of intervention type, level of difficulty, and category (Table 21).

Table 21. 3-Way ANOVA Summary for Intervention Type, Blooms Level, and Categories for Exam 3.

	Type III Sum of Squares	**Df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Square**
Intervention (Audio, Video, Interactive Video) vs No Intervention	4.433	3	1.478	8.766	<.001	.007
Level of Difficulty (Blooms)	12.632	3	4.211	24.979	<.001	.020
Category	12.192	5	2.438	14.65	<.001	.019
Intervention Type *Blooms	.588	9	.065	.388	.942	.001
Intervention Type *Category	2.570	15	.171	1.016	.434	.004
Blooms*Category	11.316	8	1.415	11.611	<.001	.018
Intervention Type*Blooms*Category	2.891	24	.120	.714	.842	.005
Error	628.273	3727	.169			

Intervention type compared to no intervention

An univariate-test performed for question scores and intervention use indicated that the effect was statistically significant for students that used an intervention compared to students that did not use an intervention for Exam 3 (univariate test), $F(3, 3727) = 10.150$, $p<.001$, partial $\eta 2 = .008$. Comparing means, all students that used the intervention audio (658 ± .014) scored significantly lower than students that did not use an intervention (.730 ± .011 (mean difference=.072, $p<.001$), video (.790 ± .026 (mean difference= .133, $p<.001$), and interactive video (.761 ± .025 (mean difference= .103, $p<.001$). Students that used intervention video (mean difference= .061, $p<.001$) scored significantly higher than students that did not use an intervention (Figure 21).

Level of difficulty (Blooms Taxonomy)

An univariate-test performed for Blooms Level found a statistically significant interaction between student scores and level of difficulty, $F(3, 3727) = 23.612$, $p<.001$, partial $\eta 2$=..019. The modified population marginal means of question scores across all level 1 questions (.855 ± .018), level 2 questions (.691 ± .013), level 3 (.797 ± .032), and level 4 questions (.654 ± .023).

Category

A univariate-test performed for categories found a statistically significant interaction between student scores and category, $F(5, 3727) = 14.892$, $p<.001$, partial $\eta 2$= .020. The modified population marginal means of question scores across the following five categories are category 1 (.755 ± .032), category 2 questions (.800 ± .028), category 3 questions (.553 ± .026), category 4 questions (.754 ± .029), category 5 questions (.809 ± .017), and category 6 (.740 ± .021).

Blooms Level and Category

A univariate-test performed for Blooms Level*Category found a statistically significant interaction between level of difficulty and category. Within the following categories, Category 1 ($F(1, 3727) = 19.846$, $p < .001$, partial $\eta 2 = .005$), Category 2 ($F(1, 3727) = 15.523$, $p < .001$, partial $\eta 2 = .004$), Category 3 ($F(2, 3727) = 21.593$, $p < .001$, partial $\eta 2 = .011$), Category 4 ($F(2, 3727) = 13.364$, $p < .001$, partial $\eta 2 = .007$), and Category 5($F(3, 3727) = 5.145$, $p = .002$, partial $\eta 2 = .004$), there was significance difference in mean scores across the various Blooms levels within each category. At the following levels, Level 1 ($F(4, 3727) = 8.255$, $p < .001$, partial $\eta 2 = .009$), Level 2 ($F(5, 3727) = 4.401$, $p < .001$, partial $\eta 2 = .006$), and Level 4 ($F(4, 3727) = 16.251$, $p < .001$, partial $\eta 2 = .017$), there was significance difference in mean scores across categories within each Blooms level.

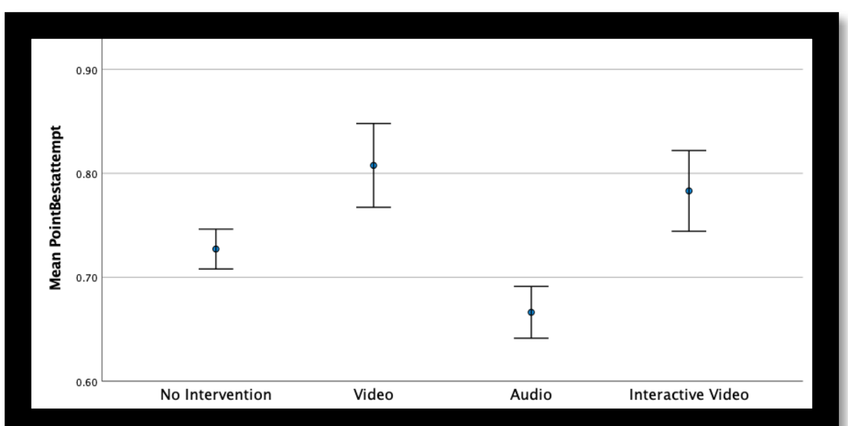


Figure 21. The mean question scores across intervention types on Exam 3.

Exam 4: Comparing Question Scores_ Intervention Vs. No Intervention

On Exam 4, there were 49 questions that fell under 4 categories: Category 1: Respiratory System and the Immune System; Category 2: Evidence for Evolution; Category 3: Natural Selection; and Category 4: Viruses and Viral Reproduction. The 49 questions were further divided into Blooms Level: Blooms Level 1: 11 questions; Blooms Level 2: 29 questions; Blooms Level 3: 5 Questions; and Blooms Level 4/5: 4 questions.

A Three-Way ANOVA was conducted on a sample of 62 participants scores on exam 4 to compare the effects of intervention use, level of difficulty, and different biological concepts covered on question scores (Table 22). There was a statistically significant three-way use of intervention, Blooms level, and category, $F(6,2949) = 2.662$, $p = .014$, partial $\eta 2 = .005$. There was a statistically simple two-way interaction between the four levels of difficulty and the four categories and between intervention use and Blooms Level (Table 22). There were also statistically significant simple main effect of level of difficulty and category (Table 22).

Table 22. 3-Way ANOVA Summary for Intervention Use, Blooms Level, and Categories for Exam 4.

	Type III Sum of Squares	Degrees of freedom	Mean Square	F	Sig.	Partial Eta Squared
Intervention vs No Intervention	3.857	1	3.857	24.772	<.001	.008
Level of Difficulty (Blooms)	4.710	3	1.570	10.084	<.001	.010
Category	5.659	3	1.886	12.115	<.001	.012
Intervention vs No Intervention *Blooms	1.225	3	.408	2.622	.049	.003
Intervention vs No Intervention *Category	.608	3	.203	1.302	.272	.001
Blooms*Category	16.859	6	2.810	18.048	<.001	.035
Intervention vs No Intervention *Blooms*Category	2.487	6	.207	1.219	.014	.003
	459.135	2949				

Intervention no intervention

A univariate-test performed for question scores and intervention use indicated that the effect was statistically significant for students that used an intervention compared to students that did not use an intervention for Exam 4 (univariate test), $F(1, 2949)= 32.083$, $p<.001$, partial $\eta 2 = .011$. The modified population marginal means of question scores across all questions for students that used an intervention (.819 ± .016) compared to students that did not use an intervention (.703 ± .013).

When conducting a pairwise comparison between intervention and no intervention use on questions on Exam 3, students that used an intervention (mean difference= .116 ± .020, CI 95% [.076 to .156], $p<.001$) scored significantly lower on all questions than students that did not use an intervention (Figure 22).

Level of difficulty (Blooms Taxonomy)

A univariate-test performed for Blooms Level found a statistically significant interaction between student scores and level of difficulty, $F(3, 2949)= 10.976$, $p<.001$, partial $\eta 2=.011$. The modified population marginal means of question scores across all level 1 questions (.800± .017), level 2 questions (.703 ± .012), level 3, (.828 ± .026), and level 4/5 questions (.734 ± .027) (Figure 23).

Category

A univariate-test performed for Blooms Level found a statistically significant interaction between student scores and category, $F(3,2949)= 14.761$, $p<.001$, partial $\eta 2=.015$. The modified population marginal means of question scores across the following four categories are category 1 (.710 ± .018), category 2 questions (.854 ± .019), category 3 questions (.781 ± .030), and category 4 questions (.695 ± .019).

Intervention Use and Blooms Level

A univariate-test performed for Intervention Use*Blooms Level found a statistically significant interaction between whether a student used an intervention and Blooms Level. Within the following Levels, Level 1 ($F(1, 2949)= 8.316$, $p=.004$, partial η2=.003), Level 2 (F(1, 2949)= 13.111, p<.001, partial η2=.004), and Level 3 (F(1, 2949)= 21.249, p<.001, partial η2=.007), there was significance difference in mean scores across the various Blooms levels depending on whether or not the student used an intervention. Comparing intervention use across all Blooms Levels, No intervention (F(3, 2949)= 4.165, p=.006, partial η2=.004) and Intervention (F(3, 2949)= 8.654, p<.001, partial η2=.009), there was significance difference in mean scores across Blooms levels within students that did not use an intervention and within students that used an intervention.

Blooms Level and Category

A univariate-test performed for Blooms Level*Category found a statistically significant interaction between level of difficulty and category. Within the following categories, Category 1 (F(3, 2949)= 28.848, p<.001, partial η2=.029), Category 2 (F(3, 2949)= 4.873, p=.002, partial η2=.005), and Category 4 (F(2, 2949)= 19.891, p<.001, partial η2=.013), there was significance difference in mean scores across the various Blooms levels within each category. At the following levels, Level 1 (F(2, 2949)= 14.704, p<.001, partial η2=.010), Level 2 (F(3, 2949)= 51.516, p<.001, partial η2=.050), and Level 4/5 (F(2, 2949)= 22.161, p<.001, partial η2=.015), there was significance difference in mean scores across categories within each Blooms level (Figure 24).

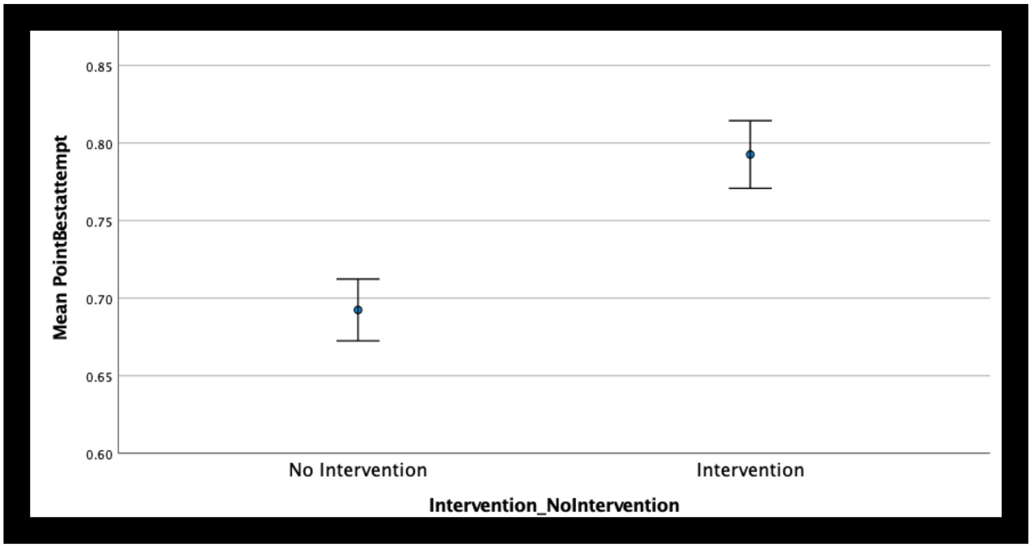


Figure 22. The mean question scores for the intervention vs. no intervention on Exam 4.

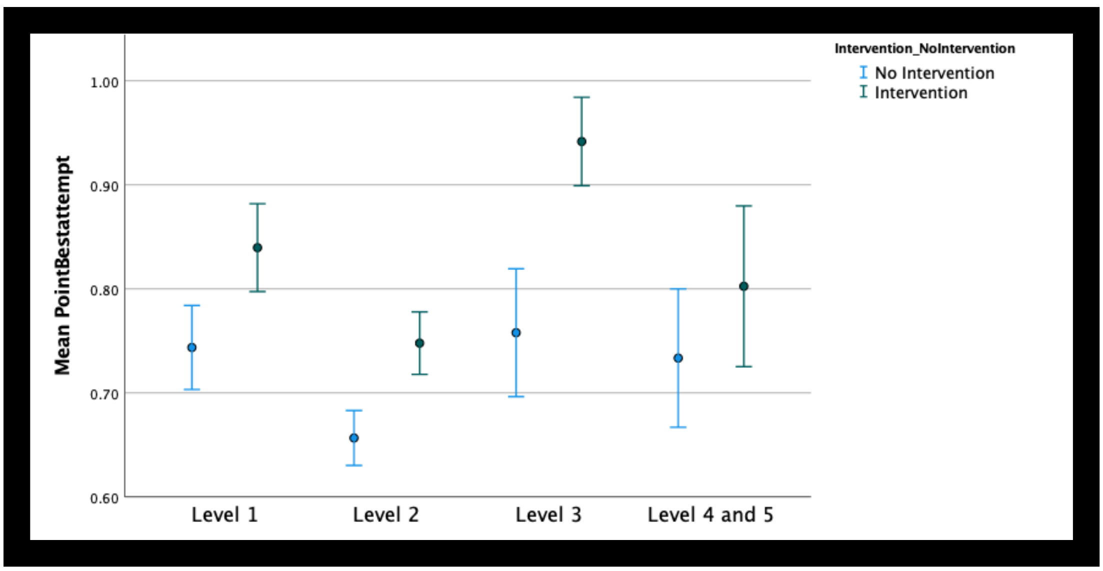


Figure 23. The mean question scores across Exam 4 depending on Blooms Level.

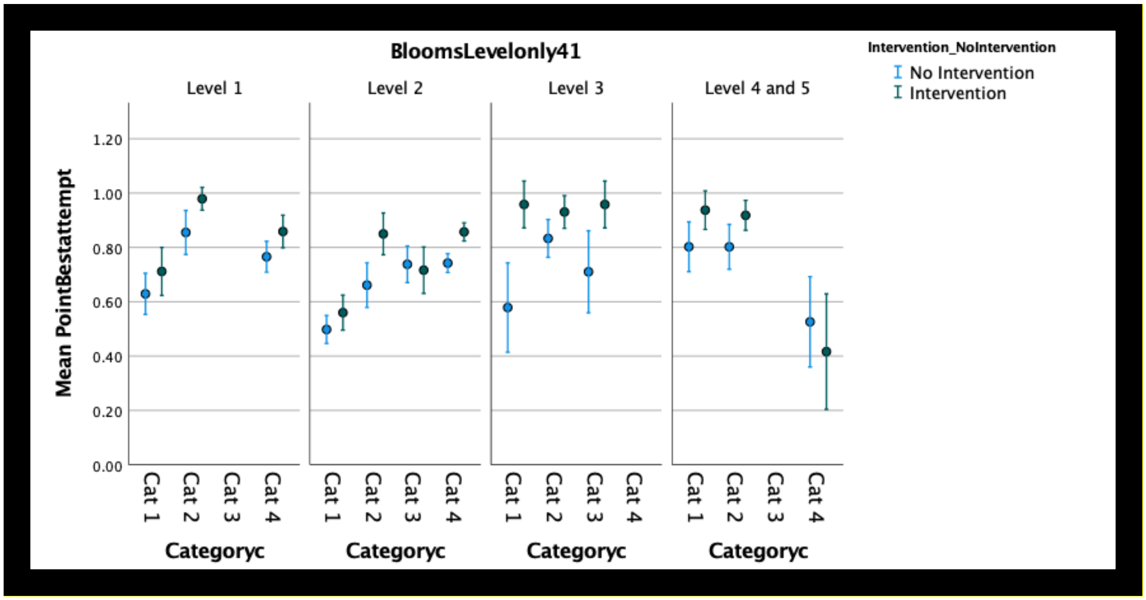


Figure 24. *Interaction between Intervention, Category, and Blooms Level.*

Exam 4: Comparing Question Scores_ Intervention Type Vs. No Intervention

A Three-Way ANOVA was conducted on a sample of 62 participants scores on exam 4 to compare the effects of intervention type, level of difficulty, and different biological concepts covered on question scores (Table 23). There was no significant three-way interaction, $F(18, 2923) = 1.008$, $p = .447$, partial $\eta 2=.006$. There was a statistically simple two-way interaction between the four levels of difficulty and the six categories (Table 23). There were also statistically significant simple main effect of intervention type, level of difficulty, and category (Table 23).

Table 23. 3-Way ANOVA Summary for Intervention Type, Blooms Level, and Categories for Exam 4.

	Type III Sum of Squares	**Degrees of freedom**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Intervention (Audio, Video, Interactive Video) vs No Intervention	4.243	3	1.414	9.029	<.001	.009
Level of Difficulty (Blooms)	3.692	3	1.231	7.856	<.001	.008
Category	3.721	3	1.240	7.917	<.001	.008
Intervention Type *Blooms	1.419	9	.158	1.006	.432	.003
Intervention Type *Category	.756	9	.084	.536	.849	.002
Blooms*Category	13.377	6	2.229	14.232	<.001	.028
Intervention Type*Blooms*Category	2.841	18	.158	1.008	.447	.006
Error	457.888	2923	.157			

Intervention type compared to no intervention

A univariate-test performed for question scores and intervention use indicated that the effect was statistically significant for students that used an intervention compared to students that did not use an intervention for Exam 3 (univariate test), $F(3, 2923) = 11.386$, $p < .001$, partial $\eta 2 = .012$. Comparing means, all students that used an intervention, intervention audio (.822 ± .035, (mean difference=.119, p=.002), video (.845 ± .025 (mean difference= .141, p<.001), and interactive video (.790 ± .026 (mean difference= .087, p=.003) scored significantly higher than students that did not use an intervention (.703 ± .013) (Figure 25*)*.

Level of difficulty (Blooms Taxonomy)

A univariate-test performed for Blooms Level found a statistically significant interaction between student scores and level of difficulty, $F(3, 2923) = 9.450$, $p < .001$, partial $\eta 2 = .010$. The modified population marginal means of question scores across all level 1 questions (.822 ± .022), level 2 questions (.724 ± .015), level 3 (.891 ± .033), and level 4/5 questions (.746 ± .034).

Category

A univariate-test performed for categories found a statistically significant interaction between student scores and category, $F(3, 2923) = 10.981$, $p < .001$, partial $\eta 2 = .011$. The modified population marginal means of question scores across the following five categories are category 1 (.753 ± .023), category 2 questions (.888 ± .024), category 3 questions (.806 ± .038), and category 4 questions (.699 ± .024).

Blooms Level and Category

A univariate-test performed for Blooms Level*Category found a statistically significant interaction between level of difficulty and category. Within the following categories, Category 1 ($F(3, 2923)= 21.408$, $p<.001$, partial $\eta2=.021$), Category 3 ($F(3, 2923)= 6.231$, $p=.013$, partial $\eta2=.002$), and Category 4 ($F(2, 2923)= 16.649$, $p<.001$, partial $\eta2=.011$), there was significance difference in mean scores across the various Blooms levels within each category. At the following levels, Level 1 ($F(2, 2923)= 10.468$, $p<.001$, partial $\eta2=.007$), Level 2 ($F(3, 2923)= 33.598$, $p<.001$, partial $\eta2=.033$), and Level 4 ($F(2, 2923)= 18.788$, $p<.001$, partial $\eta2=.013$), there was significance difference in mean scores across categories within each Blooms level.

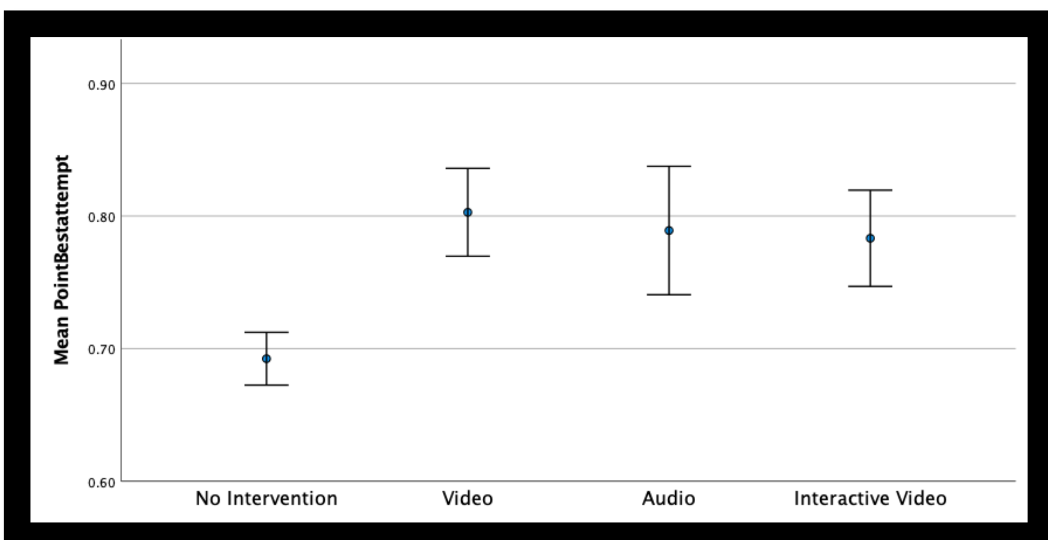


Figure 25. The mean question scores across intervention types on Exam 4.

Exam 5: Comparing Question Scores_ Intervention Vs. No Intervention

On Exam 5, there were 52 questions that fell under 5 categories: Category 1: Metabolism: Photosynthesis; Category 2: Climate Change and Human Environmental Impacts; Category 3: Ecology; Category 4: Biogeochemical Cycles; and Category 5: Sustainability and Alternative Energy Sources. The 52 questions were further divided into Blooms Level: Blooms Level 1: 10 questions; Blooms Level 2: 29 questions; Blooms Level 3: 11 Questions; and Blooms Level 4: 2 questions.

A Three-Way ANOVA was conducted on a sample of 60 participants scores on exam 5 to compare the effects of intervention use, level of difficulty, and different biological concepts covered on question scores (Table 24). There was a statistically significant three-way use of intervention, Blooms level, and category, $F(8,2968) = .375$, $p = .934$, partial $\eta 2 = .001$. There was a statistically simple two-way interaction between the four levels of difficulty and the five categories (Table 24). There was also statistically significant simple main effect across categories (Table 24).

Table 24. 3-Way ANOVA Summary for Intervention Use, Blooms Level, and Categories for Exam 5.

	Type III Sum of Squares	**Degrees of freedom**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Intervention vs No Intervention	.037	1	.037	.267	.605	.000
Level of Difficulty (Blooms)	1.017	3	.339	2.447	.062	.002
Category	6.182	4	1.545	11.153	<.001	.015
Intervention vs No Intervention *Blooms	.232	3	.077	.557	.643	.001
Intervention vs No Intervention *Category	.106	4	.026	.191	.943	.000
Blooms*Category	10.979	8	21.372	9.904	<.001	.026
Intervention vs No Intervention *Blooms*Category	.416	8	.052	.375	.934	.001
	411.274	2968	.139			

Category

A univariate-test performed for Blooms Level found a statistically significant interaction between student scores and category, $F(4,2968)= 15.733$, $p<.001$, partial $\eta 2=.021$. The modified population marginal means of question scores across the following four categories are category 1 (.810 ± .022), category 2 questions (.854 ± .017), category 3 questions (.846 ± .017), category 4 questions (.688 ± .017), and category 5 (.816 ± .016).

Blooms Level and Category

A univariate-test performed for Blooms Level*Category found a statistically significant interaction between level of difficulty and category. Within the following categories, Category 1 ($F(3, 2968)= 3.320$, $p=.019$, partial $\eta 2=.003$), Category 2 ($F(2, 2968)= 19.019$, $p<.001$, partial $\eta 2=.013$), Category 4 ($F(1, 2968)= 37.765$, $p<.001$, partial $\eta 2=.013$) and Category 5 ($F(2, 2968)= 4.981$, $p=.007$, partial $\eta 2=.003$), there was significance difference in mean scores across the various Blooms levels within each category. At the following levels, Level 1 ($F(3, 2968)= 3.818$, $p=.010$, partial $\eta 2=.004$), Level 2 ($F(4, 2968)= 4.787$, $p<.001$, partial $\eta 2=.006$), Level 3 ($F(4, 2968)= 17.251$, $p<.001$, partial $\eta 2=.023$), and Level 4 ($F(1, 2968)= 3.726$, $p=.05$, partial $\eta 2=.001$), there was significance difference in mean scores across categories within each Blooms level.

Exam 5: Comparing Question Scores_ Intervention Type Vs. No Intervention

A Three-Way ANOVA was conducted on a sample of 60 participants scores on exam 5 to compare the effects of intervention type, level of difficulty, and different biological concepts covered on question scores (Table 25). There was no significant three-way interaction, $F(24, 2936) = .788$, $p = .756$, partial $\eta 2$=.006 . There was a statistically simple two-way interaction between the four levels of difficulty and the five categories (Table 25). There were also statistically significant simple main effect of intervention type and category (Table 25).

Table 25. 3-Way ANOVA Summary for Intervention Type, Blooms Level, and Categories for Exam 5.

	Type III Sum of Squares	**Degrees of freedom**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Intervention (Audio, Video, Interactive Video) vs No Intervention	2.091	3	.697	5.079	.002	.005
Level of Difficulty (Blooms)	.847	3	.282	2.057	.104	.002
Category	5.579	4	1.395	10.164	<.001	.014
Intervention Type *Blooms	1.676	9	.186	1.357	.202	.004
Intervention Type *Category	1.643	12	.137	.998	.448	.004
Blooms*Category	7.558	8	.945	6.885	<.001	.018
Intervention Type*Blooms*Category	2.595	24	.108	.788	.756	.006
Error	402.878	2936	.137			

Intervention type compared to no intervention

A univariate-test performed for question scores and intervention use indicated that the effect was statistically significant for students that used an intervention compared to students that did not use an intervention for Exam 5 (univariate test), $F(3, 2923)= 11.386$, $p<.001$, partial $\eta 2 = .012$. Comparing means, all students that used an intervention video (.852 ± .018 (mean difference= .043, p=.046), scored significantly higher than students that did not use an intervention (.810 ± .012). Students that used intervention video (mean difference= .125, p<.001), interactive video (.824 ± .020 (mean difference= ..096, p=.004), and no intervention (mean difference= .082, p=.005) scored significantly higher than students that used intervention audio (.728 ± .026) (Figure 26).

Category

A univariate-test performed for categories found a statistically significant interaction between student scores and category, $F(4, 2936)= 13.680$, $p<.001$, partial $\eta 2= .018$. The modified population marginal means of question scores across the following five categories are category 1 (.796 ± .026), category 2 questions (.855 ± .020), category 3 questions (.830 ± .020), category 4 questions (.667 ± .020), and category 5 (.817± .019).

Blooms Level and Category

A univariate-test performed for Blooms Level*Category found a statistically significant interaction between level of difficulty and category. Within the following categories, Category 2 ($F(3, 2936)= 14.091$, $p<.001$, partial $\eta 2=.010$), Category 4 ($F(1, 2936)= 25.779$, $p<.001$, partial $\eta 2=.009$), and Category 5 ($F(2, 2936)= 4.772$, $p=.009$, partial $\eta 2=.003$), there was significance difference in mean scores across the various Blooms levels within each category. At the following levels, Level 1 ($F(3, 2936)= 2.899$, $p=.034$, partial $\eta 2=.003$), Level 2 ($F(4, 2936)= 4.619$, $p<.001$, partial $\eta 2=.006$), and Level 3 ($F(2, 2936)= 12.703$, $p<.001$, partial $\eta 2=.017$), there was significance difference in mean scores across categories within each Blooms level.

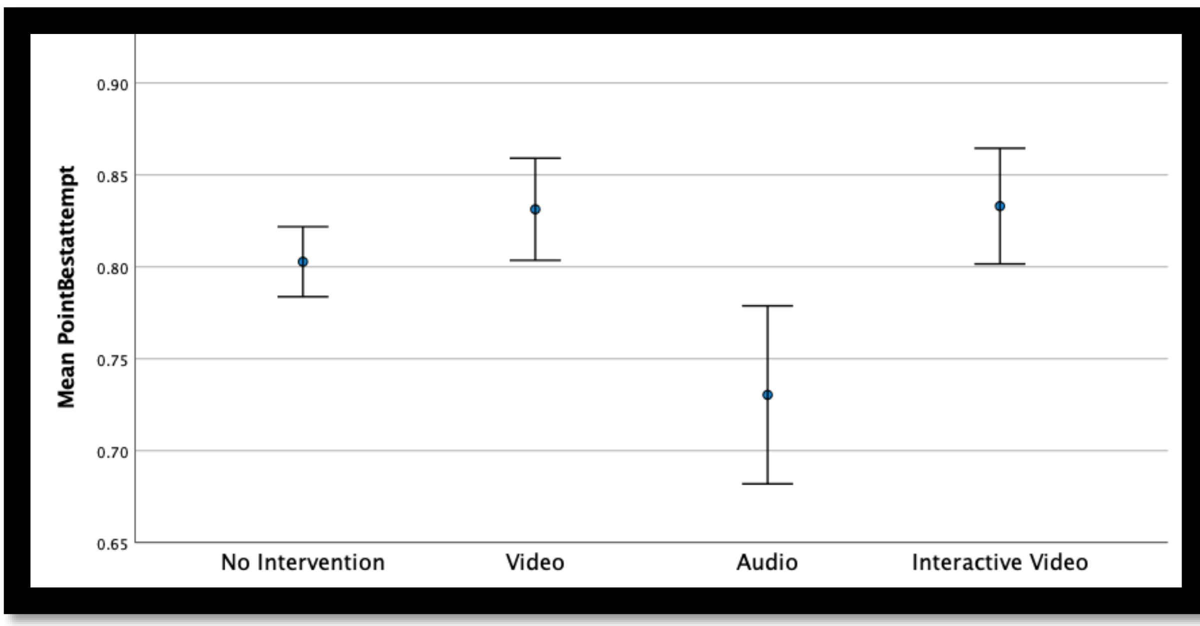


Figure 26. The mean question scores across intervention for Exam 5.

CHAPTER V-CONCLUSION

Trends in offering science-based online courses at institutes of higher learning have always been slower (Kennepohl and Shaw, 2010) than other subject matters. Unfortunately, the recent pandemic exposed how many teachers, specifically science teachers, were inadequately prepared to deliver materials to students online (Thurab-Nkhosi et al. 2021; Adedoyin and Emrah 2020). For most, recorded lectures became the way for instructors to replicate their face-to-face lectures. As faculty attempted to transition to online at an accelerated rate, the focus became solely on providing information instead of lecture capture design. In most situations, videos were unedited and continuous streaming, and there was no focus on how to deliver the information. As the pandemic continued and the move to online persisted more than one semester, instructors started to investigate factors, such as design, delivery method, and student use, regarding online lecture captures. From the research, the same reoccurring issues concerning lecture captures effectiveness became apparent concerning use and engagement (Zhang et al, 2021), and overall, what is considered high quality lecture capture content (Doi et al., 2022). While the following study was conducted prior to the pandemic, the data examined the effectiveness and ineffectiveness of different types of lecture captures in an online, nonmajors biology course, and conclusions drawn are still relevant concerning lecture captures available to students in an online classroom.

Hypothesis 1: Previous research in the field of Instructional Technology indicated that providing lecture captures only would have no significant impact on learning (Danielson et al. 2014; Ford et al., 2012; Euzent et al., 2011; Owston et al., 2011). When looking at exam scores and intervention use across all five exams for this study, the results were significantly different than described in previous studies. Students that used a lecture capture earned significantly higher exam score than students that did not use intervention. More specifically, if students used the interventions video and interactive video lecture capture, the students scored significantly higher on exams than students that used intervention audio lecture capture or no lecture capture at all. Therefore, the instruction styles, video and interactive video, are valuable instructional tool in the following nonmajors biology online course supporting that video lectures are able to build links that students typically cannot do with just reading the textbook (Kirkpatrick 1990). Since these resources serve as a viable source of information for online, asynchronous students, the same presentation of knowledge should also assist with web enhanced face-to-face courses (flipped or hybrid classroom). Based on the data if there is ever a need to switch to online, asynchronous courses again, video lecture captures would also serve viable sources to delivery information to online students (Adedoyin et al., 2020).

When comparing exam scores between exams, students that used lecture captures scored significantly higher on two out of five exams (exam 1 and 4) than students that did not use lecture captures. When examined more closely, students that used a specific type of lecture capture, video and interactive video, scored significantly higher on exams 1, 2, and 4 than students that did not use a lecture capture. Since each exam covered different biological concepts and varied in the degree of level of difficulty, the learning gains across the five different units should be considered when attempting to compare questions scores from exam to exam.

Hypothesis 2 and 3: Historically, students have struggled to learn biology (Johnstone and Mahmoud, 1980; Finley et al., 1982; Tolman, 1982; Anderson et al., 1990; Seymour and Longdon, 1991; Jennison and Reiss, 1991; Lazarowitz and Penso, 1992; Bahar et al., 1999). During a single semester, students are constantly being challenged and the continuous failure to understand the concepts negatively affects student motivation to continue in a course (Ozcan, 2003). Through the research, there are many explanations as to why biology is challenging for students (Lazarowitz and Penso, 1992; Tekkaya et al., 2001; Çimer, 2004; Zeidan, 2010): teaching methods, the abstract nature of biology (difficulty to understand), and curriculum overload (Tekkaya et al., 2001; Chiepetta and Fillman, 1998; Lazarowitz and Penso, 1992).

Blooms: Analysis across question difficulty (Blooms Taxonomy) revealed there was no significant difference in students' performance between students who used an intervention and students that did not use an intervention on higher level Blooms questions (Level 3: Application and Level 4/5: Analysis and Evaluate). When examined more closely, students that used interventions video scored significantly higher on Blooms Level 3 and Level 4/5 questions compared to students that did not use an intervention and intervention audio. While not significant, intervention audio scored lower than no intervention for Level 3 and 4/5 questions.

Categories: Due to the variability in categories covered in each of the five exams, it is important to take a closer look at comparing use of intervention and students that did not use an intervention. For Exams 1, 2, and 4, categories concerning organic macromolecules, cells, movement within a cell, energy, enzymes, respiration, cancer, cell cycle (mitosis and meiosis), immune system, viruses, and evidence for evolution were all categories in which students that used an intervention scored significantly higher on questions pertaining to these categories than students that did not use an intervention.

In 2004, Cimer found that students' attitude toward science was dependent on how topics were taught. If students were not happy about the teaching methods and how the information was being portrayed, they had a negative attitude towards biology and were disengaged and disinterested in the content. From this perspective, in an online classroom, there needs to be consideration in lecture capture design (how biology is being taught) to increase students view and success in learning biology. Therefore, I examined the various biology concepts that were taught over the semester and compared lecture captures styles and learning to see if students had the same success in learning these concepts across each lecture capture style.

Reflecting on data concerning Blooms taxonomy and historically challenging concepts in biology, the following intervention, video, provided students with a more meaningful explanation of the content and the ability to recall the information on an exam. In terms of the Cognitive Theory of Multimedia Learning (Mayer, 2005), the ability to present information through both audio and visual format simultaneously allowed students to process the content and create their own accurate mental interpretations of the materials shown in the videos. Therefore, the potential explanation as to why the following video lecture capture influenced grades in this study compared to others might be linked the lecture capture design and not necessarily whether students viewed the video lecture captures.

Lecture Capture Design

While research has shown that lecture captures available online are welcomed by students, research has also shown that lecture captures rarely help students achieve the learning outcomes for the course (Ford et al., 2012; Euzent et al., 2011; Owston et al., 2011). Part of the failure with lecture captures is that they are teacher-centered and lack opportunities for students to engage in the content being presented (Porcaro, 2011) boring students while they watch (Mann & Robinson, 2009; Moreno, 2007). Why? Instructors rarely do anything to make the lecture capture engaging (Gutbrod, Werner, & Fischer, 2006, p. 197) and post the materials after a quick recording session with no editing. Because this is the how most video lecture captures are presented to students as continuous stream of the information, the expanding number of available lectures captures in education may not necessarily be driven to improve student retention but to improve students' satisfaction (Johnston, Massa, & Burne, 2013).

According to the principles in the Cognitive Theory of Multimedia Learning, videos need to be edited to align to the 12 instructional design principles suggested by Mayer (2009). In the following study, two of the principles, segmenting (clicking) and signaling to important information, were used to improve the two types of lecture captures. For both video and interactive video, clicking slide to slide acted as segmenting tactic and broke the educational materials into short chunks. Because the student controlled when to move to the next slide and when to play the audio, students were able to process the information and free up their working memory before they moved onto the next slide (Sung & Mayer, 2013; Lusk et al., 2008; Smith, 2008).

For the interactive video, chunking information into smaller and smaller piece to match the audio added a signaling component to what the instructor was speaking about on the slide to help students identify what is important. Based on the research, signaling has been shown to clarify and increase understanding of information being presented in a video and reduce the extraneous load (Ibrahim et al., 2012; Smith, 2008). From this study, the use of both segmenting and signaling may have overloaded the students by forcing them to click too many times and overloaded their working memory reducing their ability to integrate the knowledge on the slides to prior knowledge.

In comparison to video lecture captures, audio lecture captures produced more variable results (sometimes positive, sometimes negative results). Compared to video lecture captures that were broken down into smaller units, the audio lecture capture contained one long streams of information and no visual media. When reflecting on cognitive load and how students learn, it all comes backs to working memory, difficulty of the concept's beings explained, prior knowledge, and the overall experience (Moreno & Park, 2010; Sweller, 1988, 2010). While listening to the audio lecture capture, the lengthen and the pace of the audio could have been too slow. The brain of the listener may have been processing the information at faster rate than the instructor had been speaking, and students may have gotten bored during the audio file, tuned information out, and clogged their working memory with thoughts not relevant to the topic (high extraneous load). Lamb 2015 also suggested students also with low prior knowledge of the subject matter and no visual aid to assist the student in learning the content, the student may not be able to properly process, organize, and integrate information into their memory without prior knowledge.

Unfortunately for audio lecture captures, they cannot be treated as multimedia (presentation with words, pictures, and audio), and there are no specific instructional guides based on constructivist principles to make audio lectures more engaging (Moreno & Park, 2010; Pang, 2009). Instead, instructors should follow similar suggestions for video lectures to apply to audio lectures. Audio lecture could potentially benefit from short and concise sound bites (segmenting) instead of one long streaming event to avoid boredom and high levels of extraneous load. There has also been some research on pace of the audio influences the listeners attention and could reduce boredom while listening to the audio file (Ernst and Colthorpe, 2006).

Why was their variability among lecture capture use between exams?

The potential flexibility of being able to view the lecture captures within a lengthy time frame could have potentially hindered students in preparation by feeling less pressure to view them in a weekly manner. In addition to the course design, students also could have other academic stressors within their major, and the following course could have not been considered high priority and with students waiting to watch the lectures just before the exam (Chen and Lin, 2012). By cramming before the exam, students most likely did not take detailed notes, and the lecture capture was not deemed helpful by the students. By misusing the lecture captures and having low academic success, students could deem the following lecture captures as having a negative supplement and fail to use them in the future (Owston et al., 2011).

The same rationale could be applied to why students switched between lecture capture styles from exam to exam. Students may have viewed one type of lecture capture as having low cognitive load with maximum cognitive gains, but the lack of effort, (failing to take notes or watching the lecture captures during a timely manner), had a negative impact on scores. Once deemed as a tool that hindered their learning, students failed to use the resource again.

Interestingly, Owston et al. 2011, found that students that built success using lecture captures may become too confident in their success and stop using lecture captures because they were unaware of how the lecture capture improved their learning. Owston et al. 2011 also found that that higher achieving students are able to determine sections of the lecture capture are relevant to them by speeding through the sections they did not need to review. While low level learners will tend to watch the entire lecture capture repeatedly. Low achievers most likely have not developed successful studying techniques, like note taking or reviewing only difficult concepts, and thinking listening and/or watching the lecture capture will allow the materials to “sink in.” When the students earned a low score, they did not find any value in the lecture capture and abandon any future use.

Interestingly, if at any point a student had technically difficult in accessing a lecture capture, students have been documented automatically distrusting any further use of a lecture capture since they deemed them unusable. In online courses, students located in areas with slow Internet connections and/or own computers that have low bandwidth capacity have higher reports of technically difficulties. Once again, if the student has a harder time accessing lecture captures, they will fail to use them in the future (Owston et al. 2011).

By exam five, students that did not use a lecture capture scored comparable scores to students that did use lecture capture video and interactive video, and students that used audio lecture capture scored significantly lower than all other groups. Looking over the categories, it could be assumed that the following relevant topics were a) more common knowledge to the students in the course, or b) by having little success in cramming before the exam using a lecture capture, Owston et al. 2011 suggested that students that did not use any lecture capture became stronger independent learners that learned to read the text and used provided materials within the text to prepare for assessments. If students did persist in using lecture captures successful than the lecture capture complemented their reading and note taking skills, and the students were most likely using the lecture captures to fill in areas where comprehension of the materials was low (Chen and Lin, 2012).

All the following reasons would suggest that more research needs to investigate how high achieving students and low achieving students use and view and their overall thoughts on the different lecture capture styles over the course of the semester.

Conclusion

In conclusion, whether a course is fully online or uses online lecture captures as supplemental materials for a face-to-face course, the quality of the digital content plays a significant impact on learning and student use.

Limitations

Limitations to this study include both general and specific to this study. In general, the study was conducted only once using a single, online class in a specific discipline. The findings, therefore, may not be generalizable to other disciplines, smaller/larger courses, or web enhanced courses. More specifically, the presentation style and other instructional approaches in this course could have affected the results.

Future Research

Since the early 2000s, multiple studies have been conducted on the different aspects of lecture captures (Kay, 2012). The results of the following study add to the current literature and further the understanding on lecture capture design, use, and impact in an online classroom. While the following study would be rendered more valid through repetition, the data is large enough that to suggest that video lectures with segmentation increases student success in an online, nonmajors biology course. Below are suggestions for future projects concerning lecture capture design for online students.

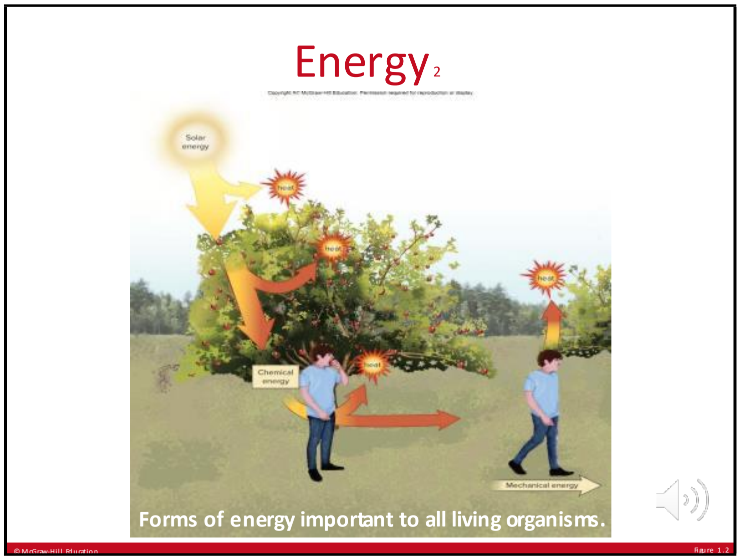
Lecture capture and student learning.

1. Although the overall findings indicated the use of a lecture capture, specifically video lecture capture, was the most effect style of lecture capture in the following course, the study did not imply why video lecture capture was an effect tool for some students and not effective tool for others. There still needs to be more research into various aspects of lecture capture design (length, speed, accessibility, visibility of instructor), cognitive load (segmentation and signaling, the number of visual aids, the clarity of visual aids in the video), supplemental

materials that are included with the lecture capture, and how the students deem the materials in the lecture capture relevant enough for them to watch.

2. A review of students having the ability to use similar lecture captures across multiple courses within biology (majors and/or upper-level courses) and across disciplines would determine if the positive impact of video lecture capture compared to audio lecture capture is the same within and across other disciplines in biology.
3. More research needs to be conducted on how students use the lecture recordings. (Do they take notes; Do they complete other activities while watching videos; when they watch them; do they watch the entire video)
4. In previous studies, students provided feedback that failing to associate points for watching video, for example, included embedded lecture quizzes to test their knowledge, or group activities after the lecture (Danielson et al., 2014) hinder students drive to listen to and/or watch the lecture captures. (No instructor in the video- lack of connectivity). In the future, embedded lecture quizzes (another type of interactive video) should be utilized to increase the engagement with the available instructional materials.

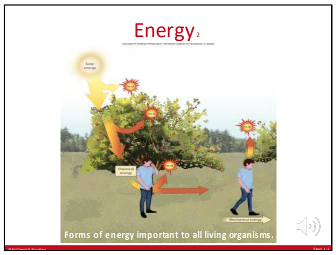
APPENDIX A– Example of Video with Segmenting



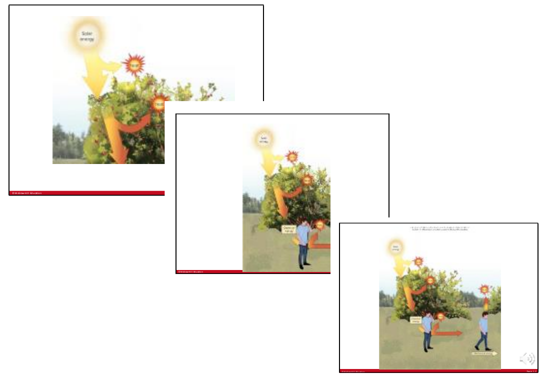
APPENDIX B- Comparison of Video and Interactive Video

Example 1:

Video (No Signaling)

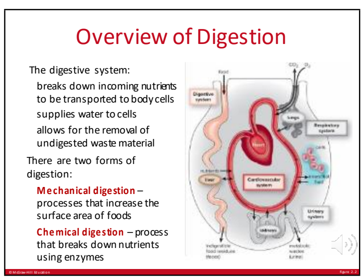


Interactive Video (Signaling)

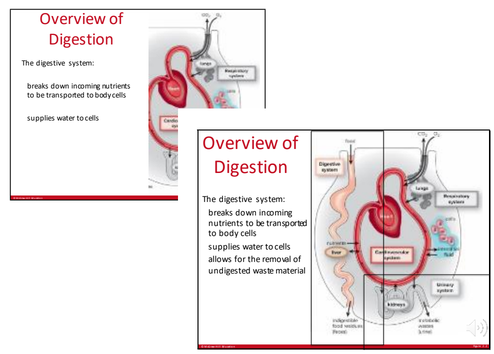


Example 2:

Video (No Signaling)

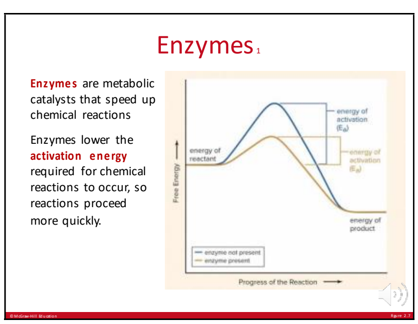


Interactive Video (Signaling)

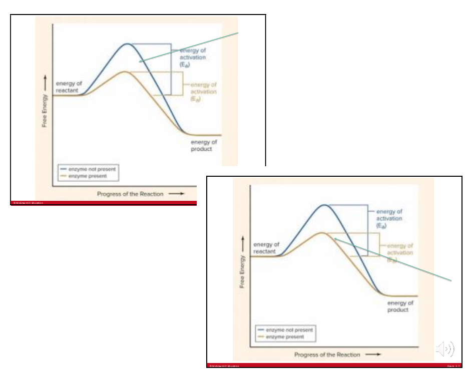


Example 3:

Video (No Signaling)

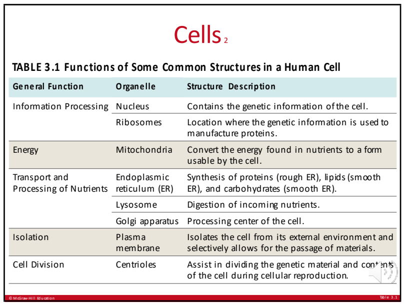


Interactive Video (Signaling)

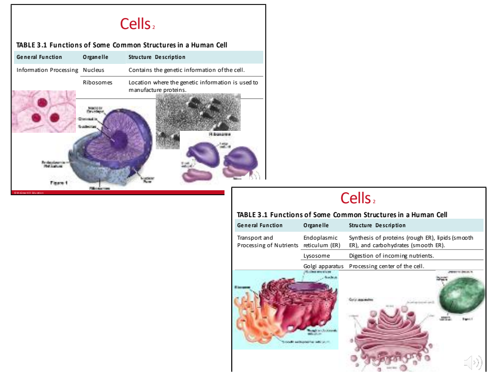


Example 4:

Video (No Signaling)

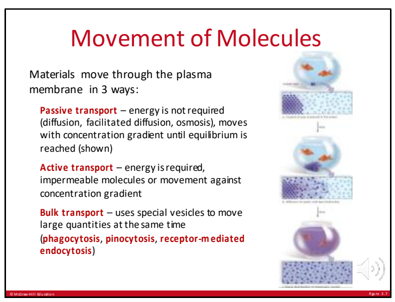


Interactive Video (Signaling)

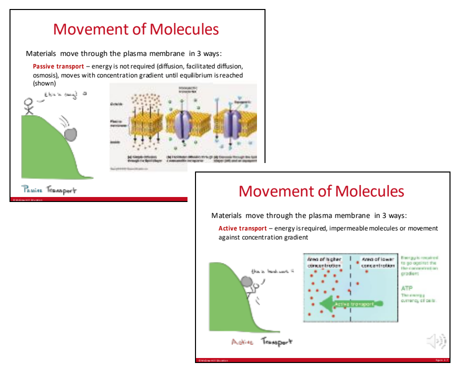


Example 5:

Video (No Signaling)

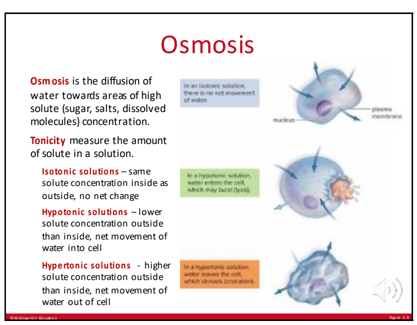


Interactive Video (Signaling)

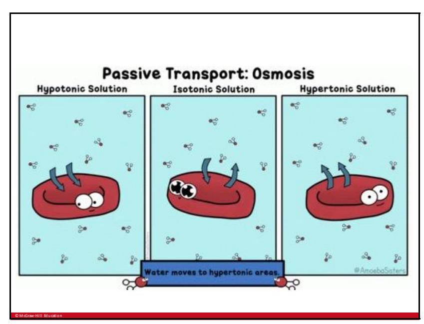


Example 6:

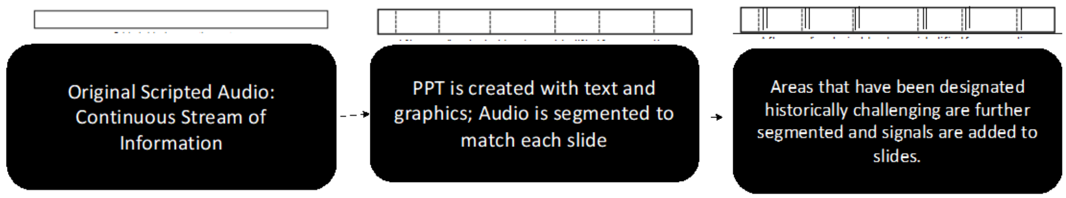
Video (No Signaling)



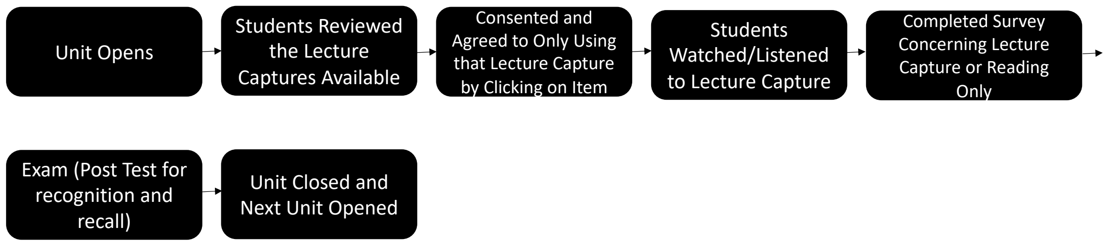
Interactive Video (Signaling)



APPENDIX C- Editing Protocol

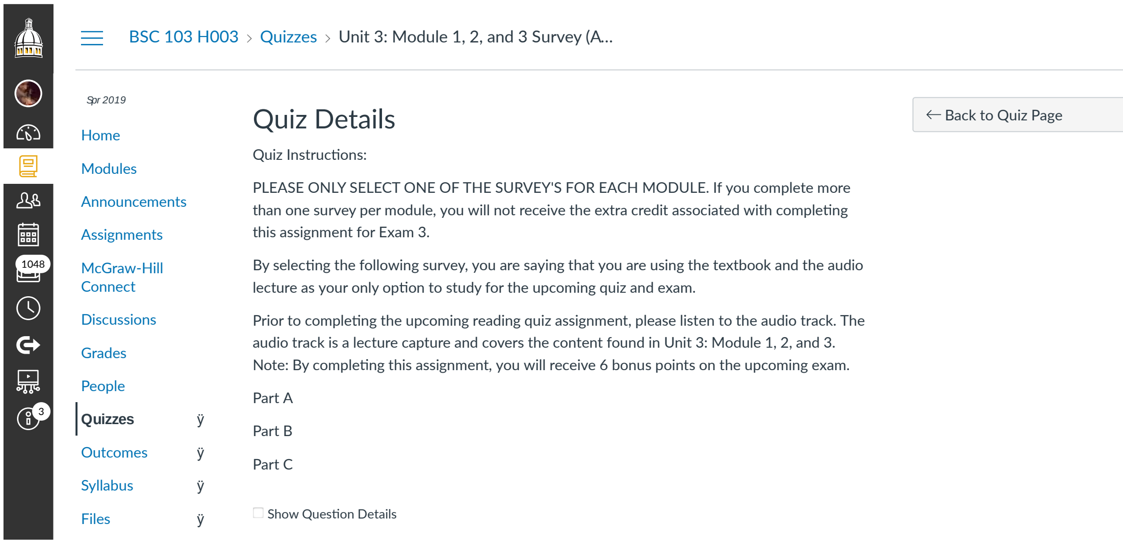


APPENDIX D- Study Procedure



APPENDIX E- Example Survey in Canvas

Part A: Study Description



BSC 103 H003 › Quizzes › Unit 3: Module 1, 2, and 3 Survey (A...

Spr 2019

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Quiz Details

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Quiz Instructions:

PLEASE ONLY SELECT ONE OF THE SURVEY'S FOR EACH MODULE. If you complete more than one survey per module, you will not receive the extra credit associated with completing this assignment for Exam 3.

By selecting the following survey, you are saying that you are using the textbook and the audio lecture as your only option to study for the upcoming quiz and exam.

Prior to completing the upcoming reading quiz assignment, please listen to the audio track. The audio track is a lecture capture and covers the content found in Unit 3: Module 1, 2, and 3. Note: By completing this assignment, you will receive 6 bonus points on the upcoming exam.

Part A

Part B

Part C

Show Question Details

Part B: Survey Questions

Pages ÿ
BigBlueButton ÿ
Collaborations ÿ
Rubrics
Library Resources
Cisco Webex

Question **1 pts**

Please rate your level of mental effort on completing the assigned task. Think of mental effort as how "hard" you had to think to complete the task.

Question **1 pts**

Prior to listening to the audio file and reading your textbook, rate the level of knowledge you believe you had on the following subjects: genes, characteristics of genetic diseases, DNA the genetic material, how DNA is copied, how genes are expressed, sexual reproduction, and general patterns of inheritance?

Question **1 pts**

After listening to the audio file and reading your textbook, rate your level of knowledge you now have on the following subjects: genes, characteristics of genetic diseases, DNA the genetic material, how DNA is copied, how genes are expressed, sexual reproduction, and general patterns of inheritance?

Question **1 pts**

After listening to the audio file and reading your textbook, please rate your level of confidence on how well you understand the following concepts: genes, characteristics of genetic diseases, DNA the genetic material, how DNA is copied, how genes are expressed, sexual reproduction, and general patterns of inheritance?

Question **1 pts**

Please indicate how difficult it was to understanding the following concepts (genes, characteristics of genetic diseases, DNA the genetic material, how DNA is copied, how genes are expressed, sexual reproduction, and general patterns of inheritance) by checking the appropriate answer.

Question **1 pts**

Rate the level of how well you believe listening to the audio file prepared you for the upcoming assessments in the course?

APPENDIX F–IRB Approval Letter

THE UNIVERSITY OF
SOUTHERN MISSISSIPPI

INSTITUTIONAL REVIEW BOARD
118 College Drive #5147 | Hattiesburg, MS 39406-0001
Phone: 601.266.5997 | Fax: 601.266.4377 | www.usm.edu/research/institutional.review.board

NOTICE OF COMMITTEE ACTION

The project has been reviewed by The University of Southern Mississippi Institutional Review Board in accordance with Federal Drug Administration regulations (21 CFR 26, 111), Department of Health and Human Services (45 CFR Part 46), and university guidelines to ensure adherence to the following criteria:

- The risks to subjects are minimized.
- The risks to subjects are reasonable in relation to the anticipated benefits.
- The selection of subjects is equitable.
- Informed consent is adequate and appropriately documented.
- Where appropriate, the research plan makes adequate provisions for monitoring the data collected to ensure the safety of the subjects.
- Where appropriate, there are adequate provisions to protect the privacy of subjects and to maintain the confidentiality of all data.
- Appropriate additional safeguards have been included to protect vulnerable subjects.
- Any unanticipated, serious, or continuing problems encountered regarding risks to subjects must be reported immediately, but not later than 10 days following the event. This should be reported to the IRB Office via the "Adverse Effect Report Form".
- If approved, the maximum period of approval is limited to twelve months.
  Projects that exceed this period must submit an application for renewal or continuation.

PROTOCOL NUMBER: 12345678
PROJECT TITLE: How to Achieve IRB Approval at USM
PROJECT TYPE: New Project
RESEARCHER(S): Jonas Doe
COLLEGE/DIVISION: College of Education and Psychology
DEPARTMENT: Psychology
FUNDING AGENCY/SPONSOR: N/A
IRB COMMITTEE ACTION: Expedited Review Approval
PERIOD OF APPROVAL: 01/02/2015 to 01/01/2016
Lawrence A. Hosman, Ph.D.
Institutional Review Board

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