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Online Versus Hybrid Instruction in Undergraduate Cell biology: A Comparative Study on Student Achievement

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by

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Abstract

There is a consistent concern for students' success in undergraduate introductory cell biology as this foundational course may impact their persistence towards earning a degree in the health sciences. Institutions need to consider the delivery method of instruction and the potential impacts on student success and enrollment. For five years, the same instructor taught an undergraduate cellular and molecular biology course using two different teaching methods; hybrid in-person and asynchronous online. Both groups have the same learning outcomes and received the same summative assessments. This exploration provides detailed procedures of the two instructional design models and compares overall semester summative and formative student achievement using a one-way multivariate analysis of variance. Quantitative results indicated that online and hybrid courses slightly differ in summative academic achievement (favoring hybrid) and significantly in formative achievement (favoring online). An end-of-semester survey was also investigated for thematic elements. Survey analysis revealed an overall positive response to both formats and insight into activities and resources that students found crucial to their learning. Implications of this study provide recommendations and elements for course design and policy.

Keywords: community college, biology, online, hybrid, assessment, student achievement

Dedication

I dedicate this work to my loving family. You have been very supportive and, by association, also endured the challenges of graduate school. I am genuinely thankful for having you all in my life!

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Special acknowledgment and gratitude towards Dr. Leping Liu, who made this work possible. Dr. Liu's knowledge and advice have been instrumental. Thank you for shaping my development in educational research, and I hope to continue to work with you!

I would like to recognize all the students who made this study possible. Your hard work and honest feedback provided me with critical insight that has contributed to this work and motivated me to improve instruction; for that, I am grateful.

I thank Timothy Ill, videographer of Truckee Meadows Community College, for recording and uploading lectures that were of axial importance to this study. I've heard many students claim that they benefit from the impression that they are in the actual classroom.

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Glossary/Abbreviations

Term	**Definition**
Online instruction	A teaching method that involves students learning from support materials that are supplied by online access. In this study, this method involves 100% online, asynchronous interaction. There are many variations, including synchronous (live), and some use both components.
Hybrid instruction	A teaching method that involves the combination of online resources with face-to-face instruction.
Flipped instruction	A method of instruction that requires students to preview and study instructional materials before arriving in a face-to-face environment.
STEM	Science, technology, engineering, and math
IRAT	Individual reassurance assessment test: a formative quiz that students take to check their understanding of chapter material. It is taken without resources and students do not receive a score when submitting.
GRAT	Group reassurance assessment test: a formative quiz containing the same questions as the IRAT. Immediately following completion of the IRAT, students gather in their group to discuss and debate over correct answers.
LMS (Learning Management System)	A learning management system is a software application for the administration, documentation, tracking, reporting, automation, and delivery of educational courses, training programs, or learning and development programs.

CHAPTER I: INTRODUCTION

Background

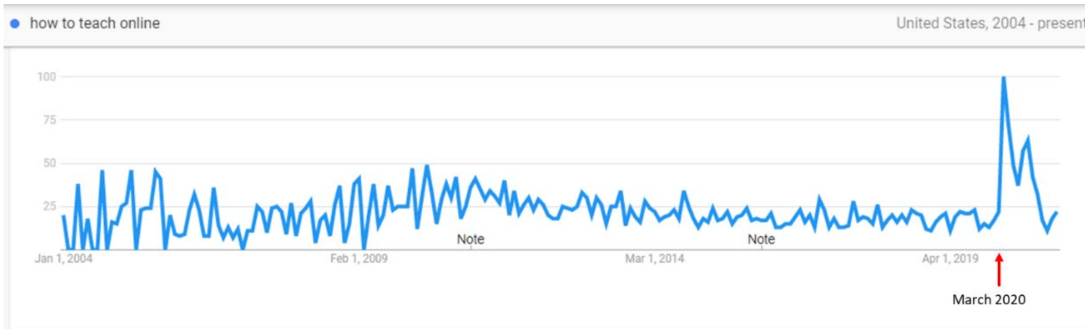
For much of higher education history and persists today, students sit in traditional rows, and teachers stand in the front of the classroom and lecture. Students are expected to listen carefully, take notes, study, and then be given an exam evaluating how well the students remembered and processed that information. However, the method of instruction is actively and quickly changing in response to an increase in the availability of faster, cheaper, lighter computers and improved access to information online.

The effect of better technology has made a pronounced impact on recent education in many ways. Online courses, interactive educational platforms, learning management systems, accessible video, and animations have made vast advances in the last 20 years. According to the National Center for Education Statistics (*The NCES Fast Facts Tool Provides Quick Answers to Many Education Questions (National Center for Education Statistics)*, n.d.), the number of students that took at least one course online has doubled from 2012 to 2018. The term "online course" has been loosely applied to represent a way of teaching a course that does not meet in person. With the support of advancing technology, the number of online courses has increased. Still, learning management systems have made it easy for instructors to allow for other variations of technology-dependent courses. Variations of models for online instruction exist, such as asynchronous and synchronous, or even a mixture of the two. Learning management systems and improved technology has allowed for increased online support, so much so that there are as many as ten distinct e-learning models (*All 10 Types of E-Learning Explained | E-Student*, n.d.).

Although the increase of technology-dependent instruction has been on the rise very recently, an unprecedented spike in online education occurred in the spring of 2020 because of the Covid-19 pandemic and social distancing pressures. According to Google Trends, a tremendous interest in "How to teach online" spiked in March of 2020. It can be assumed that instructors were scrambling to gain information on converting their courses to remote instruction (see Figure 1). The first spike noted in March 2020 aligns with when social distancing was mandated. The second, lesser spike in Figure 1 arose in August of 2020, in which one might assume that instructors were preparing for the upcoming fall semester. This same sharp increase in "How to teach online" was also evident worldwide. The impact of the pandemic undoubtedly forged the pace of reformed education in many ways and will likely be referred to as a historical moment in education.

Figure 1

Google Trends: United States search frequency "How to teach online" from 2004 to present.



The impact of the pandemic in March of 2020 caused 98% of higher education institutions to move from in-person to online by April (*Distance Learning Statistics [2021]*, n.d.). The severe and swift forced change of content delivery from primarily in-person to online brought the concerns of best practices in course design to the forefront. Arguably, many courses in higher education may have had minor alterations in course design because of short notice.

The most straightforward strategy was moving to synchronous Zoom lectures and retaining the same basic didactic pedagogy. As there was a clear up-rise in internet searches during March of 2020, many instructors sought how to teach online and had relatively little time to decide on the best method for their content. Will their course be better presented as synchronous, asynchronous, or some combination? How will the assessment be altered? In some cases, an asynchronous online design may lend itself to specific learning environments, whereas synchronous is not ideal. No matter the situation, developing an effective online course design is very time-consuming, and the pandemic undoubtedly had many instructors struggling.

Undeniably, educational research will want to evaluate the differences in how students performed in classes that were intended to be taught in-person but were switched to online midstream. Many called the current crisis "the biggest educational technology experiment in history" (J. Anderson, n.d.; Daniel, 2020). From the student's perspective, the pandemic caused many extra stressors. These include issues such as establishing a reliable home internet and finding resources such as a computer or video camera. Some may have had to juggle their schoolwork and look after their children or siblings because of school closures, economic stressors, loss of job, or loss of family or friends due to COVID. These are only a sampling of complications that could make learning problematic. The results of the pandemic switch to online instruction will be exciting and will perhaps be the topic of research for many years, providing insight as the data unfolds.

The exodus of the physical classroom caused by the pandemic and the subsequent substitution by the use of technology was coined the "Zoom Boom" (*Synchronous Instruction Is Hot Right Now, but Is It Sustainable?*, n.d.). Instead of stepping into lecture halls, students can literally roll out of bed and log into their screens, perhaps not even getting out of bed. This may have some advantages, however, as a result of "Zooming" all day in class or other meetings, students, instructors, and employees of all types are experiencing "Zoom fatigue," a term that did not necessarily exist before the pandemic. According to *Australasian Psychiatry*, Chronic Zoom Syndrome (CZS) is a new diagnosis of paramount significance in the emergence of mental health disorders (K. Anderson & Looi, 2020). The "Zoom Boomers" with CZS are afflicted with clinically significant distress and disruption to occupational and social function (K. Anderson & Looi, 2020). According to the National Association of School Psychologists, screen exhaustion results from a multifaceted combination of factors that result from videoconferencing. Some of the elements are nonverbal cues (causing stress) and negative associations with consistent physical surroundings (Florell, 2020). Concerns deliberate the effects of the overabundant application of online design caused by the pandemic. A primary concern is the loss of genuine social interactions and networking. According to a survey study about educational outcomes regarding the emergency semester switch to online led by Pypenko, et al., encouragingly, 68.5% of teachers are positive, compared to a surprising 90.0% of students surveyed. In contrast to this positive outcome, social distancing had a significant negative impact on students' and instructors' mental and physical health (Pypenko et al., 2020).

The sudden switch to remote instruction caused by the pandemic negatively affected achievement in public education, especially in math (Kuhfeld et al., n.d.). Elementary and middle schools were impacted during the pandemic in math achievement compared to the fall of 2019, exemplified by grades 3-8, which saw a drop of 5 to 10 percentile points (Kuhfeld et al., n.d.). According to Inside Higher ED, overall higher education enrollment for the Fall of 2020 dropped at twice the rate of decline recorded a year earlier, with a much more significant impact on community colleges that saw a 13% decline in freshman enrollment (*Final Fall Enrollment Numbers Show Pandemic's Full Impact*, n.d.). Likely reasons attributed to this would be the economic recession, loss of employment, dealing with new responsibilities for children or siblings, and relocation or housing-related issues.

Community college students tend to have more disparities than institutional college students (Mohammadian et al., 2021; S. Travers, 2016; Xu, 2018a). As educational inequities exist and are growing (Duncan et al., 2019), one can expect that the pandemic has widened the gap in this population. Many students who faced learning difficulties with fewer resources under normal circumstances were impacted in a much greater degree during school closures. Some students have little to no ability to connect with their classrooms from home. The gap between socioeconomic groups is exacerbated by requirements that distance learning imposes, and many had an interruption in education, leading to students falling further behind, forming the "gap population". Research shows that online learning is only effective if students have a computer with reliable internet service, along with the stipulation that instructors have been trained for online content delivery ("COVID-19 and Student Performance, Equity, and U.S. Education Policy," n.d.). This problem significantly affects children in K-12, where the children who struggle the hardest to learn effectively and thrive in school under normal circumstances are now finding it even more difficult, impossible in some cases, to receive effective instruction. These issues may have an unfortunate ripple effect to dishearten the gap population to aspire to apply to higher education institutions.

Although the pandemic push for online courses has negative implications, remote education has many positive aspects. Asynchronous online instruction offers flexible time for balancing work, kids, and school. It is advantageous to students to open their schedule to hold a day job, especially without commuting to a physical class. Less traveling saves time, money, fuel, possible traffic delays, parking (parking fees), and stress associated with rushing to class on time. For some students, affording a reliable car is a considerable expense, so an online course can be an economical solution. This difference could be a deal-breaker for those who cannot afford to pursue a higher education degree. From an administrative perspective, online courses make scheduling easy since a room isn't needed, and crowding issues may be resolved. Despite the appeal of online classes in higher education to both students and administration, there exists a hesitance for some faculty to present online, especially for biology (Kopachena, 2018).

The impact of the pandemic may well have a significant immediate effect on our educational system since most higher education instructors were forced to convert their classes to online instruction in the spring of 2020. Some instructors strongly oppose teaching online (Kennepohl & Shaw, 2010; McNeal, 2015). In the case of faculty members who disagree with the philosophy of teaching online or faculty who need training, this may have presented a problem with poor course design or lack of instructor use of technology, negatively affecting student-learning outcomes during the pandemic.

General statement of the problem

There has been an increasing concern, and it has been made a national priority to promote more students graduating with science, technology, engineering, and mathematics (STEM) related degrees to supply the demands for STEM-related occupations (X. Chen, 2013). Many high-paying careers in the modern workplace have a basis in STEM. Yet despite increasing demand, the United States faces problems with a lack of enrollment and low retention rates of students who are initially attracted to a STEM career (Turetsky et al., 2020; Watkins & Mazur, 2013; Xue & Larson, 2015). Additionally, there is evidence that introductory STEM courses, negatively referred to as "weed-out" classes, disproportionately hinder underrepresented groups (including women, Black, Native American, and Hispanic people) from obtaining STEM degrees (Mervis, 2011). In a survey by the Bayer Foundation, it was found that 57% of the department chairs that oversee undergraduate education feel that there is no need to significantly change their courses to retain more students, including those that are underserved (Mervis, 2011). Some instructors lack direction or motivation to alter the traditional didactic form of education, which perpetuate disparities and the lack of student satisfaction, achievement, and overall retention. Thus, fewer students are moving towards their goals, contributing to the loss of a more diverse professional workforce.

In a six-year longitudinal study, it was found that bachelor's degree-seeking STEM students had 48% attrition. About half of the students switched to another non-STEM degree, and the others dropped out of college altogether (X. Chen, 2013).

Moreover, this study found that while STEM students with low grade point averages (GPA) were more likely to drop out, higher GPA students were more inclined to switch to a non-STEM major. One may hypothesize that the higher-performing students are leaving STEM because of a lack of interest, or the difficulty turned out to be more difficult than perceived. Hence, the students choose a non-STEM major. A change in course design had positive changes for an introductory chemistry course at the University of Maryland, Baltimore County (UMBC). Chemistry 101 was reported as a "weed-out course" by the school newspaper. This claim helped motivate conscientious instructors to overhaul introductory chemistry courses to have fewer lectures and have more "discovery learning." The transformation was the switch from all lectures to more occasional lectures. The remaining time was spent with student teams and teaching assistants grappling together to solve problems on a whiteboard. With this change in place, researchers found that pass rates increased by 15%, attendance improved, and better student retention occurred (Mervis, 2010). These results are encouraging and inspire cogitation for renovation in instructional design since high attrition in STEM courses has been and continues to be a concern. (X. Chen, 2013; Ledbetter, 2012; Witteveen & Attewell, 2020).

Of particular note, there is a collective concern about the sustainability of the healthcare profession. More than a decade ago, health professionals made it clear that the shortage of healthcare professionals would be a severe problem. In 2009, the *National Academies Press* for sciences, engineering, and medicine published their findings stating their predictions regarding a significant lack of healthcare professionals that would be needed to care for the upcoming sizeable elderly population often referred to as "boomers," short for "baby boomers," which is the generation born between 1946 to 1964. This large population bracket comprises roughly 23.5% of the United States population (*U.S. Population by Generation 2019*, n.d.). It would be essentially doubling the number of patients aged 57- 75 in the upcoming decades, along with a predicted 25 million increase in the general population. Compounding this problem is the expected retirement of a large portion of the healthcare workforce (Medicine, 1 C.E.). A more recent report by Mercer, a prominent analyst consulting firm, concluded that by 2025, there would be a shortage of more than 400,000 home health aides and 29,400 nurse practitioners (*Healthcare Labor Market Analysis*, n.d.). Data published in 2020 by the Association of American Medical Colleges (AAMC) claim that healthcare physicians will also have a significant shortage in the coming years. This report states that in addition to a large group of retiring physicians and physicians retiring early due to burnout, younger physicians want more work-life balance and do not wish to work a whole week (*New AAMC Report Confirms Growing Physician Shortage*, n.d.). The AAMC report declares how the COVID-19 pandemic has made the lack of physicians more evident as the country's increasing health care demands have exceeded available care. Other health-related technical degrees/certification programs are also not meeting graduating enough students to meet predicted demands (Medicine, 1 C.E.). The root of healthcare problems is the demand for an increased supply of STEM students.

Unfortunately, STEM-based student enrollment and retention continue to be an issue (X. Chen, 2013; Mervis, 2011; Olson & Riordan, 2012; Wilton et al., 2019; Witteveen & Attewell, 2020).

Student experiences in first-year introductory or "gateway" STEM courses greatly influence attrition and overall persistence in STEM academics and their professional career pathways (Suresh, 2006; Watkins & Mazur, 2013). Classroom climate, faculty behaviors, and general course design are significant contributors to that experience. Studies on gateway STEM courses suggest course improvement with various methods such as psychological intervention (Turetsky et al., 2020), better communication (Meaders et al., 2020), peer or teaching aid support (Batz et al., 2015; Crouch & Mazur, 2001), and changing the learning design to encourage engagement such as flipping the course (Adams et al., 2016; Barral et al., 2018). The issues listed above may reveal ways to improve introductory course retention.

A 2012 report by the President's Council of Advisors on Science and Technology (PCAST) (Olson & Riordan, 2012). This report posits the goal for one million more STEM graduates over the next decade to meet the demands for science and technology positions and therefore bolster the economy. This report calls for the following recommendations for transformation to help retain STEM undergraduates:

1. Catalyze widespread adoption of empirically validated teaching practices.
2. Advocate and provide support for replacing standard laboratory courses with discovery-based research courses.

3. Launch a national experiment in postsecondary mathematics education to address the mathematics preparation gap.

4. Encourage partnerships among stakeholders to diversify pathways to STEM careers.

5. Create a Presidential Council on STEM Education with leadership from the academic and business communities to provide strategic leadership for transformative and sustainable change in STEM undergraduate education.

One of the salient aspects of the report is that engagement is the key to retention. Students in traditional lecture courses were twice as likely to leave engineering and three times as likely to drop out of college entirely compared with students taught using techniques that engaged them actively in class (Olson & Riordan, 2012).

Specific Statement of the Problem

To address low attrition, instructors and administrators need to know what course designs are effective for students taking an entry-level cell biology course. A better understanding of student success and course design would provide guidelines for instructors looking to renovate course design for the goal of better student achievement and retention. Of specific interest to this paper is an undergraduate cell biology course, which is foundational for anyone interested in health or healthcare.

In the fall of 2016, the researcher wanted to develop an online platform for an introductory undergraduate cell biology course. The department chair thought some instructors were hesitant to allow it, so a biology department meeting voted to decide if the online course was permitted. Mostly, the reticent faculty were concerned that most students already struggle in this course, based on their experiences. Some proclaimed that if the course were to be offered online, most students would fail because the online component would require more self-discipline than a traditional course. Other faculty expressed concerns that an online course would provide a lack of student /instructor interaction and, therefore, a lack of support, which would lead to poor outcomes, possibly worse than in-person. Consequently, the course was allowed to be taught. However, only one section would be permitted per semester as a pilot, and a follow-up was required for faculty committee evaluation to allow continuation.

In the Spring of 2017, the asynchronous online cell introductory biology course was developed and launched. After the first two semesters, an evaluation showed no noticeable difference compared to in-person instruction, although the population of students was low. Since then, at least one online course has taken place every semester for over four years. Concurrently, the researcher had also been teaching the same course but with an in-person hybrid model. Over time, the number of students has accumulated to provide a larger population to more reliably answer the question that concerns the biology faculty at the onset. Do introductory biology students achieve differently in an asynchronous online environment than in an in-person course? What experiences or opinions do students have that may lead us to gain insight into course design and better student support? These questions are the basis for this study.

Purpose and Research Questions of the Study

There are many choices in course design to meet the needs of a diverse learning environment. Instructors want to know what design model is best for student learning. The purpose of this study is to compare two models of instruction based on student achievement. Specifically, this study will explore differences in student achievement (formative and summative) among students who enrolled in two different instruction formats for an introductory undergraduate biology course. The comparison is between asynchronous online and hybrid (flipped in-person) instruction. This study will also explore student feedback on activities and resources. The two research questions for this study are the following:

RQ1: What differences exist with overall percent achievement in formative and summative assessments when comparing hybrid and online instructional models in an introductory cell biology course?

RQ2: Will analysis of a student survey indicate trends, themes, or patterns based on student experiences with online and hybrid learning? If so, does the data reveal notable differences when comparing hybrid and online teaching methods?

Significance of the Study

Academic motivation, achievement, and retention are interconnected in any learning environment (Boekaerts, 1986; Dwyer et al., 2020; T. M. Freeman et al., 2007; Laskey & Hetzel, 2011). The need for STEM student retention has been established, yet instructors are resistant/hesitant to change programs from standard lecture to other formats to enhance student motivation to learn. Introductory cell biology classes fall into the “weeder” class category for students looking into a career in the health industry in which there is a great demand. It has been established that traditional methods are not as effective as most non-traditional course designs (Barral et al., 2018; Hake, 1998; Knight & Wood, 2005a; Xie et al., 2015a). However, little research has been done to compare and establish best practices between non-traditional course designs (McCutcheon et al., 2015; Nfor, 2015; Sellnow-Richmond et al., 2020). This study will compare two “polar opposites” in terms of non-traditional methods of instruction for an introductory undergraduate cell biology course. One course being an asynchronous online course where students are independent and have few instructor and peer interactions. The other course is a hybrid “flipped” design in which students meet regularly, are highly engaged, and interact more with the instructor and peers.

CHAPTER II: LITERATURE REVIEW

Introduction

This chapter will cover a literature review of challenges in STEM education, followed by an appraisal of how concerned educators have addressed these challenges. The focus will then shift to a review of improvement attempts by instructional design components, followed by a focus on the literature, specifically on online and hybrid learning formats. This chapter will include the history of methods used for STEM instruction, theoretical approaches, design challenges, changes and attempts towards STEM retention, student/faculty attitudes toward instructional design, and the reasons for recommendations for reform of course design and delivery specifically dedicated to cover these components towards online and hybrid instruction. Aspects of the two teaching methods will tend to focus on literature involving undergraduate biology related to similar specific parameters of this study.

Issues in Undergraduate STEM Learning

STEM courses in higher education provide a crucial role in creating a strong workforce for the future, providing national security, and stabilizing the economy. Employment that required a STEM-based education has increased three times faster than non-STEM jobs in a ten-year period between 2001 and 2011, which came to 7.6 million STEM workers (Langdon et al., 2011). The U.S. Department of Commerce projected to continue this growth in that publication. The United States will need about 1.3 million additional STEM workers by 2018 (Langdon et al., 2011).

The National Science Board (2010), appropriated by the National Science Foundation, claimed that the United States, a world leader in science, may be falling behind when compared to other nations. In 2012, the National Science Board reported that the United States had a lower ratio of STEM to non-STEM degrees when compared to other countries, including many that have fewer resources. Stakeholders and policymakers became concerned that the United States would lose its leading role in the global market (Watkins & Mazur, 2013; Xie, 2014; Xie et al., 2015b). Concern was primarily focused on the leading competitor, China.

In 2009, China outscored the world in science, math, and reading according to the Program for International Student Assessment (PISA), which is delivered to 15-year-olds in 65 countries. Comparatively, U.S. students' performance on this exam was unexceptional, causing the Secretary of Education Arne Duncan to declare this a "wake-up call" (Xie, 2014). At that time, China also surpassed Japan in the PISA assessment, which was no small feat. This success may be due to the Chinese government systematically increasing investment funds into scientific research and development. Those investments continued to escalate (Griffiths et al., n.d.). In a historic moment in 2009, China matched the U.S. with the dollar amount of funding dedicated to research and development, a 28% increase for China that year.

At this time, the United States reacted for fear of losing its dominance in science. Broad calls to reform STEM education expounded, especially in undergraduate STEM education. In July of 2009, with funding from the National Science Foundation, the final report of a national conference organized by the American Association for the Advancement of Science presented a document entitled: "Vision and Change in Undergraduate Education: A Call to Action" (*Vision and Change in Undergraduate Biology Education » Final Report*, n.d.). This document had a diverse collection of scientists and educators contributing and was produced in efforts to support STEM reform, especially in biology (Ledbetter, 2012). The "Call to Action" document conveys general and specific suggestions for instructional reform that employ student-centered learning and a more engaged learning format.

Additionally, in 2009, President Obama initiated the "Educate to Innovate" campaign, which was a movement dedicated to improving international achievement among American students in STEM. In 2012, the President's Council of Advisors on Science and Technology (PCAST) presented a report entitled: "Engage to Excel: Production One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics." In this document, the PCAST offers five salient recommendations to reform undergraduate introductory STEM courses, which were mentioned in the introduction of this paper. Authors of PCAST claim that the main obstacles involve "faculty awareness and performance, reward and incentive systems, and traditions in higher education" (Olson & Riordan, 2012). This official document gained national attention when received by President Obama, as it allowed for a heightened awareness of the necessity to improve science education. The document, as was titled, stated that the United States would need about one million more STEM graduates by

2022 to meet the predicted demand and maintain an economic status quo. Since student retention in STEM courses is a significant problem with a 40 to 50% student loss, it is logical that the most cost-effective solution is to prevent as little as 10% loss over a decade which would allow success to obtain the "one million" goal (Turetsky et al., 2020).

STEM Student Retention

Introductory STEM courses, also known as "gateway courses" or more adversely known as "weeder courses," are typically large introductory classes that are cost-effective and do not allow much interaction between the student and instructor. These courses may have hundreds of students per semester and have many student failures (Alzen et al., 2018). The reputation of a "weeder" course is a "sink or swim" ideology, where students must struggle to learn the material in a traditional lecture format. Those who manage to do well have thus survived the "weeding" process and are left intact to continue and grow, whereas many student "weeds" are uprooted and cast aside. Some of these "weeded" students will change to a non-STEM major, in which it is easier to obtain better grades, and some will drop out indefinitely.

Regarding STEM dropout rates, Astin and Astin (Astin & Astin, 1992) found very similar results to a study in 1997 (Seymour & Hewitt, 1997), that about 40% of undergraduates leave engineering, 50% leave biology, and 60% leave mathematics. A more recent study by Spaulding et al. found that at least 60% of STEM majors will change or drop out altogether (Spaulding et al., 2020). Many reasons may exist for students' attrition in undergraduate STEM; however, one reason that has been universally identified by exiting students is poor instruction (Feldon et al., 2010). A study by Witteveen claims that STEM students suffer a "grade penalty" in the first couple of semesters by merely enrolling in STEM classes and were significantly associated with leaving STEM (Witteveen & Attewell, 2020). Of those that changed out of a STEM major, 90% say they were concerned about the substandard quality of instruction, along with three-quarters of those that stayed in science courses (Watkins & Mazur, 2013).

Of the students that successfully obtained STEM degrees, 74% claimed that poor instruction was a significant problem (Seymour & Hewitt, 1997). STEM students stated that faculty were distant and lacked connection with a "coldness"' in the classroom, boring presentations, general disorganization, and lack of planning that epitomize poor instruction (Seymour & Hewitt, 1997). Additionally, approximately 55% of the student population did not understand the connection between concepts taught and how they would apply to the assigned problems. (Seymour, 2002).

Many scholars have used the metaphor that a STEM pipeline, or supply of students, is "leaky" as students leave for various reasons. The literature declares that if we could just patch the "leaks," perhaps the deficit of STEM students would then be able to support the demands of the technological era. Some researchers believe that we could improve STEM retention by better recruitment (Dwyer et al., 2020) or by improving methods of instruction (Batz et al., 2015; Canning et al., 2018; Corneliussen, 2012; Spaulding et al., 2020; Turetsky et al., 2020). Not only is retention in STEM a concern, but according to the National Science Board 2012, STEM enrollment was noted at 14 percent of all undergraduates, despite the two-thirds of the freshman population that expressed interest in STEM (Griffiths et al., 2012). This shows a staggering 50% loss of STEM candidates before the point of entry into college.

The Underrepresented in STEM

While the data shows truncated enrollment and low retention in STEM, this is especially true for traditionally disadvantaged students (Hill et al., 2010; Nakamura, 2022; Riegle-Crumb & King, 2010; Watkins & Mazur, 2013). There is growing support for a disproportionate number of underrepresented students leaving STEM. A review by Chen et al. (2013) found that those more likely to leave STEM are underrepresented groups, women, students from low-income families, and first-generation college students (X. Chen, 2013). Although there is a balance of both genders taking math and science in high school and equal preparedness for colleges, fewer women pursue careers in STEM (Hill et al., 2010). In middle school, girls tend to avoid science and math classes which makes them less prepared for future courses in STEM (McLaren, 2009). Hill and associates claim that there is an underrepresentation of women in gender stereotypes which causes socialization of bias throughout childhood (Hill et al., 2010). This socialization can result in girls feeling less confident in STEM, and this may likely extend into higher education, where men enroll in STEM majors disproportionally (Riegle-Crumb & King, 2010).

In a similar predicament to gender stereotypes, many potential STEM underrepresented racial/ethnic group students may be lost (Dawkins, 2021). Significant academic performance gaps have been identified with first-generation students and underrepresented minorities in university STEM disciplines (T. M. Freeman et al., 2007). In high school, it was found that Hispanic students were disproportionately enlisted into science courses of a lower level, which makes it probable that this would prevent them from success in STEM in college (McLaren, 2009). Reinforcing this dilemma is research by Dwyer et al., which advocates that obtaining a STEM degree is strongly related to prerequisite course grades in Calculus, General Physics I, and Chemistry (Dwyer et al., 2020).

Grade discrimination may also be a factor in minority students' persistence in STEM. Data from Bar and Zussman suggests that Republican professors assign lower grades to Black students (Bar & Zussman, 2012). If the assigned grade is lower than the actual performance, then a student's self-efficacy could be hampered, causing the frustrated student to exit STEM. Also noted in the Bar and Zussman study is that more Republican professors teach STEM, exacerbating the decrease in student retention.

Another underrepresented subgroup in higher education and STEM fields is first-generation college students (FGCSs). Members of this category are likely to be of an underrepresented racial or ethnic group and are more apt to be transfer students (Dika & D'Amico, 2016). FGCSs make up 25% of the undergraduate population in the United States and involve a more significant proportion in regional 4-year state institutions

(Engle, J. & Tinto, V., 2008). Low-income, first-generation students are approximately four times more likely to leave higher education after the first year than students without these barriers (Engle, J. & Tinto, V., 2008). Colleges that have specific programs dedicated to supporting FGCS students indicate better retention. Thus better support for identifying, preparing, and counseling this population should be the priority of any higher education institution (Waters, 2012).

Transition to Higher Education - problems

As mentioned, there is a concern about a 50% loss of STEM candidates before entry into college. STEM students, in particular, struggle with the transition from high school to college. Many factors can have a negative impact, which can challenge even the best academic students. Some contend with the fast change in pace from a relatively slow senior year in high school to the fast pace of college courses. Surveys that involved interviews with 460 STEM attrition and non-attrition students found that three of the top four reasons for leaving were 1) lack or loss of interest in science, 2) poor instruction, and 3) an overwhelming pace (Seymour & Hewitt, 1997). Freshmen may also need to improve "soft skills," vital to success, especially in an academic STEM environment. Soft skills include regular class attendance, consistent concentration, effective study techniques, being metacognitive, and acting on weaknesses by seeking help and asking questions (Laskey & Hetzel, 2011). Students that have not been exposed to traditional lecture-oriented teaching methods may be negatively affected, adding to the "leaky" STEM pipeline (Hake, 1998).

To this point, the literature establishes that STEM undergraduates face many challenging situations. A summary of reasons that have been discussed are disparity by gender, race, or first-generation, transition issues from high school to college, and poorly taught “weeder” gateway courses that are large, non-interactive, and have the potential to be disorganized. Hence, it is critical to develop a supportive learning environment with quality teaching, accessible academic advising, and other support to successfully engage and retain college STEM undergraduate students towards the goal of completing a degree (Xu, 2018b).

Approaches sought to plug “leaks” in the STEM pipeline

The problems noted above represent a call for reform and require strategies to be incorporated into undergraduate STEM education. Much research has been conducted to retain students in STEM, including support factors, especially for the underrepresented, and to employ different approaches to instruction and encourage social networking. For example, successful programs such as the Howard Hughes Medical Institute (HHMI) Professors Program nearly doubled the retention rate of STEM majors at Louisiana State University by giving underrepresented and underachieving STEM majors additional opportunities to be mentored by faculty and peers, to receive academic support, and to participate in undergraduate research experiences (Wilson et al., 2012). Better recruiting may be a significant factor in sealing the leaky pipe, as under-represented students who attended more inclusive STEM high schools were significantly more likely to be in a STEM bachelor’s degree program than control groups two years after high school graduation (Means et al., 2018). A study by Dwyer found that STEM graduate predictors were strongly correlated with a students' grades in prerequisite courses such as calculus, general physics, and chemistry, suggesting that a students' high school experience is foundational for acquiring a STEM degree (Dwyer et al., 2020). Reinforcing this finding, Dika et al. found that early academic performance and perceived preparation in math support persistence in STEM (Dika & D'Amico, 2016). These findings are essential when we consider guiding students towards their potential with a strong foundation in STEM and especially encouraging the underrepresented towards STEM to invoke interest and support their confidence should they choose a STEM major for higher education.

Breaking the Tradition of Instruction

Undergraduate courses involving STEM show improvement in academic outcomes by using engagement and active learning (Adams et al., 2016; Connell et al., 2016; S. Freeman et al., 2011; Styers et al., 2018; Wilton et al., 2019). Studies have shown that even minimal alterations to the traditional lecture-based class can improve results (Connell et al., 2016). Changing a lecture-based course to a more student-centered format led to increased learning gains, even though lectures still accounted for 60–70% of class time (Knight & Wood, 2005b). Researchers Eddy and Hogan found that including a slightly modified course structure, which included pre-class guided-reading questions and some in-class activities completed in informal groups, had students achieving higher exam scores than the low non-modified course structure. That data was notable, especially for first-generation and African-American students (Eddy & Hogan, 2014).

Student social networking can contribute to perseverance as students involved in social networks are more likely to take the next level of bioscience course than control (Turetsky et al., 2020). Other researchers found that a degree of "centrality" in a social network can successfully predict a student's persistence up to 75%, suggesting that increasing social integration may help improve STEM continuation (Zwolak et al., 2017). This data indicates that we may expect a higher dropout rate during the social distancing of the COVID pandemic and, more importantly, supports creating an interactive learning classroom environment whereby students can connect with other students.

Peer mentoring has been a popular method that institutions have implemented to address the issue of student retention in STEM. In general, this method involves a peer mentor (or tutor) who is typically a graduate student that is a successful veteran of the coursework and facilitates the learning of students who are currently enrolled. Research implicates that this method works especially for those from underrepresented groups (Dagley et al., 2016). The peer instructor method is the basis for social constructivism. It allows for the expansion of the learner from the center of the zone of proximal development (what a learner can do unaided) into the position of what a learner can do in the presence of a "more knowledgeable other," described by Leon Vygotsky (Aura Hapenciuc, 2019). Other reasons for the success of peer mentoring may include the belief that students may have less anxiety with peers than interacting with a more intimidating instructor. Peer teaching allows students to become more aware of their learning and take ownership, thus developing better metacognitive skills to become lifelong learners (Stigmar, 2016). Peer mentoring also allows an encouraging environment to work with other peers enrolled in the course, which has the benefits of an increase in team building and collaboration skills, simultaneously offsetting the tendency for some students to be isolated, which as previously discussed correlates with dropout.

One method of increasing student-centered learning is to employ Just-in-Time Teaching (JiTT). Using this method, students prepare for a class by completing a reading assignment and taking an online quiz before class. Depending on the extent of the preparation, this could also be interpreted as a form of "flipping" a course; however, with JiTT, the instructor checks the item analysis of the pre-class quiz before the lecture to see where the students are struggling. This allows for a focus on the topics that students may have found challenging. A format of instruction of this kind allows for more student-student and student-instructor interactions, which is one of the "Seven Principles for Good Practice in Undergraduate Education," according to Chickering and Gamson (Chickering & Gamson, 1989). In their research, Marrs and Novak found that using this method of instruction had many benefits, including higher attendance, significant improvement in student retention, improved development of a students' metacognition by a consistent formative assessment which provided for less student cramming, and better study habits and a significant improvement on summative exam scores (Marrs & Novak, 2004).

Student-centered learning

The past 35 years have influenced the constructivist theory, which has increased the interest in developing teaching methods to involve students in the learning process (Baeten et al., 2013a). The constructivist learning theory is defined as an "active process in which learners are active sense makers who seek to build coherent and organized knowledge" (Mayer, 2004). Baeten et al. define student-centered learning as containing the following three significant characteristics: "(1) an active involvement of the students to construct knowledge for themselves by selecting, interpreting and applying the information to solve assignments (Struyven et al., 2008), (2) a coaching and facilitating teacher, who is present to help students out with questions or problems and safeguards their learning process and (3) the use of authentic assignments, for instance practical cases and complex vocational problems" (Baeten et al., 2013a). This learning occurs as a process of active construction of knowledge instead of a reception in a passive situation. In the attempt to foster a students' active understanding and implement the construction of knowledge in a discovery setting, along with the idea that there would be improved student involvement and, therefore, more "buy-in," education researchers developed teaching methods to fit the constructive learning theory. As a result, student-centered teaching methods which fall under the constructivist learning theory have been more prominent in the last couple of decades. Examples under the constructivist umbrella include student-centered, case-based, inquiry-based, and problem-based learning. Well-guided student-centered teaching methods are generally thought to enhance deep learning and aim at understanding (Lee & Hannafin, 2016; Mayer, 2004). The constructivist movement claims that traditional lecturing and one-way instruction often fail to ensure a deeper understanding and application of knowledge (Baeten et al., 2013b). This assumption brings us to a central question of this study: "What are the effects of different modes of teaching, and how do they affect learning?" This study compares two methods of instruction in which one way (hybrid) is more of a student-centered approach and is interactive and involves an in-person environment. The other teaching method is an entirely asynchronous online environment where the student is essentially working independently. The next two sections review the literature based explicitly on hybrid learning and online instruction models.

Online instruction

History

Prior to Internet development in 1989, undergraduate institutions have primarily offered traditional instructor-centered, in-person courses. Before the internet, remote instruction (now synonymously referred to as online or distance learning) might have involved taking a "correspondence course," which primarily consisted of physical resources such as at-home study packages and textbooks (Hallyburton & Lunsford, 2013). Technology expanded resources roughly in the order of remote radio education, audio conferencing, telecourses, then videotape or DVD. As the Internet grew roots, so did a revolution in higher education (Weber, 2014). An exponential growth occurred with technology-assisted education with the development of improved internet access along with faster computers and enhancement of memory/cloud availability. In addition, the development of online courses became more manageable with the support of commercially available learning management systems (LMSs) such as Blackboard™ and Google Classroom™, as well as open-source LMSs such as Canvas™ and Moodle™ (Al-Hawari et al., 2021).

Alongside LMS development is the birth and growth of MOOCs (Massive Open Online Courses). The New York Times dubbed 2012 as the "Year of the MOOCs," and at the same time, the concept of MOOC was criticized as the "educational buzzword of 2012" (John Daniel, 2012). MOOCs became popular around 2011 and have continually increased, reaching 81 million participants through 9,400 registered MOOCs as of 2018 (Stracke et al., 2019). These platforms emphasize the ability to enroll many students (Massive) on a free (Open) online platform in which instruction is typically educator-led with traditional delivery (John Daniel, 2012).

In a synergistic movement parallel with MOOCs, Open Educational Resources (OER) developed. The Student Public Interest Research Group reported that textbook prices rose 82% between 2002 and 2013 and that 48% of higher education students claimed that the cost of books had impacted their decision on which classes to take ("Cost of College Textbooks out of Control, Group Says," 2014). Open Educational Resources (OER) are comprised of any material; textbooks, images, audio, and video multimedia that can be freely available electronically and predominantly free of copyright license restrictions for use (Steele, 2013). This grew and developed with its beginnings in 1997 when the

California State University created MERLOT (Multimedia Educational Resource for Learning and Online Teaching) to identify and provide access to primarily free, online curriculum materials for higher education. Rice University created OpenStax, which offers free college-level textbooks and has saved students millions. At the same time, the Massachusetts Institute of Technology (MIT) in 1999 decided to freely share their courses dubbed OpenCourseWare (MIT OCW) (Bliss & Smith, 2017). As these entities and other free resources become available, foundations such as the Hewlett Foundation funded the OECD (Organization of Economic Corporation and Development) and the United Nations Education, Scientific, and Cultural Organization (UNESCO), which promotes openly licensed materials to the world at no cost (Bliss & Smith, 2017). The idea that educational materials would become free started a fundamental movement that would change the world as well as a crisis in the textbook industry as instructors were able to switch to adopting free resources saving students a great deal of money which opened more opportunities for economically challenged students that may not have been able to afford a higher education otherwise (Chan, n.d.).

Similar to the MOOC and OER growth in the past twenty years, so have online courses in higher education. Twenty years ago, online courses were not standard, and now they are crucial to developing any current curriculum. In the fall of 2018, at least 35% of students were enrolled in a distance education course by a degree-granting postsecondary institution (*The NCES Fast Facts Tool Provides Quick Answers to Many Education Questions (National Center for Education Statistics)*, n.d.). This statistic changed abruptly as campuses closed the third week of March 2020 to hinder the spread of the SARS-CoV-2 novel coronavirus, forcing roughly 14 million U.S. students (and their instructors) to switch to online (Hess, 2020). UNESCO claims that worldwide, over half the world's student population was affected by school closures a year later, and it is estimated that over 100 million more children will fall below reading proficiency levels as a result (https://plus.google.com/+UNESCO, 2020). With the recent increase in COVID cases due to the more contagious Delta variant, Dr. Anthony Fauci declared that “Things are going to get worse” in an interview on August 1, 2021, primarily due to virus spread via non-mask compliance alongside the non-vaccinated population (News, n.d.). With the anticipation of campuses reopening in the Fall of 2021, the new emerging variants caused mask requirements and some courses reverted to online. New variants may be the “new normal” so online courses have never been so important in supporting today’s education and thus has established the need for proper instructor training and development of effective online learning platforms.

Next to MOOCs and the OER movement, the COVID-19 pandemic is one of the most significant historical impacts on online education delivery. Instructors had to adapt from face-to-face to remote instruction quickly. This rapid transition has brought many concerns associated with online learning. Numerous instructors who are not versed with online education may have a poor teaching infrastructure and be unfamiliar with using technology properly (Carrillo & Flores, 2020). The pre-existing technology gap problem was profoundly exacerbated by the mass migration online and brought sharp attention to stakeholders and policymakers to support students who don’t have access. Additionally, it can be problematic for some students that have to adapt to doing schoolwork in a complex home environment ("'This Is Not Teaching,'" n.d.; Zhang et al., 2020). A COVID education transition case study from Peking University summarizes five high-impact principles for online education:

> "(a) high relevance between online instructional design and student learning, (b) effective delivery of online instructional information, (c) adequate support provided by faculty and teaching assistants to students; (d) high-quality participation to improve the breadth and depth of student's learning, and (e) contingency plan to deal with unexpected incidents of online education platforms." (Bao, 2020).

Benefits of Online Courses

Online courses have many beneficial factors, especially for nontraditional students who work or need to balance their family life without worrying about travel and time commitments associated with in-person classes. Online classes are more flexible and allow students with jobs and family obligations to take classes that would be inaccessible otherwise. The hassle of traveling, parking, and walking to a class to be on time can be a stressful experience in itself. Online courses support a lower SES (socioeconomic status) population by not requiring transportation, so savings in fuel and automobile-related expenses (repairs, insurance, parking) can be significant, thus supporting a more diverse audience. The online course is more affordable for the student, but it also relieves costs associated with providing allocation of space, building maintenance, and overcrowding of classrooms (Panigrahi et al., 2018).

Benefits of Hybrid courses

A hybrid course can take many forms, and so the term "hybrid" fluctuates with the form of delivery. A hybrid course, also sometimes referred to as a blended course, means that some part of a course is supported by electronic resources (web-based). This electronic resource replaces a portion of traditional in-person instruction (Snart, 2010). One of the most popular forms of the blended model is to deliver declarative knowledge online (as homework) and then use class time for active learning and discussion. If students passively learn by watching recorded lectures before activities involving, reinforcing, or engaging them, this is commonly known as "flipping" a course.

Comparative achievement: Online vs. Hybrid

Many studies have taken place to ascertain the benefits of one design over another. While many studies would find significant differences in summative achievement in teaching biology favoring in-person to hybrid (Mohammadian et al., 2021; Poelmans et al., 2018), an extensive review reported in 2009 claimed better performance in online learning (Means et al., 2009). Most research supports a small to no significant difference in achievement between online and hybrid courses (Baker et al., 2020; Hauser, 2016; McCutcheon et al., 2015; Nfor, 2015; Shea & Bidjerano, 2013; Snart, 2010).

Purpose of the study

The purpose of this study is to gain insight by comparing two models of instruction based on student achievement. Specifically, this study will explore differences in student achievement (formative and summative) among students who enrolled in two different instruction formats for an introductory undergraduate biology course. The comparison is between asynchronous online and hybrid (flipped in-person) instruction. This study will also explore student feedback on activities and resources.

CHAPTER III: METHOD

Recently, unprecedented numbers of courses are adopting online instruction with the COVID-19 pandemic, especially in higher education. Many studies exist that consider the benefits and pitfalls of online courses at the community college level in biology, as noted in the literature review. Before the pandemic, implementing a hybrid model of instruction was steadily increasing in higher education and had mixed reviews regarding its effectiveness (McNally et al., 2017a). The recent mass movement toward online teaching has undoubtedly had a significant impact on the environment of learning for many higher education students. One concern is that too many online courses may create a feeling of "disconnect," which can cause a lack of motivation to learn (Mheidly et al., 2020). Another concern is that if instructors are not adept at online instruction, students may feel discouraged or have negative feelings toward online instruction.

This study does not attempt to address these concerns directly. However, this study aims to discover if differences exist in achievement between online and hybrid instruction in the same undergraduate introductory cell biology course before the COVID pandemic. Thus, this study aims to allow for a deeper understanding of not only how the delivery of content may affect student academic success but also ascertain if there are differences in how students feel about these teaching methods from a firsthand experience since attitude is a critical element of motivation and learning (Connell et al., 2016; Díez-Palomar et al., 2020). This study will compare the online model to a hybrid course with the same instructor and identical student outcomes. Formative and summative assessments will be described and compared, and qualitative aspects of both learning environments will also be explored. This chapter addresses the research questions, design of the study, participants, procedures, measurements, and data analyses methods.

Research Questions

RQ1: What differences exist with overall percent achievement in formative and summative assessments when comparing hybrid and online instructional models in an introductory cell biology course?

RQ2: Will analysis of a student survey indicate trends, themes, or patterns based on student experiences with online and hybrid learning? If so, does the data reveal notable differences when comparing hybrid and online teaching methods?

Design of the Study

This study will employ a non-randomized quasi-experimental design to examine student learning achievements based on two different teaching methodologies (hybrid and online). Qualitative and quantitative data will be collected from class sections of the same course (Biology 190A) taught using hybrid and entirely online methods over approximately five years. In this quasi-experimental study, learning achievements are measured with formative and summative assessments of the course. The groups are defined by those enrolled in one of two teaching methods (online or hybrid) and are identified as the two levels of the independent variable (the Instructional Method).

Setting and Participants

The proposed study is retrospective, and the data will be obtained from students who attended and completed an introductory undergraduate cellular and molecular biology course (Biol 190A). Students who take this course are typically trying to satisfy a requirement for an associate's degree in science or bachelor's degree in the health sciences. Some students take this course to fulfill a requirement for a non-science major. The data will be compiled over time by the researcher (also the instructor) who instructs at Truckee Meadows Community College (TMCC) in Reno, Nevada.

Students interested in biology or a health science major will take higher-level science courses like microbiology or anatomy/physiology. To enroll in these higher-level courses, a student must earn a grade of a C or better in this cell biology course. As described previously, this foundational course can be considered a "gateway" course. Thus, it is safe to assume that the students' experience in this introductory course will profoundly affect the trajectory of their success or demise. This is the premise that this study seeks to gain insight to determine if specific instruction methods should be promoted over another.

A diverse population of students is included in this study. TMCC does not require a high school degree and comprises a student body from different backgrounds, races, cultures, educational statuses, ages, work experience, and SES (socioeconomic status). Many enrolled are first-generation college students and represent a minority. Some students are non-native language learners. Historically, this class (Bio 190A) has a significantly higher female student enrollment, typically 75 to 90% (instructor enrollment records).

High school students associated with the TMCC high school program can enroll in this course, whereas other students may be transferring from distant or local colleges. Some students already have earned an undergraduate degree and are looking to change their career paths. The community college has non-traditional students who may be parents and work full or part-time while simultaneously being enrolled in other classes. Numerous obligations create a noticeable strain on time commitment towards study and success. Historically, the age of students can range from 16 to 60+, but the median age is about 22, according to the TMCC Factbook 2017. (*Ir-Factbook-2017.Pdf*, n.d.). TMCC reports that in 2016 approximately 57% of the student body was White, 27% Hispanic, 6% Asian, 4% mixed race, 2% African American, and 1% Native American. All participants' race, gender, age, and names were de-identified for this study.

Selection of Sample and Sample Size

Only students that attend the entire semester are to be selected for this study, and so this is specifically defined as students who complete all six exams. Each class has a capacity of 32 students and typically starts the semester at maximum. Data for this study will include past classes taught for about five years. This will amount to roughly 200 students per group for both teaching methods. According to the results of a power analysis by *G*Power,* with the desired effect size (eta-square = 0.25), α err prob (=.05), and Power (*1–β* err prob = .95), for two groups and two measurements on each group, we would need a minimum of 53 participants in each group (a total of 106 participants) for the data analysis (MANOVA). The sample size is approximately 200 students per group. Therefore the MANOVA method can be considered for this study (Lehman, 2013).

The Researcher

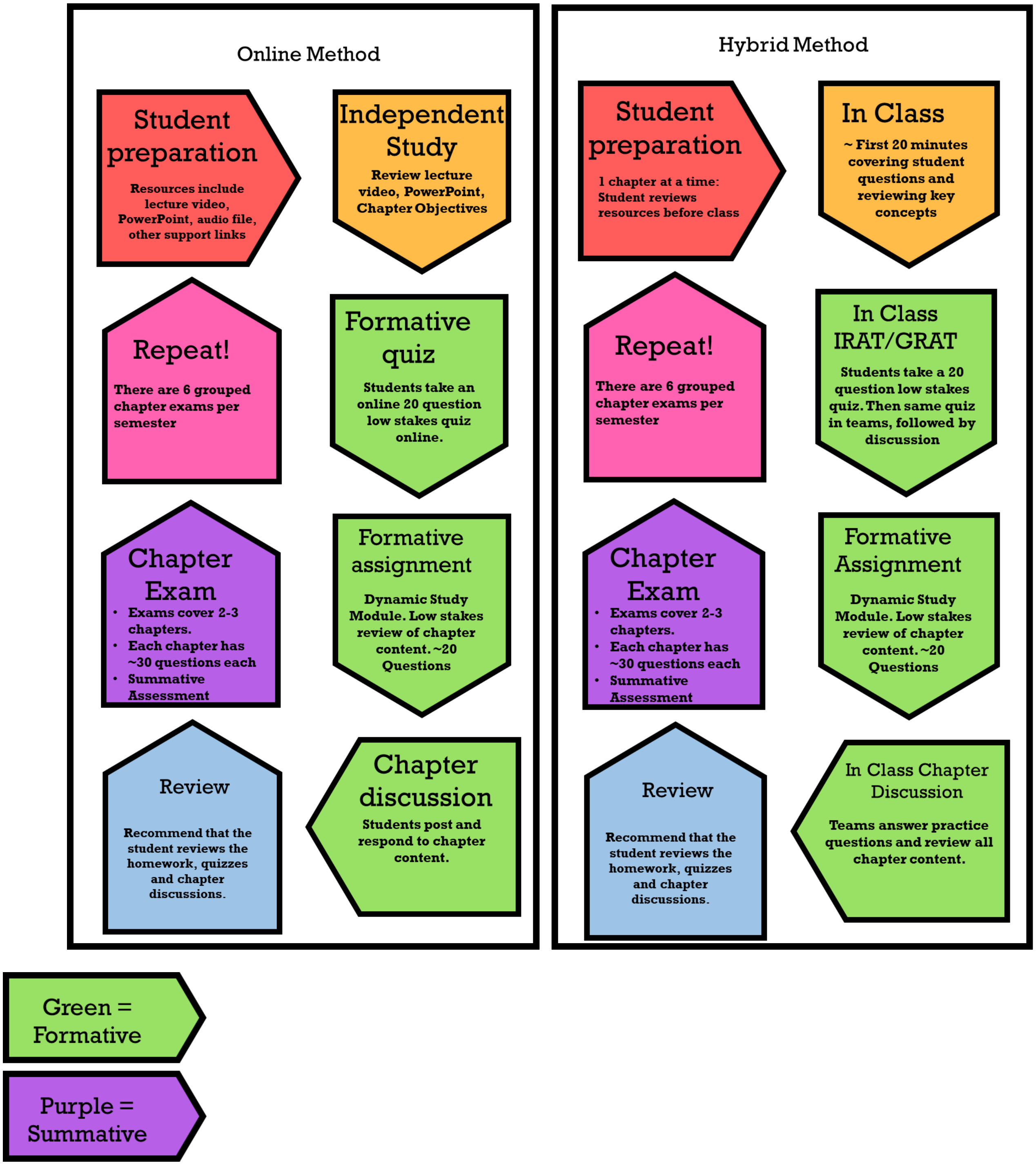
The researcher has been teaching undergraduate biology for Truckee Meadows Community College since 2002 and holds a degree in biochemistry and a Master's degree in education. The researcher has taken graduate courses in biology and prerequisite graduate courses for a doctorate of philosophy in higher education. The researcher has been teaching online since 2010 and started a flipped hybrid design in 2015.

Procedure

This section presents the main procedures planned for the study, including the two instruction methods, course design, and formative and summative assessment procedures. A general infographic of the overall course design for both methods is shown (see Figure 2).

Figure 2

Online and Hybrid Course Design Graphic



Two Instruction Methods

Online

"Online" will reference the class taught solely online. Students independently learn the material at their own pace and asynchronously contribute to discussion boards, complete homework, and take secure high-stakes summative assessments within a pre-established timeline. All high-stakes exams involve a proctoring service. Each of the six exams has a one-week window of time in which they are to be submitted.

Hybrid

Hybrid instruction is described as the combination of technology-facilitated instruction along with on-site face-to-face instruction (Okaz, 2015). "Hybrid" will be the short reference for the instructional method involved in this study, which is in-person twice a week for 75 minutes. This method is also typically referred to as a "flipped" learning design, but the term hybrid specifies the involvement of supportive online technology. With this instructional method, students are expected to have reviewed the assigned online learning material before arrival. In contrast to the online teaching method in this study, hybrid students must take summative high-stake exams on the day posted per the syllabus schedule.

Student Resources – for both groups

Both instructional methods cover the same learning outcomes, as it is the same course. The same textbook and online resources are required, and both courses were designed and taught by the same instructor. The main resources identical to both teaching methods are the lecture video recordings, downloadable PowerPoint files, downloadable audio files, the textbook, and study guides (student learning objectives) for each chapter.

A professional videographer recorded videos while the instructor taught content presented via PowerPoint in front of a live classroom in a traditional didactic manner. These lecture videos were uploaded and are available to students at any time via access from the learning management system by chapter module. The chapter videos include closed captioning and can be viewed faster or slower than normal speed. Each chapter PowerPoint file is downloadable and contains specific learning objectives for the chapter and is the same file that the instructor uses on the video recordings. A separate downloadable file includes all learning objectives covering concept goals for unit exams, identified by chapter and subchapter headings. Students can use this file by "answering" learning objectives electronically using a word processing program or printing and writing notes directly into the spaces provided.

A crucial common resource available to both online and hybrid classes is the textbook and the online support application. All students must purchase an online component to do the assigned online homework. The online purchase provides the student with two primary resources, 1) a fully searchable online version of the textbook and 2) access to the online homework and student support. This online platform is provided by Pearson® Education and is called MyLab Mastering (hereafter shortened to MyLab). Since the physical textbook comes as a package that deals with the required online access code for $10-15 extra, most students opt to have the physical text along with the online purchase. As mentioned, MyLab is the delivery platform for online homework assignments. Not only do students do their homework here, but Mylab also offers many additional options. Students can build their own review exams, review homework assignments, and look through prepared flashcards and interactive video activities.

Recommended method for student study – for both groups

For both class designs, the recommended strategy for students to study is the same and uses the same resources. As mentioned, this is a "gateway" course typical to a community college setting, and many students may be returning from a long break in their education, so it is imperative to develop successful study strategies. I recommend that students print out the learning objectives and the PowerPoint slides at two slides per page. These printouts should be given a general inspection to assess the expectations for content, followed by playing the chapter lecture video while taking notes onto the objective learning printouts and pausing or rewinding as needed. Since each chapter video is about 75 minutes long, I suggest that they take a brief 5-minute study break every 25 minutes or so as in the "Pomodoro" technique, a time management strategy developed by Francesco Cirillo in the 1980s (Cirillo, 2013). On completion of the chapter video, I suggest the students review the list of learning objectives, check for understanding, and if not completed, refer to the PowerPoint slides, review the video, or search the textbook for clarification.

If there are gaps in understanding, each course has a different approach to help overcome these difficulties. For the online group, I encourage the online students to ask their fellow students (the instructor is also included) for clarification via the asynchronous online chapter discussion board. In this discussion, not only can students get credit for posting their questions, but other students can get credit for answering them. Their peers typically provide “at their level” examples and analogies to the students' benefit. If not answered by students, the instructor can also give input to the online discussions. The 20-minute allotted review time at the beginning of each class is available for the hybrid group. Students can ask the instructor questions about material that confused them. Similar to the online course discussion board, the instructor will redirect student questions to be answered by peers to support peer-to-peer reinforcement and learning. All students are repeatedly reminded to seek individual instructor help if facing difficulties.

Assessment Procedures

Research Question 1 determines if differences exist between teaching methods, explicitly focusing on achievement in formative and summative assessments. This section will describe the purposes of formative and summative assessment, the procedures used for evaluation in this study, and how specific adaptations were made with formative assessments to align with each teaching method.

Assessment Overview: Summative and Formative

Formative assessments in this study, as will be described in detail, are defined as homework, discussions, and low stake quizzes. A formative assessment aims to provide the student with crucial metacognitive information about their status of understanding content. It gives application, practice, and reinforcement to student learning outcomes. Awareness is essential; if students are not performing well on quizzes, they are now more aware of what they don't know and what they need to know to understand the subject matter thoroughly. The formative assessments allow for application and practice to develop knowledge and prepare the student for the heavier weighted high-stakes evaluation; the summative assessment. Since the setting and delivery of the two teaching methods are inherently different, two of the three formative assessments needed to be different to align with each learning environment. These differences will be explained in this section.

A summative assessment is an evaluation at the end of a larger instructional unit and typically has a higher weighted point score towards a student's final grade, hence the term "high-stakes." The summative assessment allows for evaluating progress in significant sections of instruction. It can provide vital feedback to allow for re-strategizing study methods in the case of poor performance. An example of one summative assessment in this study is an arranged exam, typically covering two to three chapters of material. Procedures of the summative assessments and the differences between groups for formative assessments will be described in detail in the following sections.

Summative Assessment – same for both methods

The summative assessments (grouped chapter exams) are identical for both teaching methods, so the comparison is straightforward. The instrument for each summative grouped chapter exam (see Table 1) is a combination of primarily multiple-choice questions and, to a lesser degree, true/false questions. There are about 30 questions that represent each chapter, and since most exams cover three chapters (the one exception is Exam 2, which has two chapters), there are approximately 90 questions per exam. Students are not allowed to use notes or resources during the examination process. The time allotment for each exam is 75 minutes unless the student has a specific accommodation. The average completion time for a 90-question exam is about 45 minutes.

The overall letter grade for the class is based on an achievement weight of 70% summative and 30% formative. These weight differences are not an essential component of this study; however, this aspect is worth mentioning since the different weights give more emphasis to summative exams. Summative exams in this study are secure, proctored, and students are not allowed to use outside resources.

Questions delivered to students were carefully mapped to align with the learning outcomes and have been edited/modified over several years before this study began. In the early stages of assessment design, the researcher set forth an open discussion policy that if a student has a concern or is confused about an exam question, or if the material did not align with course objectives, students would be asked to communicate any issues. The student was awarded bonus points if a legitimate error was found, clarification was needed, or if the question did not align with course objectives. Over several years, working with students' direct feedback allowed for rewriting and removing questions. Over time, the summative assessments have become reliable instruments.

Each question has been categorized and associated with specific learning objectives disseminated to students as study guides. Careful attention has been paid to evenly distributing questions aligned with learning objectives throughout each chapter. Additionally, an inspection of item analysis statistics and performance values and modification over time has resulted in no need for further adjustments. This vetting process was done well before this study occurred, so the summative exams are a reliable instrument.

The summative exam questions are delivered using a quiz feature provided by Canvas™ LMS. Although the summative exams are identical between teaching methods, there is a different time window for online students versus hybrid students for taking the exams. The hybrid method has students taking the chapter exams on preassigned testing days as planned in the syllabus, and these students go to a computer classroom and are proctored by the instructor. In contrast, online students have a one-week window in which they must take the chapter exams. Online students have two proctoring options; they can use the in-person proctoring center located on campus, or they can use a secure online monitoring service, which involves a video and audio recording of the student during examination via the student's device. In summary, the reliability of the summative assessment is sound, and the delivery method for both teaching methods are comparably secure.

Formative Assessment – Hybrid vs. Online

Given the nature of each learning method, asynchronous online instruction requires a different delivery for formative activities than the hybrid classroom. Whereas the summative assessment is equivalent between teaching methods, the fundamental differences in the delivery of the two teaching methods require different engagement and, therefore, various style assessments to support these conditions. One of the formative assessments is identical between teaching methods, and two of the three formative assessments are similar but different, as will now be discussed. As shown in Figure 3, labeled "Practice #1", this assessment, called the "instructor built online homework," is the same between both teaching models. The following line in figure 3, "Practice #2," shows an assignment called Dynamic Study Module for the online student, whereas the hybrid students have an IRAT/GRAT (Individual Reassurance Assessment Test/Group Reassurance Assessment Test) assignment; to be described. Lastly, there are asynchronous chapter discussions for the online students, and the hybrid course has synchronous chapter reviews/discussions. The available amount of work and point weighting is similar between the two methods. For the remainder of this section, the differing formative assessments between teaching models will be described in detail, which includes the "instructor built online homework," Dynamic Study Module versus the IRAT/GRAT quiz, and the asynchronous online discussion and the chapter discussion/review activity for the hybrid model.

Table 1

Online and hybrid: Comparison of formative assessments

Formative Assessments	Teaching Method	
	Online	Hybrid
Practice #1: Same assessment.	Instructor made online homework ~20 review questions	Instructor made online homework ~20 review questions
Practice #2: Similar number of questions. Different delivery, questions are not identical. Low stakes practice/review.	Dynamic Study Module ~20 activities/practice questions	IRAT/GRAT TBL 20 Questions
Discussion/practice #3: Question and answer interactions; allow for engagement.	Asynchronous Chapter discussions/review	Synchronous Chapter discussion and review

Practice #1: Instructor built online homework- Same for Online and Hybrid

This homework assignment involves an assembly of about 20 instructor-selected chapter questions and activities provided by the MyLab textbook support. The questions and activities for this assignment allow the student to check for understanding of the learning objectives presented in the lecture. Some questions are multiple-choice, and some are answered after watching a short video or animation. Other questions involve students doing a "drag and drop" matching or ordering activity. The assignment is lenient in that it allows for several attempts and hints until students get the correct answer. The time it usually takes a student to complete this assignment is about 45 minutes, and since the assignment allows for multiple attempts, most students get full points. The online program automatically determines the percentage correct at the due date. For both methods of instruction, this assignment is due for all chapters just before the summative chapter examination.

Practice #2: Online, Dynamic Study Module, Hybrid- IRAT/GRAT

Online formative assessment- Dynamic Study Module

As mentioned, the first formative assignment (instructor-built online homework) shown in Table 1 is common to both instructional methods. The nature of this online course being asynchronous would not allow for an interactive assessment that the hybrid class can accommodate. The online course has an assignment that uses the MyLab Mastering site called a Dynamic Learning Module, a Pearson® education product. This chapter assignment allows students to get automatic feedback based on their performance as they go through a set of questions and activities related to student outcomes associated with concepts of each chapter. This assignment also allows for multiple attempts, and a student can get hints to answer questions. The question can allow for interaction with the e-text (electronic textbook), so if students are struggling, the student is guided to visit the section of reading pertinent to understanding particular questions or activities. This assignment typically has about 20-25 questions and takes a student about an hour to complete. This assignment has equal point value to the comparative IRAT/GRAT activity in the hybrid course and the number of questions but is very different in design. Points are based on assignment completion, and the number of questions/activities completed or marked correct.

Hybrid formative assessment: TBL and the IRAT/GRAT quiz

The hybrid course design is such that the students know that they need to prepare and study the chapter materials in advance to serve them best. As discussed, the chapter module of the learning management system has pre-recorded lectures, downloadable PowerPoints, textbook support, and learning objectives for students to prepare. Students know that they have the opportunity to ask questions to review any concepts that need further clarification for the first 20 minutes of the in-person class. This also allows the instructor to review the material, mainly focusing on the more complex topics, while asking questions to engage the students and check for their understanding. It is an adequate time to engage and receive student feedback regarding content difficulty and common misconceptions and to clarify misunderstandings.

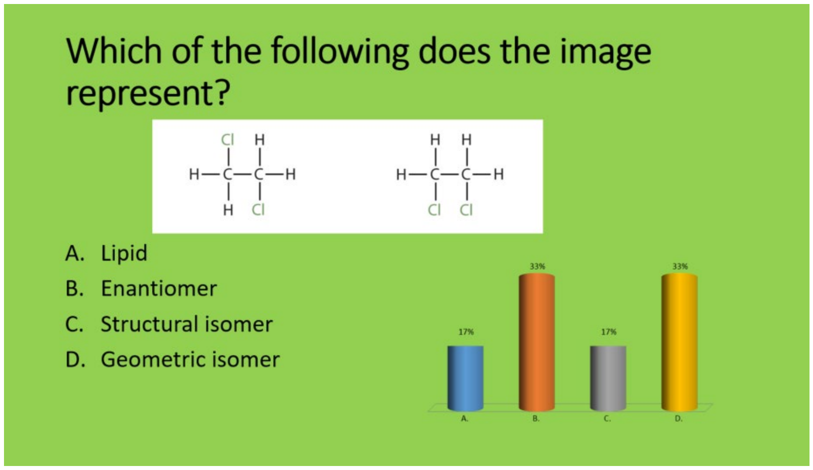
Then begins a well-recognized instructional strategy called Team-Based Learning (TBL), which Professor Larry Michaelson initially developed in the 1970s (Michaelsen et al., 2004). The first phase of a classic TBL is pre-class preparation, whereby students use the support material provided online to review the content for a chapter before coming to class. The second phase of the TBL involves a low-stakes assessment called the Individual Readiness Assurance Test (IRAT). The IRAT of the hybrid method employed a 20-question multiple-choice quiz for each chapter. This assessment is distributed as a printout to each student and is taken individually, without resources. The resulting score (obtained by using response ware or clickers) is not revealed to the student; however, the instructor can follow student performance. Importantly, this data quickly identifies those who need extra support. The IRAT also provides the student with crucial metacognitive awareness as they will have a good idea of how well they grasped the concepts based on their confidence level as they were answering questions.

The next part of the TBL is Phase 2, referred to as the Group Readiness Assurance Test (GRAT), which has students gathering in pre-assigned teams to answer the same set of 20 questions. Teams will debate, discuss and decide which answers are correct. Groups usually take about 20 minutes to reach a consensus for all the questions, and data was obtained using audience response ware. See Figure 2 above for an infographic of the hybrid design teaching method.

The post-GRAT activity involves the final 15-20 minutes of class. A PowerPoint display of each question is delivered in the same order, coupled with clicker response software. The polling software would display a histogram of how many teams chose each option, as shown in Figure 3.

Figure 3

Team response report for GRAT or review question.



Note: Histogram shows popularity reports by percent on options selected A through D.

A short discussion would ensue for each question as the instructor would guide the students through details of why each answer is correct and concepts that eliminate incorrect answers and provide strategic tips on how to look for keywords in questions. The polling software would compute each team's GRAT scores, which counted for 10 points (double the IRAT). Scores are based on the percentage of questions marked correct.

Team selection

The number of team participants varied based on students' attendance in their respective teams; on average, teams had 4-5 members. Initially, teams are selected randomly. After the first exam, the instructor carefully reassigned teams. This selection aimed to put at least one high-achieving student into each group. In this way, at least one person on each team would serve as the "more knowledgeable other" to provide social influence and to encourage learning to hopefully contribute to their peers' zone of proximal development as proposed by Lev Vygotsky, as well as influence another learner's behavior as proposed by Albert Bandura (Gredler, 2009). Students are reassigned into different teams at least one more time a semester to allow students to meet and interact with others, developing social skills desired by employers.

The TBL activity is highly interactive and engages students between their peers and the instructor. The instructor also has time to visit among teams during instruction to check for progress and obtain more personal feedback. This is a very different design from the online method, where there may be just as much content and many questions for practice, but interaction is extremely limited unless students make the extra effort to form study groups. The following section describes chapter discussions and how they are very independent in the online method of instruction compared to the hybrid course.

Practice #3: Online- Chapter Discussion/ Hybrid- Chapter Review

Online: Asynchronous chapter discussions

While the hybrid course has students discussing chapter questions in teams, the online course has an asynchronous discussion per specific chapter. The chapter discussions, in comparison, do not happen in one review day as in the hybrid course. Thus, the online design significantly differs in that this assignment is due at regular intervals as scheduled in the syllabus rather than the grouped discussion (two or three chapters) as experienced by the hybrid course. Full credit is assigned to students who contribute at least two significant entries to the online discussion board for each online chapter discussion. The definition of a significant entry can be of the student's choosing, such as providing a mini quiz, bringing up a point of confusion, asking classmates about learning objectives that they found confusing, providing helpful resource(s), images, mnemonic devices, or answering another student's questions. Any variation or combination that counts towards the minimum of two entries is required for this assignment. The instructor also contributes as needed, making corrections and asking pertinent questions. Most conscientious students usually do pretty well on this assignment and typically earn full credit for participation. The instructor grades this assignment based on a rubric presented to the students before the first online discussion. Students are encouraged to review all postings before the chapter when the discussion is completed and before the chapter exams. Many quality entries allow students to review the chapter material.

Hybrid: Formative Chapter Discussion and Review

This assessment occurs one class meeting before the next summative grouped chapter exam. Teams gather, and multiple-choice/true-false questions covering all chapters are presented one at a time on the screen by PowerPoint, which is linked to Turningpoint® audience response software. Teams are given a few minutes to discuss the questions among themselves and are tasked to come to a consensus. At that point, a team representative employs a response clicker to select their agreed-upon correct answer. Once all team entries have been accounted for, the histogram displays the number of teams and chosen options (as shown in Figure 3). This provokes a discussion about the reasoning behind each incorrect option and why the answer is correct. This process is repeated for each chapter that will be tested, and the number of questions covered is usually 30 to 35. Each question gives an opportunity to review, discuss misconceptions, and go over strategies for eliminating incorrect answers, finding keywords, and learning how to avoid pitfalls. The number of questions covered varies due to different discussions. Therefore, 30 points for this assessment (10 points per chapter) are assigned to the team with the highest number of correct answers. A ratio is used to give points to other teams. For example, if team A got the highest number of questions right, which was 25, they earned 30 out of 30 points for that assignment grade. If Team B earned 20 correct, then $25/30 = 20/x$, and x is solved as 24 points out of 30. In this way, teams compete for the highest number correct, so the assignment tends not to penalize so much for overall incorrect.

In summary, there are three formative assessments for each learning method involved in this study. One of those assignments is identical between teaching methods. Although the IRAT/GRAT 20 question set per chapter is similar in the number of practice questions that hybrid students see, the hybrid class is a very different experience. It has a high level of engagement and interaction with the instructor and peers compared to an online assignment. In the same sense, the online chapter discussions have an independent involvement online, whereas the hybrid class has direct interaction. The different settings will affect the student experience and thus will undoubtedly affect their learning (Kennepohl & Shaw, 2010; Mellanby, 2014; Mervis, 2010b). These differences in formative assignments are necessary for the specific environments of each instructional method. Comparing overall student performance on these formative assignments may provide insight into which method is better for learning. Besides investigating quantitative data on student achievement, a student survey was analyzed to understand how formative experiences affect learning. The following section discusses measurements of the assessments involved.

Measurements and Instruments

Quantitative measurements- Summative Assessment (same for both instructional methods)

As previously mentioned, the summative chapter exams are identical between online and hybrid teaching methods. There are six summative chapter exams worth points, as shown below; see Table 2. A calculation will be made for each student in this study to obtain the total percent correct in this category. This is achieved by taking the sum of points earned and dividing by the total points possible (850) for all summative exams.

Table 2

Summative Assessment: Online and Hybrid		Textbook chapters covered
Exam 1	(150 pts)	1-3
Exam 2	(100pts)	4-5
Exam 3	(150 pts)	6-8
Exam 4	(150 pts)	9-11
Exam 5	(150 pts)	12-14
Exam 6	(150 pts)	15-17
(Sum of student earned points/850)x100 = semester % achievement.		

Summative Assessments (exams) are identical for both teaching methods

Quantitative measurements- Formative Assessments

The total point values associated with formative assessments between the two methods are the same, even though the context and delivery are different for two of the formative assignments in this study (as previously described); see Table 3.

Table 3

Online and hybrid: Comparison of formative assessments

Formative Assessments per Chapter: Online		Formative Assessments per Chapter: Hybrid	
Assignment	Points	Assignment	Points
1 instructor built online homework assignment ~20 questions	15	1 instructor built online homework assignment ~20 questions	15
1 online "Dynamic Study Module" homework assignment ~20 questions.	15	IRAT and GRAT quiz 20 questions.	15
1 Online asynchronous discussion	10	Synchronous chapter discussion review activity	10
Total	40	Total	40
(Sum of semester student earned points/total possible)x100 = semester % achievement			

*Note***.** For each student, an overall formative assessment percent correct value for each instructional method will be calculated by adding up all points earned, dividing by the total possible, then multiplying by 100.

Qualitative Instrument/Measurement: Student Survey

Qualitative data analysis can provide a deeper understanding of quantitative conclusions and vice versa. A qualitative student survey will be explored to gain insight into students' dispositions or preferences. The survey is offered online via the LMS at the end of the semester (see appendix) and is entirely voluntary. However, students were informed that a small amount of extra credit would be added to their overall score for completing it. These values were used to seek differences between groups to provide insight into possible correlations to student achievement.

Data Collection

Quantitative

The quantitative data for formative and summative assessments was obtained from a spreadsheet export of the grade book LMS (Canvas). These data were compiled into a single excel file, and student identifiers were removed. Students who did not complete the semester were removed from the study group. The two factors used for this comparison study are the semester percent achievement for formative and summative assignment scores per student. To obtain the overall percent correct for each category, the student earned sum of total correct points for all formative and summative assessments were divided by the corresponding total points possible and multiplied by 100.

Qualitative

The data for each survey question was downloaded from the learning management system, imported into a word processing program with removed student identifiers, and grouped by survey question.

Data Analysis

Quantitative: Research Question One

To answer research question 1 (When comparing hybrid and online instructional models in an introductory cell biology course, what differences exist with overall percent achievement in formative and summative assessments), the data will be best analyzed using a one-way MANOVA.

The teaching method is the independent variable, with two levels or groups (hybrid and online). The dependent variables are the overall percent correct formative and summative assessment scores. The one-way MANOVA ("multivariate analysis of variance") was used to determine whether there are any differences between two independent groups on more than one continuous dependent variable. Variance refers to a possible difference between group achievement scores (summative and formative). Statistical significance between the teaching methods used the social science convention of $p \leq 0.05$. The effect size was evaluated using eta-squared and Cohen's *d*.

Formative Assessment

Formative assessment values represented a dependent variable in this study and were calculated using the same method as summative. This was achieved by taking a semester sum of all correct points a student earned and dividing it by the total points possible, then multiplying by 100. These were computed into the one-way MANOVA as Formative Hybrid (FH) and Formative Online (FO), see Table 4.

Summative Assessment

The instrument for the summative assessment is the same between the two teaching methods, which are the 6-chapter exams as previously described. An overall percent correct score was calculated for all six exams for each student. This value was obtained by dividing the total correct points earned for all exams divided by the total points possible and then multiplied by 100. This value was calculated for each group and was employed in a one-way MANOVA as Summative Hybrid (SH) and Summative Online (SO). Figure 7 demonstrates the analysis method of the one-way MANOVA.

Table 4

Analysis of the One-Way MANOVA.

Method (IV) With two levels	Formative Assessment (DV 1)	Summative Assessment (DV2)
Hybrid	FH	SH
Online	FO	SO
	Dependent Variables	

Note. FH= Formative Hybrid, FO= Formative Online, SH=Summative Hybrid, SO=Summative online

Qualitative: Research Question Two

Research question 2 (Will analysis of a student survey indicate trends, themes, or patterns based on student experiences with online and hybrid learning? If so, does the data reveal notable differences when comparing hybrid and online teaching methods?) has the objective to understand the student experience between instructional methods. The data analysis for research question 2 was performed in two parts: (a) content analysis on open-ended questions, whereby comments were read and sorted based on themes or trends for each method of instruction; and (b) descriptive analysis was performed to analyze the results from the Likert Scale.

Research Design Assumptions and Limitations

This is a quasi-experimental design, and a one-way MANOVA will be conducted. A sufficient sample size (~200 students per group) was involved in this study; however, a larger sample size would strengthen the results. Also, the measurement of student learning will be consistent using an incremental scale as the average percentage of achievement (the percentage of overall correct answers) may increase the chance of obtaining equal variances in the dependent variables between groups.

The two groups in this study may not be “equivalent groups” because of some possible confounding variables (Cook & Campbell, 1979; Shadish et al., 2002). Inherent differences in these groups may contribute to significance. For example, there may be the reputation that online courses are more challenging, so perhaps a higher percentage of more motivated students would sign up for an online course than an in-person course. In a study of this nature, some other confounding variables may exist. Differences found between groups may result from differences not identified by the research. For example, it may be more tempting for a student who works full time to take an online course due to schedule conflicts. This student is not the same as a full-time student who has more time to dedicate to study.

Students voluntarily completed the end-of-semester survey and were offered bonus points for its completion. Therefore, one may assume that only students that needed bonus points would be motivated to complete the survey by biasing the data. In addition, students that did not complete the semester did not have the opportunity to complete the end-of-semester survey; therefore, this input was not included.

Hybrid students experienced a much different examination experience regarding summative reporting in two ways. Firstly, hybrid students had a single calendar day and time in which they were to take the exam, whereas the online students could schedule the day/time within a one-week window. Secondly, the examination environment itself varied between the two methods. Hybrid students assembled in one computer room, whereas some online students had the option to take the exam at home with the secure proctoring software, and others utilized the proctoring center on campus.

CHAPTER VI: RESULTS

This study compared student achievement between hybrid and online instructional models in an introductory cell biology undergraduate course. Specifically looking for differences in overall semester achievement with formative and summative assessment (research question 1). The data from the courses were exported from Canvas LMS, deidentified, and overall assessment achievement was calculated. This final data was entered into the statistical program IBM SPSS™ version 28. Results will be discussed in the first part of this chapter regarding research question 1.

To address research question 2, the end-of-semester student survey was analyzed to interpret student disposition, searching for principal themes and comparing those results between the two instructional methods. As mentioned in the methods section, student responses to open-ended survey questions were exported from the LMS, deidentified, and loaded into word processing documents. These documents were manually interpreted. Similarly, Likert style questions were exported, deidentified, combined, and calculated. This data is displayed in the second half of this chapter.

Results for Research Question 1

RQ1: What differences exist with overall percent achievement in formative and summative assessments when comparing hybrid and online instructional models in an introductory cell biology course?

A one-way MANOVA was conducted to examine differences in student academic performance between the two groups of instruction (hybrid and online) to answer this question. The two dependent variables are overall semester percent correct scores in the formative and summative assessment.

A preliminary analysis of data screening was performed. The results indicated that normality assumption was not assumed for either hybrid group (Shapiro-Wilk statistic = .909, $p < .001$) or online group (ShapirWilk statistic = .742, $p < .001$). Because a MANOVA is robust to nonnormality, it is suggested that further transformations are not necessary (Mertler & Reinhart, 2017, p. 137). Therefore, transformations on the data were not conducted, and the original data were used for the MANOVA test. The descriptive analysis is shown in Table 5.

Table 5

Descriptive Statistics

	Method of Instruction	Mean	Std. Dev.	N
Formative	Hybrid	81.77	10.97	229
	Online	92.53	9.94	207
	Total	86.88	11.78	436
Summative	Hybrid	66.89	13.95	229
	Online	64.21	13.49	207
	Total	65.62	13.7	436

Note. The means and standard deviations of overall % correct in formative and summative assessment.

Then, the MANOVA test was conducted. The Box's Test of Equality of Covariance Matrices checks the assumption of homogeneity of covariance across the groups. The results were not significant (Box's $M = 6.53$, $F_{(3, 50112529)} = 2.166$, $p = .09$), indicating that there are no significant differences between the covariance matrices. Therefore, the assumption was not violated, and Wilk's Lambda was the appropriate test to examine from the Multivariate Tests results.

The MANOVA test first examines if there are overall differences in student learning (as measured by the combination of formative and summative assessment percentage scores) between students who learned with hybrid instruction and those with online education. The multivariate tests results indicated a significant difference was found in overall assessment scores between students who learned with the two methods of instruction (Wilks' $\lambda = .785$, $F(2, 433) = 59.12$, $p < .001$, $\eta^2 = .215$).

Secondly, to determine differences in student learning measured by formative assessment percentage scores between students who learned with hybrid instruction and those with online instruction, the univariate test results for formative assessment were examined. A significant difference was found in formative assessment ($F(1, 434) = 114.3$, $p < .001$, $\eta^2 = .208$), with scores higher in the online group ($M = 92.5$, $SD = 9.94$) compared to the hybrid group ($M = 81.8$, $SD = 10.97$).

Finally, to determine differences in student learning measured by summative assessment percentage scores between students who learned with hybrid instruction and those with online instruction, the univariate test results for summative assessment were examined. A significant difference was found in summative assessment ($F(1,434) = 4.16$,

p = .042, η^2 =.010), with scores slightly higher in the hybrid group (*M* = 66.89, *SD* = 13.95) than the online group (*M*= 64.20, *SD* = 13.5).

The summary of adjusted means and unadjusted means for each group was summarized in Table 6.

Table 6

Adjusted and Unadjusted Group Means

	Formative		Summative	
Group	Unadjusted M Std. Dev.	Adjusted M Std. Er.	Unadjusted M Std. Dev.	Adjusted M Std. Er.
Hybrid	81.77 10.97	81.774 .694	66.89 13.95	66.897 .908
Online	92.53 9.94	91.103 .730	64.21 13.49	64.208 .995

In summary, the data presents a significant difference in overall student achievement between hybrid and online groups. The MANOVA also showed a significant difference in student achievement with formative assessment, with mean score values being approximately 10% higher with the online group. Lastly, there was a significant difference in student summative achievement scores, with mean scores approximately 2.5% higher in the hybrid group.

Results for Research Question 2:

RQ2: Will analysis of a student survey indicate trends, themes, or patterns based on student experiences with online and hybrid learning? If so, does the data reveal notable differences when comparing hybrid versus online teaching methods?

The data analysis for research question 2 was performed in two parts: (1) content analysis on four open-ended questions, whereby comments will be read and sorted based on themes or trends for each method of instruction; and (2) descriptive analysis will be performed to analyze the results from Likert scale survey questions. The number of students that responded for each group is estimated between 120 and 190 per group (not all students surveyed answered all questions).

Content Analysis: Open-Ended Questions

Thematic analysis was used to analyze responses to open-ended questions. The following four open-ended questions will be discussed in this section for each teaching method: 1. Would you recommend this course to a friend, why or why not? 2. What advice would you give a student that has signed up for this course? 3. Were the assignments/activities/discussions/exam reviews helpful for your learning? 4. What constructive comments do you have for this course?

Student responses were exported from the learning management system (LMS), deidentified, and sorted by teaching method and survey question. These documents were examined, and common themes were identified for the four open-ended questions. The analysis includes positive and negative aspects found in the data. The hybrid teaching model will be discussed first, showing results for each question in succession, followed by online instruction in the same manner. All student responses reported below were taken directly from the survey report and have not been edited or corrected for misspellings, typos, or other grammatical errors.

Results Online Group: Themes Identified by Question

1. Would you recommend this course to a friend, why or why not? Most responses were positive, noting that the class was well organized and had excellent support materials. However, many students pointed out that the course will need a strong sense of self-motivation while setting a strict schedule and committing time.

> "I would recommend this course to another student, it was fun and engaging the teacher participated in a good manner with the students and helped out when you needed it.
>
> "I would recommend it but let them know that they have to stay organized especially if they are taking other classes simultaneously."
>
> "This class was the most organized online class I have taken so far, however there is a lot to learn, more than I expected, and I would not recommend this online course to anyone who does not have extra time to fully understand the material."
>
> "I feel like you are a great teacher and I would recommend this class, it was just super hard for me. I feel you give us a lot of tools to help study."
>
> Many comments stated that the course was not advisable with a busy schedule:
>
> "The only reason I would not recommend taking this class online is that it's a lot of material to learn, so you need to have the ability to self-motivate yourself to work on it on your own. For that reason, I probably would elect to take it in person if I had to take it again. It didn't work that way with my work schedule this semester, but I do feel like I have a good base of knowledge to move onto

> microbiology with. If it comes down to a scheduling conflict, I would recommend taking this class online only if the person is confident in their ability to self-motivate, attend extra study sessions, tutoring center, etc. It's a LOT of information to process on your own."

Although most students were happy with the organization and course support, the recommendation was contingent on self-discipline and setting a large amount of time dedicated to a regimented study schedule.

2. What advice would you give a student that has signed up for this course? Similar to the previous question, students were strong to advise a strict schedule while staying organized. Reiteration of advice to "watch the lecture videos" occurred throughout the survey responses, along with the need to dedicate time towards learning the content. One student claimed that the lecture videos "saved my life for this online class". The following quotes demonstrate these themes:

> "My biggest advise for this class is not to underestimate it. It's challenging and fast paced with a lot of information in quick succession. So, you need to be organized and stay motivated. If you aren't organized in a class that moves at this pace, you will fall behind. The subject matter is interesting and the online format has a lot of different ways to learn it, so I would suggest finding a rhythm that works for you early on and then staying consistent. Build positive habits! Also, repeat *the lecture videos*, power-points, and other materials as you go through

your objectives multiple times to help with retention and understanding. And ask for help if you need it!"

"Watch the recorded video they were very helpful. If you are a full time employee and taking multiple classes, this class isn't for you. This class requires a lot of time to be put into it at least 2-3 everyday minimum! Make sure you get ahead of the class to give yourself more time to study, and when it comes to studying flashcards are your friend!

"Manage. Your. TIME! I would literally map out which sections of the chapter I would read what days, and which days I would allot to watching the videos, etc."

The quote below demonstrates that many students suggest building a schedule around this particular course so that less demanding courses are taken simultaneously and time can be better managed:

"I would advise any students who are wanting to take this course to maybe take some easier courses along with it, rather than packing on another hard course or two. This course really takes a lot of time and dedication, especially in the online format. Be prepared to really work for your grade in this class, you cannot be too prepared!"

As noted in the first of the two quotes above, not only was the suggestion of watching the videos a theme, but students found that watching the videos several times was helpful, as shown below:

"Watch and re-watch the lecture videos- they contain a wealth of knowledge, much of which is directly on the test!"

"Utilize the lecture videos. The ability to continually access these videos played a huge role in my success. I watched each chapter's prior to the discussions, and then a second time to review before each exam.

In summary, students suggest that watching the videos many times, while being able to dedicate time towards this course were major themes found.

3. Were the assignments/activities/discussions/exam reviews helpful for your learning? Responses were mostly positive about support material. The homework assignments were designed to help the student to review concepts and to test their knowledge in a way that doesn't penalize their grade. The homework assignments were designed to allow for multiple attempts and provides hints if students are struggling with questions. Students appreciate this aspect as in the following quote:

"I think the Pearson homework was helpful and I liked going through the dynamic study modules because it made you repeat till you got it right which was great for studying"

"I like how the assignments gave us hints and review topics."

Regarding the discussions, most students found them helpful for reasons of keeping them on schedule and for review. With any chapter discussion, students appreciated that they were allowed the freedom to post any kind of related concept to the content.

" I think they provided good accountability to keeping up with information."

> "I liked doing the discussions with freedom. I think it made it fun having to find ways to ask questions and if people utilize it for studying, it is beneficial to have different resources to go off of."

This provides another study guide containing many practice questions, mnemonics, and concepts. After the discussion was completed, all student entries could be easliy reviewed. A benefit of this is that peers present the content, so language is at a collegial level. However, the comment below provides that not all students used this resource.

> "I liked having the ability to do what ever kind of post I wanted, but I will be honest, I never looked at anyone elses post aside from the one I would respond to."

4. What constructive comments do you have for this course? The responses for this question were diverse, so strong themes were not present. A small number of students mentioned changing the number of summative exams as in the following quote.

> "If I could suggest something it would be having weekly chapter quizzes or exams instead of 3-4 chapters per exam only because I tend to forget quickly what I have learned and I feel as though having weekly exams would be easier if they involved only 1 chapter at a time"

The practice of having one exam per chapter would drive up the administrative challenge and cost associated with remotely proctored testing. Further research may indicate that more frequent testing could be used for assessment, and this practice may provide a method for competency-based evaluation.

Results Hybrid Group: Themes Identified by Question

1. Would you recommend this course to a friend, why or why not? The data suggest results are mostly positive. A theme noted here is that students benefitted from online recorded lectures. Secondly, many students found that active involvement and practice suited their learning. This is demonstrated by the following quotes taken directly from the survey responses:

> "I actually really preferred this class structure. I have difficulty just listening to a teacher lecture day after day, my attention wanders frequently. I like that I can watch at home when I have time and pause when needed. Also, having the video to go back to at any time is very helpful. The IRATs/GRATs are awesome because it gives us an idea of what kind of questions the teacher will ask and how they structure their questions. Exam review is very important, it helps me to determine which areas I'm weak in, and then I have time to adjust before the exam. I'm a very independent learner so that is probably why I enjoyed this class so much."

> "I liked the flipped environment, and being able to watch lectures multiple times was very helpful."

> "I really liked how this class was formatted, it helped my learn more because it made me actively have to try and learn stuff on my own instead of coming to a lecture and possibly just zoning out the whole time. Definitely hope that many more of my classes are like this in the future, or more teachers pick it up."

> "This was the first time I have taken a flipped class, and I really enjoyed it more than I expected. It was nice to have the lectures available when studying and being able to pause the videos to take notes. Being able to review during class time instead of being lectured at the whole time really helped the information stay with me."

Regarding lecture videos that were available online, many students noted the advantages of this resource. The ability to re-watch, pause, and view at a faster pace was mentioned many times as helpful in taking notes or reviewing before an exam. The video resource seems to be a positive resource, however, on the contrary, a large group of students mentioned that watching the video lectures outside of class time was a hardship. This is demonstrated in this example:

> "Wouldn't have minded the flipped classroom idea if I had more time to watch the videos. I know that it was really hard for me to keep up with them because I work a lot and I work a lot of night shifts so it was very hard to find time."

This problematic theme was also identified in the next survey question.

2. What advice would you give a student that has signed up for this course?

Finding time to watch the videos as a problem was reiterated many times in this survey question. The following are examples of student advice specific to this perception:

> "cons: requires too much time, 1hr+ online video lec+75min in class+more than two hours for online homework. everything times two so total 14hrs."

> "Dont take this class if you have a full plate because its impossible to be fully prepared for test if you do both work and school full time."

Along the lines of the hardship of finding time to watch the videos, a prominent theme of this question was that students strongly advise their colleagues to find the time to watch the videos. As noted in one of the quotes below, a student mentioned that they believed other students don't watch the videos enough:

> "To watch the videos study for the IRAT like a real test."
>
> "I will tell him to watch the videos closely, treat the reviews as it was the exam and give this class a lot of time to study."
>
> "WATCH THE LECTURES....too many people don't watch them..."
>
> "* Ensure adequate time is set aside to watch the videos FULLY."

Indeed, watching the videos is a time-consuming activity. Each chapter has 75 minutes of lecture. A word search of the survey data showed that the word "time" is prevalent. In fact, the word "time" appears abundantly in all four survey questions. Therefore, alongside the video recommendation, "time" itself was identified as a prominent theme. Students reiterated how much time the course requires:

> "My advice would be to set aside a lot more time for studying than you would expect to in order to completely understand the material. Time is very valuable and detrimental for this class."

> "The class requires more discipline because of the videos you watch at home. It's like attending class twice, once at home and then taking quizzes in the class. If you procrastinate, I suggest not taking this class."
>
> "Watch the lecture, take notes, watch lecture again, do homework, then do flash cards. Lots and lots of flashcards. Study time is essential for this style of learning and I wish my work schedule would have been changed earlier in the course. I was able to dedicate more study time at the end of course and it made a huge difference."

On the first day of class, the importance of time needed was emphasized verbally and stated directly in the syllabus: "this course takes about 15 hours per week to keep up on studies." In summary, not only was watching the videos a theme in this survey question, but also "time" itself was added to emphasize the importance of watching the videos.

3. Were the assignments / activities / discussions / exam reviews helpful for your learning? The most common theme was that the homework assignments were helpful along with the IRAT/GRAT activity. A significant number of students liked the engagement and the practice questions in the IRAT/GRAT that helped prepare them for the exam. This was demonstrated by these comments:

> "I really liked the idea of the IRAT/GRAT every class. I usually have pretty bad test anxiety and I believe that the constant practice helped me to stay on top of my game both in not procrastinating ang for test type practice."

"I think this is a great exercise to be able to discuss with peers"

Another theme was that the review activity was mentioned as helpful by many because it allowed them more practice prior to the exam while interacting with their peers as in the following quotes:

"I think the review activity was good. It makes you question your answers against the individuals in the group and keeps you engaged."

"I enjoyed it. acted as like a sneak peak for what to expect on the test. what will the questions be worded like?, what would they be about?, what things should we be wary of?"

Since this particular survey question is framed in a positive tone, the responses were mostly positive; however, the following survey question was framed for constructive feedback, and comments were aimed to provide improvement and criticisms of this teaching method.

4. What constructive comments do you have for this course? One theme that occurred was that students claimed that the IRAT questions were not the same difficulty as the exams, so some students felt as if they were not appropriately prepared for the exam:

"I enjoyed the flipped classroom format because it focused a lot more time and reviewing and classmate interaction but the IRAt and GRATs I feel like did not have similar questions that the test did."

This was an interesting, unexpected theme and would require further research to compare the actual difficulty of the IRAT questions to the exam question difficulty.

Another common theme was that the students wanted more time for lecture review of the content. The chapter review, which is the first 20 minutes of every IRAT/GRAT class, is the time set aside for students to ask questions based on the videos that they should have previewed before coming to class.

> "The review session was great for answering specific questions. I just wish that review would spend more time on review and allow less time on the Irat and Grat."

> "The review is very helpful. The lack of time to review was the only downfall."

Perhaps the IRAT/GRAT questions are less demanding than the exam questions. This would require further analysis and would be an exciting exploration of the data. What are the difficulty values of these questions? How do these values compare to exam questions? Is this observation valid or perceived because the IRAT/GRAT questions are very low stakes compared to exam questions?

Table 7

Summary of Themes Presented by Analysis of Open-ended Student Responses.

Open-ended Question	Online	Hybrid
1. Would you recommend this course to a friend; why or why not?	Mostly positive, caveats specific to have self-discipline and schedule time.	Mostly positive, time commitment and schedule management recommended. Too much time spent on prep and class.
2. What advice would you give a student that has signed up for this course?	Watch and re-watch lecture videos Manage study time Stay on schedule Must be self-disciplined	Watch lecture videos Manage study time
3. Were the assignments/activities/ discussions/exam reviews helpful for your learning?	Pre-recorded videos Discussions helped stay on schedule. Homework provided practice and review	Pre-recorded videos Peer interaction with GRAT and reviews Homework provided practice and review
4. What constructive comments do you have for this course?	More discussion interaction More chapter exams covering fewer chapters.	More review time before activity Quiz question difficulty did not match exam difficulty.

Summary of the Themes between the Two Groups

Table 7 summarizes themes identified in both learning groups. Interpretation of the data revealed that a similar majority considered their learning environments a positive experience. However, the hybrid model presented a sense of extra pressure due to required in-person attendance with the addition of watching assigned lecture video homework. The most common theme paramount to students' learning was the pre-recorded lecture videos. With the importance of managing the lecture videos, students need to have self-discipline and time management.

Hybrid responses revealed a feeling of an extra time commitment as they needed to show up for in-person instruction in addition to watching the videos, along with typical study and review; this consumed extraordinary time. The online course mentioned re-watching the videos more often than the hybrid model. The implication is that online students may have better time management skills or simply have more time available.

The majority of both groups found the homework assignments and discussions helpful. It was mentioned that homework provided an excellent resource for practice and reinforcement. The online class found the discussions useful, and many students claimed they liked the design that allowed them to post whatever they decided. Although the asynchronous class discussions in the online group were different by design, the students yearned for more interaction. Even so, online students commented that the discussions helped their study schedules. Discussions with the hybrid group occurred within their team as they participated in the GRAT activity. Many students claimed that this peer engagement and discussions were helpful.

Results of Likert scale questions

This section will cover eight Likert question results from the end-of-semester survey. Three of those questions are common to both groups: 1. “Would you recommend this class format to a friend?”, 2. “How would you rate the homework assignments as helpful?” and 3. “Did you watch all the lecture videos?”. Three Likert scale questions were specific to the hybrid group, and two were specific to the online group. The eight questions are listed per group in table 8.

Table 8

End-of-Semester Likert Survey Questions

Eight Likert Scale Survey Questions	Online	Hybrid
1. Would you recommend this class format to a friend?	X	X
2. How would you rate the homework assignments as helpful?	X	X
3. Did you watch all the lecture videos?	X	X
4. How helpful were the IRAT/GRAT activities?		X
5. On a scale of 1-5, 1 being lowest and five being best, how would you rate the review sessions as helpful?		X
6. The group interaction helped me understand the material.		X
7. On a scale of 1-5 1 being lowest and 5 being best, how would you rate the chapter discussions as helpful?	X	
8. How helpful were the Chapter quizzes on Pearson Mastering?	X	

Question results for Online and Hybrid

Likert Q1: Would you recommend this class format to a friend?

The first Likert style question (Would you recommend this course format to a friend?) is similar to the first open-ended question: "Would you recommend this course to a friend, why or why not?". There were 200 student responses from the hybrid group and 159 in the online group. The question was rated using four possible options (see table 9), with two options in the positive (strongly recommend and recommend) and two negative options (not recommend and strongly not recommend). Results are reported by the percent of total responders per option.

Table 9

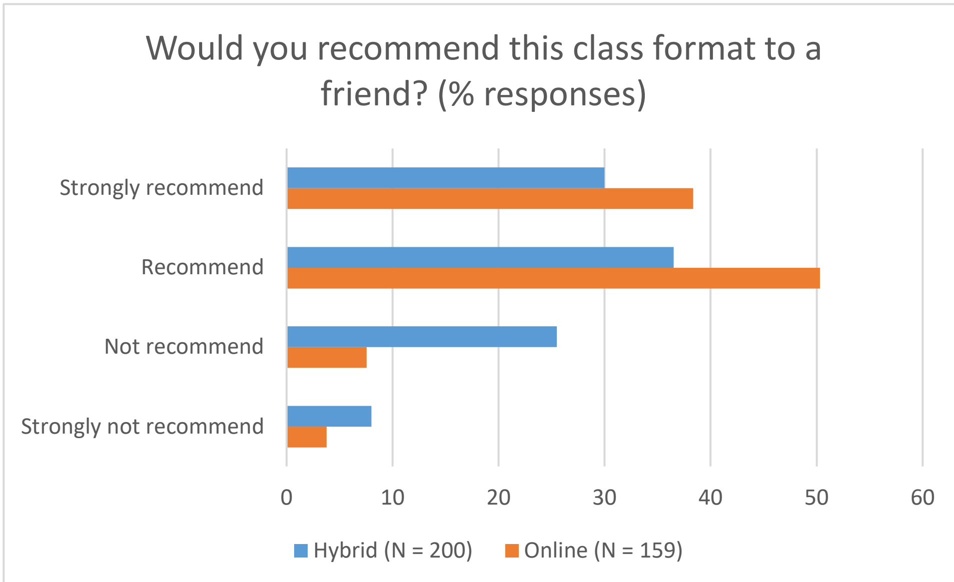
Likert Survey Question results: Would you recommend?

Would you recommend this course format to a friend?	Hybrid, N = 200, %	Online, N = 159, %
Strongly recommend	30	38.4
Recommend	36.5	50.3
Not recommend	25.5	7.6
Strongly not recommend	8	3.8

The hybrid method survey responses favored the recommendation, with 66.5% overall positive (30% + 36.5%). However, the online method result was higher, with 88.7% overall positive (38.4 + 50.3%). Using these numbers, the online group reported 22.2% more positive recommendations than the hybrid method. Also noted is a large difference in the "not recommend" category, with 25.5% of hybrid responders selected versus 7.6% in the online group. The hybrid group had 33.7% overall not recommending (25.5% + 8%), whereas the overall value for not recommending the online course is 11.4% (7.6% + 3.8%). The overall "not recommend" value is 22.3% higher in the hybrid group when compared to online. This data is summarized graphically (see figure 4).

Figure 4

Likert Survey Results from the Two Groups: Q1. Recommendation



Likert Q2: How would you rate the homework assignments as helpful?

The second Likert style question asks how helpful the homework assignments were. Although the assignments were not identical between groups (see method for details), this question explores the metacognitive aspects of "homework" in general. There are two homework assignments for the online course and one for the hybrid. The Likert scale options were rated on a scale of 1 to 5, with 5 being the most helpful. Results for ratings 1-5 are reported in percent of the group total, with the hybrid group having 285 responders and the online group having 159 responders for this survey question (see Table 10).

Table 10

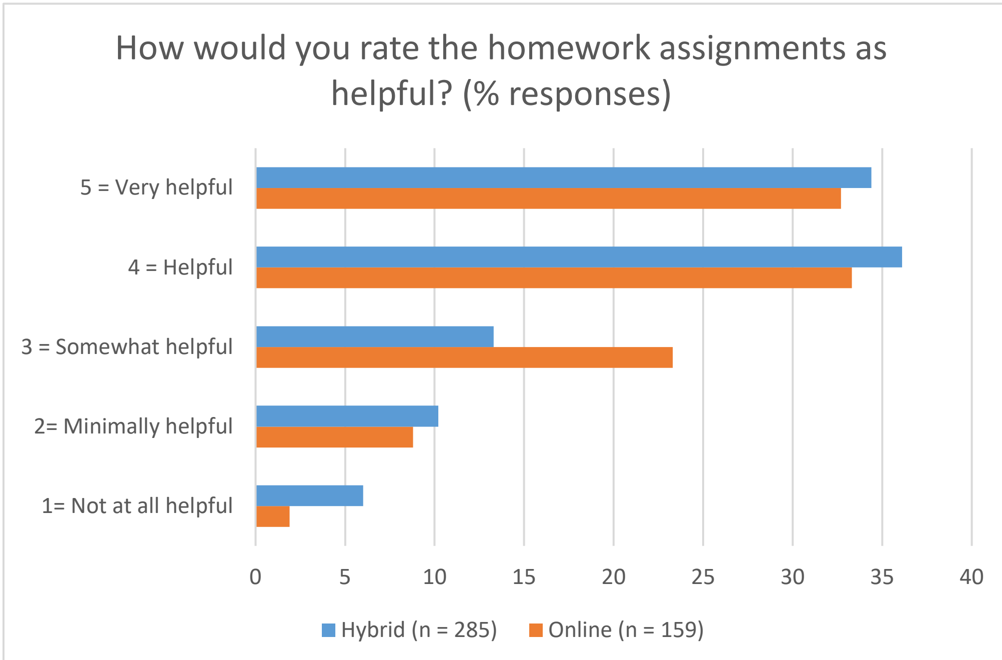
Likert Survey Question results: Homework

On a scale of 1-5, 1 being least and 5 being best, how would you rate the homework assignments as helpful?	Hybrid, N = 285, %	Online, N = 159, %
5 = Very helpful	34.4	32.7
4 = Helpful	36.1	33.3
3 = Somewhat helpful	13.3	23.3
2= Minimally helpful	10.2	8.8
1= Not at all helpful	6	1.9

The hybrid method responded with a 70.5% overall positive (34.4% + 36.1%) for the homework being helpful. The online group responded with 65.9% overall positive (32.7 + 33.3%). Overall positive percentages are slightly higher in the hybrid group. The data in Table 10 is represented in Figure 5 below.

Figure 5

Likert Survey Results from the Two Groups: Q2. Homework



Likert Q3: Did you watch all the lecture videos?

The third common Likert style question involves a self-report on student use of the pre-recorded videos. Data shows the percentage of students who responded from the population (N) who answered each option's survey (see Table 11). Student response options start with "yes," meaning the student watched all of the lecture videos. Options sequentially rise in increments of missing "1 or 2" more until "more than 6" video lectures were missed. Results show the hybrid group is much less (N = 46) than the online group (N = 141) because the survey question was introduced later in the hybrid study. Results are reported in percent of the total, and the values are not similar between groups (see table 11 and figure 6).

Table 11

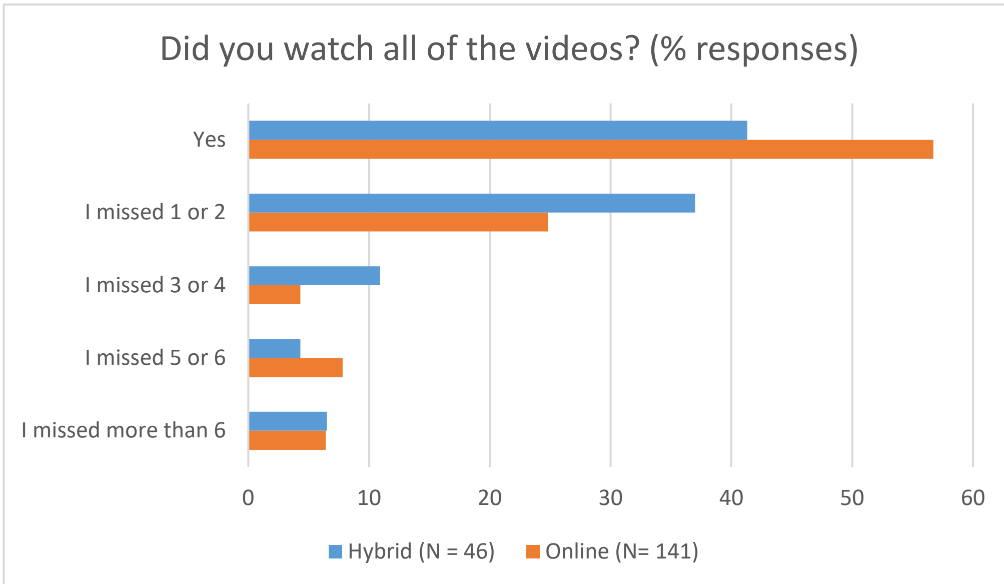
Likert Survey Results from the Two Groups: Q3. Video

Did you watch all of the videos?	Hybrid, N = 46, %	Online, N = 141, %
Yes	41.3	56.7
I missed 1 or 2	37	24.8
I missed 3 or 4	10.9	4.3
I missed 5 or 6	4.3	7.8
I missed more than 6	6.5	6.4

This last option, "I missed more than 6" represents missing 35% or more of the 17 lecture videos available. The online group reported "Yes" 15.4% higher than the hybrid group. The online group missed fewer video lectures than the hybrid group, as reported by the second option (only missed one or two). The online group was less than the hybrid group by 12%. Although the differences in the first two options are large when compared separately, the combination of values for these two options is similar. The result for the hybrid group is 78.3% for the hybrid group (41.3% + 37%) and 81.5% for online respondents (56/7% + 24.8%).

Figure 6

Likert Survey Results from the Two Groups: Q3. Video



Questions for Hybrid

Likert Q4: How helpful were the IRAT/GRAT activities?

The following three questions were specific to activities in the hybrid group. The first of this set asks students how helpful the IRAT/GRAT activity was (see table 12). Recall that the IRAT is the individual reassurance assessment test, where students take 20 question quiz independently, and the GRAT (group reassurance assessment test) is the same 20 questions reviewed as a peer group. The total time required for both activites is about 40 minutes.

Table 12

Hybrid Likert Survey Results: Q4. IRAT/GRAT Activity.

How helpful were the IRAT/GRAT activities?	N = 46, %
Very helpful	41.3
Helpful	35.4
Somewhat helpful	17.5
Not at all helpful	5.8

A majority 76.7% (41.3% + 35.4% =) of the students found the activity helpful. This majority is consistent with the content analysis data. Most research involving peer-to-peer interaction shows positive student reviews and learning outcomes (S. Freeman et al., 2011; Wilton et al., 2019). The activity retains the same groups for the review activity, which is the next question in this set.

Likert Q5: On a scale of 1-5, 1 being lowest and 5 being best, how would you rate the review sessions as helpful?

This question is specific to the chapter review discussion activity that occurs one meeting before a summative chapter exam. Students engage with each other, and the instructor as practice questions are presented for each chapter. Incorrect answers provide discussion to clarify misconceptions. The overall positive response was 79.5% (38.9% +30.6%), as shown in table 13. This data also agrees with the content analysis that asked students what they found helpful. The next Likert question relates to the previous two questions; it asks about group interaction in general (see table 14).

Table 13

Hybrid Likert Survey Results: Q5. Review Activity.

On a scale of 1-5 1 being lowest and 5 being best, how would you rate the review sessions as helpful?	N= 193, %
5 = Very helpful	38.9
4 = Helpful	30.6
3 = Somewhat helpful	19.2
2= Minimally helpful	8.3
1= Not at all helpful	3.1

Likert Q6: The group interaction helped me understand the material

The group interaction is a general question that involves both the GRAT activity and the review. The question seeks to identify how many students prefer this specific method to support their learning. A majority (39.8% + 41.7% = 81.5%) of the students found group interaction helpful (see Table 15). This result concurs with content analysis. Peer-to-peer interaction can help students promote their learning with the pedagogical belief in social constructivism (Stigmar, 2016). Given this, the online course has an asynchronous interaction with chapter discussions, so genuine peer conversations are absent. The next Likert question addresses how this activity impacted their educational experience.

Table 14

Hybrid Likert Survey Results: Q6. Group Interaction.

The group interaction helped me understand the material	N = 103, %
Strongly agree	39.8
Agree	41.7
Neither agree nor disagree	7.8
Disagree	9.7
Strongly disagree	1.0

Questions for Online

Likert Q7: The group interaction helped me understand the material

The online course has three formative assignments, which break into two major categories: discussion (one per chapter) and online homework (two per chapter). The discussions are by chapter, and students must submit at least two significant contributions. They have the freedom to make any sort of entry they wish, as long as it aligns with the content. The results for students rating their experience from very helpful to not helpful at all are shown in table 15. A majority (34.8% + 27.4% = 62.2%) of the students found the discussions helpful.

Table 15

Online Likert Survey Results: Q7. Chapter Discussion

On a scale of 1-5 1 being lowest and 5 being best, how would you rate the chapter discussions as helpful?	N = 164, %,
5 = Very helpful	34.8
4 = Helpful	27.4
3 = Somewhat helpful	22.6
2= Minimally helpful	12.2
1= Not at all helpful	3.0

Likert Q8: The group interaction helped me understand the material

This question seeks to assess the value of the assigned homework assignments. There are two sets, for the online course. Each assessment is designed for student review and practice. The results show a majority of 81.5% found the homework as helpful or very helpful (39.8% + 41.7%), see table 16. This data coincides with the results of question #3 (Were the assignments/activities/ discussions/exam reviews helpful for your learning?), where students claimed the homework helped them review the content, but the due dates kept them on track in their studies.

Table 16

Online Likert Survey Results: Q8. Homework Quizzes

How helpful were the Chapter quizzes on Pearson Mastering?	N = 141, %
5 = Very helpful	36.2
4 = Helpful	34.8
3 = Somewhat helpful	26.2
1= Not at all helpful	2.8

CHAPTER V: DISCUSSION

This study aimed to compare two models of instruction with an undergraduate introductory cell biology community college course based on student achievement. This chapter includes discussions regarding the results of formative and summative scores by employing a one-way MANOVA. Interpretation of themes presented in the end-of-semester student survey will also be discussed. This chapter concludes with implications of the results, recommendations, and suggestions for future research.

The two research questions for this study are the following:

RQ1: What differences exist with overall percent achievement in formative and summative assessments when comparing hybrid and online instructional models in an introductory cell biology course?

RQ2: Will analysis of a student survey indicate trends, themes, or patterns based on student experiences with online and hybrid learning? If so, does the data reveal notable differences when comparing hybrid and online teaching methods?

Quantitative results: Summative Student Achievement

Summative assessments typically cover a significant instruction segment and are usually weighted heavily. As long as assessment questions align with student outcomes, summative assessments are considered an accurate overall measure of a student's knowledge.

The result from the MANOVA determined that there was a significant effect of method of instruction on summative assessment, with scores higher in the hybrid group

(M = 66.89, SD = 13.95) than in the online group (*M*= 64.20, *SD* = 13.5). However, the p-value of .042 is close to the non-significant cutoff value of .05, and the hybrid group average is a mere 2.7 percentage points higher than the online average. Perhaps many educators would say that about 67% and ~64% difference is not substantial. While studies would find significant differences in summative achievement in teaching biology favoring in-person to hybrid (Mohammadian et al., 2021; Poelmans et al., 2018), an extensive review reported in 2009 claimed better performance in online learning (Means et al., 2009). Most research, however, supports a small to no significant difference in achievement between online and hybrid courses (Baker et al., 2020; Hauser, 2016; McCutcheon et al., 2015; Nfor, 2015; Shea & Bidjerano, 2013; Snart, 2010). The findings in this study for summative achievement scores agree with the literature majority.

This is important because many faculty have negative opinions about offering courses online (Kennepohl & Shaw, 2010; Kopachena, 2018; McNeal, 2015). Approval to teach this course online in 2017 was barely met as about half of the faculty believed that online instruction would significantly negatively impact student success.

Given the recently forced acceleration of online courses driven by the global pandemic, a renewed study of faculty opinions would be interesting. A post-pandemic survey of 71 instructors and 122 students declared that most thought that remote learning could effectively replicate critical components of content delivery and assessment. Additionally, as instruction slowly transitioned to in-person, retention of specific online features was deemed necessary (V. Chen et al., 2022). Attitudes regarding online instruction may have been significantly impacted due to being forced to re-design in-person courses. This study began in the spring of 2017, with only one online course being offered at Truckee Meadows Community College on a trial basis, with faculty being hesitant to provide this format due to the belief that students would not be successful. In contrast, the fall of 2022 provides five online cell biology courses. As more online courses are being offered, further research may provide greater insight into similar study comparisons.

Implications

Summative scores have long been considered an essential indicator of achievement. Results from the current study add to the debate in the literature on the value of online instruction. The groups in this study involved a polar opposite approach to instruction from an engaged in-person flipped hybrid format to a fully independent asynchronous online course. The minimal advantage of face-to-face classes over online classes may be interpreted as alignment with student preference (Hoch & Doughe, 2011; Sellnow-Richmond et al., 2020). The implications imply that online courses rival the quality and success of any other teaching method with intentional design. This information may influence policymakers and stakeholders as the demand for more online courses continues, especially if student success rates are similar to in-person courses.

Quantitative results: Formative Student Achievement

Formative assessment is to allow for practice and rehearsal while being low stakes. Formative assessments, such as homework and the IRAT quizzes, provide important metacognitive information that can significantly improve a student's performance on summative exams (Ibabe & Jauregizar, 2010).

In contrast to summative achievement, there was a highly significant effect ($p < .001$) with higher scores on formative assessment in the online group ($M = 92.5$, $SD = 9.94$) compared to the hybrid group ($M = 81.8$, $SD = 10.97$). There were three formative assessments for the online group, with only one assessment in common with the hybrid group. The hybrid and online environments have inherent limitations based on design differences. Reasons supporting the online group result of 10% overall higher average formative scores may be due to a less hectic schedule than the hybrid course. This is based on the hybrid students' comments that it was difficult to manage time with the requirement to travel, pre-study, and attend class. Also, the hybrid course's IRAT/GRAT activity may have been more difficult because the IRAT is proctored and the GRAT is timed, whereas all the online homework assignments have no time limit (besides the due date). Homework done online has the likelihood that students will look up answers, which may have also been a factor. In either case, the formative homework assignments were notably helpful, according to the end-of-semester survey. Perhaps the online group is better at staying on top of their due dates. Surprisingly, an online asynchronous course's inherent "silent" nature would support more missed due dates. And if one assumes that notion, then why wouldn't the in-person class have just as high of a formative grade, if not better, when physical presence would support awareness? The design of the formative assignments is such that most points are awarded for simply doing them, so missing an assignment would have the greatest impact. This concurs with thematic results whereby students claim that the homework is helpful and necessary due to the influence on their grades.

Implications

It has been established that formative practice improves summative scores (Alexander et al., 2020; Ibabe & Jauregizar, 2010; Petrović et al., 2017), although specific comparisons involving hybrid and online formative achievement were not found. The online homework specifically allows students to have multiple opportunities to improve their scores and give hints if needed. Since average summative achievement scores were found essentially the same for both courses, other factors such as time management may be involved with differences informative achievement. This data would be interesting to explore which formative assessments are strong predictors for summative success. Preliminary data obtained from the hybrid group does suggest a correlation between IRAT and summative achievement. A deeper exploration of predictors for achievement with this study may provide insight to support student success and retention.

Research question 2: Open-ended questions

This section will compare and discuss group thematic results with the four open-ended questions. Supporting data, such as Likert results, will be included. Implications will be included at the end of each of the four survey questions.

1. Would you recommend this course to a friend, why or why not?

The majority of responses in the narrative were positive for both groups, which is mainly supported by the Likert question (see Figure 5), which asks the same question. Although the Likert data does indicate a majority in favor of recommending both formats, a closer examination reveals a notable difference between the two groups. The hybrid Likert group reports a combined percent positive (highly recommend, and recommend) at 66.5%. In contrast, the online group reported 88.7%. The difference of 23.2% in favorable preference is noteworthy. The negative shift in preference is revealed, with 25.5% of hybrid students reporting they would not recommend the course format, contrasting with 7.6% from the online group. What elements did hybrid students encounter to explain a lower preference than online?

A major difficulty in analyzing and comparing hybrid courses with the literature is the broad variation in blending and balancing the web-based and in-class components, including other course-dependent factors that compound the complexity. In addition to these variables is the notion that electronic culture is changing rapidly. It is conceivable that the current attitudes of online learning will be different 5 years from now. Similarly, how can we compare today's preferences to those reported five years ago? Learning preference is a moving target as technology becomes more available and used in education. Research a decade ago found that students prefer traditional face to face instruction (Clayton et al., 2010; Hoch & Doughe, 2011). In a recent study involving attitudes and preferences with online and hybrid instruction, hybrid was shown the preferred method (Baker et al., 2020).

Although most students were satisfied with the organization and course support, the recommendation for the hybrid course was heavily contingent on self-discipline and setting a significant amount of time dedicated to a regimented study schedule. Implications from the hybrid narrative revealed a theme of students being overtaxed, possibly more so than online students. One comment in the narrative from a hybrid student stated they were not aware of the course format. When students enroll in hybrid courses and are unaware of the delivery format, they may experience a violation of expectation that reduces their motivation to attend to the material (Sellnow-Richmond et al., 2020).

The hybrid course involved in this study was a flipped format, which most entry-level students are not familiar with. Students who may be anxious about taking a biology course may be shocked as flipped format expectations and design are far from traditional—reviewing the online lectures before class requires much more work and time management than merely showing up for a passive lecture. The shock of having a hybrid format may be a factor in the negative deflection towards not recommending the course.

The “active involvement” theme presented by the hybrid narrative supported a positive recommendation based on how peer engagement suited their learning. Another positive article noted by both groups is that students benefitted from online recorded lectures, which will be discussed in question #3 (What was helpful for your learning?).

A study by Clayton et al. indicated significant differences in motivational beliefs and learning strategies. Students who preferred traditional environments showed a mastery goal orientation and greater willingness to apply effort while learning. Students who chose less formal settings were more confident that they could manage a non-traditional class (Clayton et al., 2010). Therefore, students’ achievement goals and self-efficacy influenced their choice of an online or hybrid learning environment.

Implications. These findings have implications for understanding students’ motivation for learning in diverse educational settings. Presenting students' data exhibiting the correlation of IRAT scores on summative exam performance may increase student motivation and “buy-in” to the course design. Best practices would advertise the hybrid course with a footnote explaining design and expectations. Additionally, it may be beneficial to send enrolled students a description of the flipped method well in advance to the start of the class. This advance notice would also allow students more time to reschedule to another course if this method doesn’t suit their learning preference.

2. What advice would you give a student that has signed up for this course?

The hybrid and online groups both agree on the importance of watching the pre-recorded lecture videos. Both groups also emphasize the advice for success is to manage time. The time needed for the course was the most encompassing common theme found in the narrative. Consensus on the importance of watching the videos is reiterated, reinforcing the need for time management to watch them. A hybrid student comment supports this: " WATCH THE LECTURES….too many people don't watch them..." Challenges that a typical nontraditional community college student face is having to manage a full or part-time job in addition to other courses, and some students may have children to attend to, which makes the demand of time and management of time one of the biggest challenges in being successful (S. Travers, 2016). The schedule and environment of the hybrid course are strict. If students are not prepared for class, then the class time is wasted, and no gains are made. McNally et al. found that there are students who are likely to resist a flipped environment, which would directly impact outcomes (McNally et al., 2017).

In contrast, the online group does not experience as much extrinsic pressure. By nature of design, the online cohort still does experience a series of due dates for formative assignments, but students have more flexibility to manage time to adjust their schedules. More freedom in this sense for the online group may be a significant contributing factor to more positive ratings found in survey question #1. In addition, the online group knew what to expect when they signed up for the course. In contrast, the hybrid group may have experienced a sense of "I didn't sign up for this" attitude. A comment from a hybrid student illustrates this: "I will be honest, flipped classroom environment terrified me at first since it was my first time experiencing this type of study approach, but as week after week went by and I figured out the system, my anxiety level have decreased."

The notion of the online group experiencing less pressure or perhaps having more available time is supported by the theme of advice to watch and rewatch the lecture videos. This theme is presented more often in the online group. This implies the greater freedom and flexibility that exists with the online group versus the strict schedule of the hybrid group. Students in the hybrid group may have experienced hardship with the program, especially when the schedule required two IRAT/GRAT activities per week. However, complaints did not appear in the narrative specific to this postulation.

Implications. Improvements can be made to schedule changes with the hybrid course, such as meeting two days apart rather than one, i.e., Monday/Thursday, not Monday/Wednesday. Students should be encouraged to write out a study schedule. For example, encourage students to plan and enter a note on a calendar what day to watch the lecture video and what time. Pointing out the research on the first day of class that committing to goals by writing them down significantly increases adherence (C. J. Travers et al., 2015). In summary, the hybrid group likely experienced anxiety with a new and unfamiliar method of instruction. The addition of a strict hybrid schedule and the challenge to pre-watch lecture videos may have exacerbated negative attitudes causing resistance, as noted by previous studies (McNally et al., 2017; Travers, 2016)

3. Were the assignments/activities/discussions/exam reviews helpful for your learning?

The most prevalent theme identified from the narrative analysis in both courses was the importance of having pre-recorded online lectures as a resource. Students mentioned that watching the videos was essential to their learning. Students mentioned the benefits of pre-recorded videos, such as being able to: (a) watch them in sections; (b) watch them anytime; (c) pause the video to take notes and process; (d) re-watch; and (e) rewind and repeat sections that need attention. Although not mentioned in the narrative, the videos can also be seen at a faster or slower pace. Thematic results of the importance of the video concur with the results found in Likert question #3 (Did you watch all of the videos?). For this Likert question, both groups reported about 80% had either watched all 17 lecture videos or missed at most two videos. Many more students from the online group claimed that re-watching the videos was helpful.

From the video, other resources for learning are supported. All videos are captioned, and one student said it would be helpful to provide a printout of the captions. A few students appreciated the resource of downloadable audio files of the video recording available was beneficial to have while driving or doing mundane chores. Studies show significant differences in learners' motivation and retention with video-based learning (Choi & Johnson, 2005; Enfield, 2013; Wolf, 2018).

The hybrid group reported that the group interaction was helpful, reiterated this by the hybrid Likert questions #'s 4, 5, and 6. These questions asked group interactive items such as the IRAT/GRAT, the review, and overall attitude about group interaction.

The positive majority values were 76%, 79%, and 62%, respectively. Studies indicate that group interaction is valuable in learning (Michaelsen et al., 2004; Wilton et al., 2019). Groups were strategically set up with at least one high achiever, a “more knowledgeable other,” as theorist Lev Vygotsky phrased the term. Along with Vygotsky's theories, group work would support the social construction of knowledge and expand the “Zone of proximal development” as peers teach each other.

The homework assignments were a significant resource that helped students in both the narrative and, according to Likert question #2 (How helpful was the homework?), 70% of hybrid and 65.9% of online students reported that the homework was helpful or very helpful. These assignments are designed to help the students review concepts and test their knowledge in a way that doesn’t penalize their grades. The homework assignments allow for multiple attempts and provide hints if students struggle with questions.

Review sessions for the hybrid class were also noted in the narrative. The students found the practice questions helpful and the ability to discuss them. According to the narrative, consistent due dates for these formative assignments encouraged students to keep on top of their studies so less last-minute cramming would be avoided.

The central theme that students found most helpful was the pre-recorded online videos. The homework and the group work were secondary themes in being helpful. Review sessions (hybrid) and online chapter discussions (online) were useful in the narrative analysis.

Implications.

The overarching theme was video recordings were most helpful. This aspect would be interesting to study because most learning management systems monitor student access to videos. Perhaps the time spent watching videos is a predictor of academic performance. A recent study in a lab science course shows no significance to this point (Doggrell, 2020).

Regular formative homework was another resource that students claimed was helpful. The homework had regular due dates to keep students up with the pace of the course, and the design was low stakes, which allowed for multiple attempts. Students seemed to be more apt to complete the assignments without a punitive scoring system.

The hybrid course appreciated group work. Students enjoy being social, and this may have supported learning by peer to peer teaching. Perhaps the group interaction is a factor that contributes to the slightly higher average summative achievement with the hybrid group.

4. What constructive comments do you have for this course?

Responses in the narrative were highly variable, so no strong theme was identified, although some comments will be briefly addressed for the online and hybrid group.

For the online group, a more interactive chapter discussion was suggested. This would be difficult for an asynchronous design however having a “first submission” due date followed by a “second submission” date may prove helpful as students may find a better rhythm by posting questions/ ideas in the first round, then answer questions on the second round.

The online group also mentioned that exams contained too much information and that separating each chapter into a mini-exam, may help students focus on chapter content one at a time. This would be an exciting design to pilot and use comparative data in this study to determine if there are summative score differences.

The hybrid group mentioned they would prefer more interactive review time during the first part of the IRAT/GRAT activity. The typical amount of time used to review is about 20 minutes. Perhaps having students do the IRAT as an assignment due out of class (but prior to start) may be a viable solution to creating more review time. Students may enjoy this part of learning because they can actively engage in their learning. Rather than passively listening to a lecture, this discussion involves engaged didactic quizzing, students being called out to answer questions and recall facts. A typical lecture doesn't allow this because students don't typically study beforehand in-depth, so they don't know the content. Asking students to review what they learned is much more interactive, and students usually want to answer questions.

The hybrid group mentioned a concerning number of times that the IRAT activity had questions far more straightforward than what was presented on the exam. This would be an interesting hypothesis to explore. Question performance values may reveal differences in difficulty between these two groups. Perhaps the lower stakes value of the IRAT allows for less knowledge blocking anxiety.

Summary and Conclusion

The quantitative data supports a significant difference between the groups in formative and summative achievement, with a more noticeable difference in informative achievement (higher with the online group). Summative achievement scores were slightly higher in the hybrid group. This data supports that a student can achieve just as well by enrolling in an online course or an engaging in-person course for this level of biology. The qualitative analysis supports no substantial difference in positive or negative experiences between the two methods of instruction.

This study evaluated student narratives based on their learning experience about what resources were most helpful, what advice they would give others, and if they would recommend the course. Reviewing the comments in detail provided greater understanding and perspective. Students highly value the pre-recorded lectures and need to manage the time to oversee these and other assignments. Online students may have been slightly happier than hybrid students, possibly due to a more flexible schedule, since hybrid students are being quizzed often and have to keep a more regimented schedule to show up and have already reviewed the material. Also, at the beginning of this study, at least two hybrid courses did not notify the flipped design of the course at registration.

The findings from this study are based on two very different designs; however, neither design was haphazard. Both courses were highly organized. For example, each course contained a detailed “Start Here” module to clarify expectations. In the learning management system, support materials for each chapter were available in “modules” in advance. Support materials included downloadable PowerPoint presentations (same as those covered in the pre-recorded lecture videos), and chapter study guides were provided for students to answer questions actively. Much time was spent to ensure assessment clarity and alignment. The summative assessments included a diverse difficulty level. Perhaps the finding of similar student achievement with summative scores is due to the condition of both courses having a high degree of clarity, support, and organization.

Implications for further research

Further exploration would be necessary to determine if there are any strong predictors of academic success. Because this study did reveal that students recommend watching videos, does watch or re-watching lecture videos predict higher exam scores? Perhaps another factor influences academic success such as IRAT scores, quality of online discussions, or involvement with peer discussion.

Many students claim that anxiety associated with high-stakes exams can be crippling. Are IRAT questions indeed less difficult than the exam questions as some students claim, or is this an effect of anxiety? If not, is there a factor of anxiety relating to high stakes student performance? If so, this would need adjustment.

Another topic to study would be to investigate why students drop or audit the course. Is there a difference between these course designs and retention? Student attrition is critical with STEM-based courses, so insight may help lessen the “leak” of the pipeline.

Recommendations

The most prevalent theme provided by student feedback was the value of the pre-recorded videos. Supporting the diversity of different learners does not go without appreciation. Videos should have captioning, and instructors should provide a downloadable transcript of the captions, and a downloadable audio file from the video.

For the flipped style hybrid course, include a note about this design in the class description as students register. In addition, contact students well in advance to further describe expectations and the nature of the course and open the course in advance to the standard calendar start date. Student “buy in” is essential; presenting research articles that claim better learning by flipping (Barral et al., 2018; Enfield, 2013) may help student morale and motivation to do preparative work. With group assignments, provide each group with at least one high-achieving student. This promotes the achiever to reinforce their understanding by teaching others, and other students may glean positive study habits and learning methods from the "more knowledgeable other."

Online courses should include a component in the start-up of the course entitled "is an online course for me?" to make sure students are aware of the nature of the self-discipline that the course requires. Most higher education institutions provide links of this nature. Allow freedom for online discussions; students may participate better when they can be creative with posting content, such as asking for clarification, providing a mnemonic or supportive learning resource, or creating their own quiz questions.

Assign homework and discussions at regular intervals. For homework questions, allow for hints and multiple attempts without penalty and provide rationales.

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Appendix

End of Semester Survey

Note. Not all questions surveyed were used in this study. Some questions are specific to either hybrid or online.

1. Any constructive comments or suggestions for the homework assignments?

2. On a scale of 1-5, 1 being lowest and 5 being best, how would you rate the chapter discussion sessions as helpful?

3. Any comments or suggestions for the discussion's activity?

4. Would you recommend this class to a friend? Why or Why not?

5. Would you recommend this course to a friend?

    1= Strongly recommend

    2= Recommend

    3 =not recommend

    4= Strongly not recommend

6. How helpful were the Chapter quizzes on Pearson Mastering?

    1= Very helpful

    2 = helpful

    3 = somewhat helpful

    4 =Not at all helpful

7. Any comments, suggestions or ideas about your experience in this class.. anything or the following: objectives, PowerPoint, recorded videos, exams, exam proctoring/availability, online format, discussions, point values, audio files, etc...

8. Regarding the online videos:

1 = I watched them all, some more than once

2 = I missed one or two

3 = I missed 3 to 5

4 = I only watched about half of them

5 = I watched less than half.

9. How many hours did you spend on average for this course per week?

1 = more than 15

2 = 10 -15

3 = 5-10

4 = Less than 5

10. If a person you know is signed up to take this class, what bits of advice would you give them?

11. If you were forced to choose one or the other (like this question) and I know you worked, suffered and studied, as you would for any class…but to choose one vs. the other… did you like this class?

1 = Yes

2 = No

12. Was design of the online site easy to navigate?

1 = Yes

2 = So-so

3 = No

13. Was the Introductory Module (Start Here!) easy to follow so you knew class expectations?

1 = Yes

2 = So-so

3 = No

14. Do you have any suggestions for the startup module or homepage design?

15. Do you have input regarding ANKI electronic flashcards?

16. Did you find the ANKI flash cards valuable?

1 =Didn't use them at all :(

2 =Didn't use them much : /

3 = Eh.. so so :|

4 = Helpful! :)

5 = Very helpful! :D

17. What is your estimated final grade?

1 = A

2 = B

3 = C

4 = D

5 = Hopefully not this one