REEXAMINING THE UNDERGRADUATE INTRODUCTORY BIOLOGY LABORATORY PEDAGOGY

by

Laura Bernice-Flippo Camp

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ABSTRACT

In response to COVID guidelines, a flipped laboratory learning model was implemented in an undergraduate biology laboratory curriculum. As a result, class size was decreased and the course pace was increased. Learning outcome data collected over three years compared the effects on student learning due to these changes (*N*=543). Owing to the decreased in-person laboratory time and increased pace of the course, student preparedness when arriving at the laboratory session was imperative to their success in learning the material and completing the laboratory exercise in the allotted time. To accomplish this goal, we improved some of the previous existing resources already in place and created a flipped laboratory method. Students came prepared for the laboratory exercise before they attended the laboratory class and were better able to achieve success possibly due to the required pre-laboratory assignments. Online video recordings of the laboratory procedures and a narrated PowerPoint that explained the concepts of the lab exercises, along with the laboratory manual and lecture material, were provided to the students before laboratory attendance and were used to complete pre-laboratory quizzes. The effectiveness of these resources and the flipped-learning pedagogy was determined using end-of-course student and faculty surveys, learning outcome data, and a teacher journal. The effect on learning outcomes using the flipped-learning model was compared to student learning outcomes in the same course in previous semesters. Faculty surveys compared observations of the students and the course pre- and post-COVID. This paper addresses how a flipped learning approach improved student preparedness by providing a flexible learning format that allowed students to become familiar with the material and the procedures before attending the laboratory class. Student preparedness using the flipped-learning model contributed to successfully increasing learning outcome scores along with the student and faculty perceptions of the class as a whole. Faculty and student surveys revealed that flipped learning and schedule changes resulted in both positive and negative student experiences, however, the majority of the findings were positive. Faculty surveys found the course design and challenges encountered to be useful in making further improvements to the course.

INTRODUCTION AND BACKGROUND

Context of the Study

As a full-time science laboratory coordinator and an instructor in the Department of Natural Science & Mathematics since 2013, my job is to coordinate, modify, and instruct Richard Bland College's introductory biology laboratory courses with professors that instruct the BIO101 lecture course. As a group, we collaborate and regularly modify the Biology 101 (BIO101) lecture (a 3-credit introductory, non-majors biology course) and the associated Biology 101 Laboratory (BIO101L) course (a separate 1-credit course) based on learning outcomes (LO) data analysis. Importantly, the BIO101L course reinforces the concepts taught in the BIO101 lecture by providing hands-on experiences for students to apply the knowledge taught in the BIO101 lecture in an experiential format. The BIO101 lecture and BIO101L courses typically consist of first- and second-year college students, most of whom are not planning on majoring in biology but are taking these classes to satisfy the "Investigation of the Natural World" laboratory science requirement for an Associate degree. Because the laboratories can only hold 24 students for safety reasons, the BIO101L course typically has between 8 and 24 students per laboratory section, while the BIO101 lecture classes have between 10 and 36 students per section. Most semesters, there are between 125 and 175 students enrolled in the BIO101L course. Enrollment in BIO101L was 99 students in the Fall of 2020 and 146 students in the Spring of 2019, both of which were much higher than Spring 2021 enrollment at 43 students.

Before the Fall semester of 2020, students attended the laboratory course once a week for 2 hours over a 14-week timeframe. During the Spring 2020 semester, RBC changed the in-person laboratory meetings to an online format halfway through the semester due to the COVID-19 pandemic. As a result, many changes were made to the Fall 2020 schedule for the BIO101L sections, specifically related to the amount of time in the laboratory and the number of students in each section. To meet the social/physical distancing state guidelines, the laboratory occupancy decreased from 24 to 12 students and all students were required to work alone rather than in pairs or groups of 3 or 4 during laboratory exercises as had been done in the past. In addition, the number of hours students were physically required to be in the laboratory changed from 2 hours once a week for 14 weeks to 1 hour twice a week for 7 weeks. This condensed schedule was implemented in anticipation of another wave of COVID-19 cases which would have forced in-person classes and laboratories to be converted into an online format as had been done in the Spring, and obviously, this mid-semester conversion was not optimal for student learning and success. Because faculty members and students felt that the converted online BIO101L experience in Spring 2020 was inferior to the in-person laboratories and due to the fear of another COVID-19 outbreak in October 2020, the accelerated, streamlined version of the BIO101L was employed to ensure completion of the experiential laboratories in person during the first half of the semester.

The purpose of this action research study was to investigate the effects of the implemented scheduling and delivery method changes made to the biology laboratory courses, specifically, RBC's BIO101L, on learning outcomes with quantitative comparison to prior semesters. One purpose of tracking student learning outcomes is to aid in identifying at risk students and increase student success.

As a consequence of the COVID-19 pandemic, RBC biology faculty restructured the BIO101L course to make it more streamlined to reduce the number of hours students physically spent in the laboratory, which helped with scheduling double the number of BIO101L sections to reduce the enrollment in BIO101L sections from 24 students to 12 students due to social/physical distancing guidelines. Rather than students listening to a background and procedure lecture in class for 30-45 minutes prior to the start of the laboratory, students were provided online pre-laboratory modules, which included a narrated PowerPoint with a quiz and a procedure video with a short quiz for each laboratory. Students were allowed two attempts on the quiz assessments and were encouraged to use their laboratory manual, and the information provided in the PowerPoint videos as resources to answer questions. Thus, the redesigned BIO101L course required students to complete foundational online assignments (i.e., background and procedural information) using the Canvas Learning Management System (LMS) before coming to the laboratory, which allowed for the completion of the in-class, hands-on experiential exercises within the new 1-hour timeframe. Because of the accelerated format of the BIO101L, the BIO101 lecture and BIO101L topics, which normally parallel and complement each other, were out of sync, making the narrated PowerPoints especially important for exposing students to the topics normally covered as part of the lecture class. Upon arrival for the BIO101L class, students should have had the background knowledge for the subject matter covered in that laboratory, as well as an understanding of the activities would need to be completed in the 1-hour laboratory class.

Focus Question

The events of the Spring of 2020, which caused RBC classes to move to a remote delivery method, continuing the semester with only online classes and laboratories, created an interesting situation for the Fall 2020 semester. With the multiple waves of COVID-19 cases over the summer, the RBC laboratory faculty predicted that another wave of cases may occur in October, and to avoid a similar mid-semester online conversion as in Spring 2020, an accelerated plan for delivery of content and reduction of in-class time for introductory laboratories was created and implemented. The study is based on the changes that were made to the reduction in the amount of physical class time (from 2 hours to 1 hour), the accelerated pace (7 weeks rather than 14 weeks), the decreased number of students in each laboratory (from 24 to 12), and the lack of group work (students worked alone).

My focus questions was, What are the effects of changing the pedagogy in an undergraduate biology laboratory course with respect to learning outcomes and student success?

In addition, the following focused questions were also investigated as part of this study:

1. What are the quantitative differences in learning outcomes' assessment after the implementation of the change in the format of Fall 2020 and Spring 2021 semesters compared to prior semesters?

2. If there are quantitative differences in the pre- and post-treatment learning outcomes' assessment, what were the possible reasons the learning outcomes were affected by these changes?
3. What was the student response to the accelerated format and the decreased laboratory time during the semester?
4. What was the faculty members' response to the scheduling changes, their teaching strategies, and the impact on the student learning?

The data collected over several semesters before the Fall of 2020 were compared to the data that resulted from the restructuring modifications to the laboratory format and pace in Fall 2020 and Spring 2021. Other than a few minor changes made to the laboratory exercise assignments pre- and post-treatment, the laboratory exercises and assignments were essentially the same. Any differences or changes made were not considered to have an effect on the results. This action research project was necessary to understand the effects of these changes and to make modifications based on assessment for future semesters. It is highly likely that any of the applied changes showing improvement in student learning will become permanent changes to the format and/or scheduling of the laboratory sessions. This study enabled RBC faculty in the Department of Natural Science & Mathematics to see the advantages and disadvantages of the implemented changes to the schedule and how incorporating a flipped classroom in a laboratory setting influenced student learning and overall student success. The data, combined with the student and faculty experiences, may provide evidence of an alternative model for laboratory teaching that uses time originally spent on a pre-laboratory briefing to discussions related to the laboratory procedures. This model could have implications for biology educators and be used for introductory laboratory courses in the future.

Support Team

Dr. Kevin Peters, Professor of Biology at Richard Bland College of William & Mary, and I have worked together for several years and have been the driving force behind reshaping our biology laboratories, having written many laboratory exercises for several biology courses together. Dr. Peters helped with editing and attention to detail, ensuring the writing of this document was clear and understandable, as well as easily translatable for publication.

Dr. Shawn E. Holt, Professor of Biology and Chair of the Department of Natural Science & Mathematics at Richard Bland College of William & Mary, implemented the scheduling and format changes for the Fall 2020 semester and also developed the learning outcomes for the BIO101 lecture and BIO101L classes, which are used for assessment each semester as part of accreditation with the Southern Association of Colleges and Schools Commission on Colleges (also known as SACSCOC) and the State Council on Higher Education in Virginia (also known as SCHEV). Dr. Holt also helped with the Protection of Human Subjects in Research and RBC's Institutional Review Board (IRB) approvals, and he has extensive experience with hypothesis-driven research, writing scientific papers, and evaluating methodology.

Dr. Walter Woolbaugh, Professor of Science Education at Montana State University, was my project advisor. Dr. Woolbaugh provided invaluable guidance, instructional feedback, and much needed support that allowed for the completion of this project.

CONCEPTUAL FRAMEWORK

Brief History of the Scientific Laboratory

Students use a laboratory to make observations, perform tests and carry out experiments in their study of science (Tamir, 1976). Laboratory exercises in which students have hands-on experience with equipment, make observations and draw conclusions are critical to their education (Hofstein et al., 2013). Historically, laboratory experiences have been a key part of teaching and learning science in order to involve students in concrete experiences although not all educators were convinced of their effectiveness. The addition of science classes to the curricula in schools began at the end of the 19th century, and the use of the laboratory in teaching and learning science has been questioned and has changed over the years since it was added to the curriculum.

The use of the experiential laboratory has evolved from not including laboratories at all to becoming an integral part of the science curriculum (Tamir, 1976). In the late 18th century, a scientist named Joseph Priestly, used teaching techniques with students to train them to perform experiments designed to prepare them for a practical life (McEvoy, 2021). In the mid-1800's, the use of the biology laboratory was presented in a lecture as superior to in Great Britain by Charles Kingsley on *How to Study the Natural Sciences*, and he encouraged others to get out of the classroom in order to let students explore and experience nature. These supporting views were expressed in statements such as, "An experiment is worth very little to you, unless you perform it yourself, ask questions about it, or vary it a little to solve difficulties which arise in your own mind" (Kingsley, 1846, p. 1), as well as, "The use of eyes and hands: the scientific method – cannot be taught by means of blackboard and chalk or even by lectures and demonstrations alone; individual eyes and hands must be actually and persistently practiced right from the very earliest period in the school career" (Armstrong, 1910, p. 9).

Science laboratories in the United States were becoming more common by the late nineteenth century. Only a few schools were built without including physics and chemistry laboratories and the laboratory became the classroom. In 1892, the National Education Association recommended that physics and chemistry be required for admission to college and be taught in combination with laboratory work (Rosen, 1956), which ultimately resulted in an increase in hands-on experiential laboratories in high schools and colleges (Otero & Meltzer, 2017). In 1892, L. Griffin wrote: "The laboratory has won its place in school. Its introduction has proved successful. It is designed to revolutionize education. Pupils will go out from our laboratories able to see and do" (cited by Rosen, 1954, p. 202). Thus, the experimental method of teaching physics and chemistry using the laboratory exclusively was eventually modified to be a mixed course of the laboratory, a textbook, and the lecture (Rosen, 1979).

One movement gaining popularity as they moved forward was progressive education, however, there were disagreements about the use of laboratories in the United States and Great Britain. The progressive education movement pushed an investigative approach to science education. "Practical" courses focused on applying science to everyday life including chemistry experiments making soap and ink (Packard, 1903). In July 1905, at a National Education Association convention with science instructors, it was noted:

> In the laboratory, the student is introduced at once to the difficult subject of measurement, required to make immediate use of such unfamiliar instruments as the diagonal scales, the Vernier caliper, and the balance sensitive to a centigram; to report his results in terms of the metric system, to discuss errors, sources of errors, percentage of error, averages, and probabilities; to deduce laws from data that cannot be made to prove anything, and to apply these laws to a set of problems that have no apparent relation to his immediate scientific environment, or to the questions that he is so anxious to have answered (Packard, 1903, p. 881).

There was definite disagreement amongst the educators at that time as to the use of laboratories or if there was a benefit to the students. Dr. Charles R. Mann, a University of Chicago physicist, blamed poor teachers, poor textbooks and concepts that were not connected to daily life. His vision was to improve high school physics teaching as he realized the outcomes they were seeing were not satisfactory. In 1906, the Central Association of Science and Mathematics Teachers formed a committee consisting of Mann and two high school teachers with the task of determining which classroom activities engaged and interested students (Otero & Meltzer, 2017). The following were among some of the comments at the time. “Laboratories have not solved the problems of science teaching…we do not know how to use laboratories most effectively” (Mann, 1910, p. 228). Newberry noted that boys would rather do the experiments while girls usually preferred the demonstrations and he felt that demonstrations were more clear and helpful than experiments, especially to slow learners (Newbury, 1934).

The physics and chemistry laboratories were included as part of the United States high school curriculum by 1910 due to a consensus that the curriculum should include science, the increase in emphasis on laboratory work in the colleges, the influence of college admission requirements, and Americans popularizing it as a progressive idea.

Some educators at the time felt that laboratory work was impractical, overly expensive and too sophisticated for high school students (Rosen, 1954). Some educators were critical of the work students performed in the laboratory. Other educators thought that the experience in the laboratory was invaluable, representing the other extreme. There were suggestions that the only student work that should be included in the course should be based on the laboratory work and that any other material discarded (Science Masters' Association, 1953). The recurring theme among the reformers of the time was that the teachers needed to emphasize scientific inquiry and engage students in science (Otero & Meltzer, 2017).

Many studies from 1918 to 1976 were performed to determine if the laboratory or demonstration methods were effective. Most of the studies did not show that the laboratory was a superior method of teaching science (Tamir & Iowa, 1976). Public education expanded rapidly after World War I and the method of instruction focused on lectures and textbooks while laboratory work was used to illustrate information in the textbooks. In the late 1950's and through the 1960's, the laboratory changed to become more of the focus of science instruction and shared equal importance with lectures and discussions (Romey, 1968) and the importance of laboratories has developed based on the opinions of scientists who developed the curriculum during that time (Tamir & Iowa, 1976).

In the late 1970s and early 1980s, educators again questioned the effectiveness and role of the laboratory. The research findings of Hofstein and Lunetta (1982) stated, "Science educators have expressed the view that uniqueness of the laboratory lies principally in providing students with opportunities to engage in processes of investigation and inquiry" (p. 203). Hofstein & Lunetta were concerned with how to define the goals of the laboratory in science education and felt they coincided with those for science learning in general. The suggestion was to make laboratory work unique and significant with its own defined goals (Hofstein & Lunetta, 1982).

In 1985, a study by Champagne et al. found that traditional laboratories were too technical, and students did not have enough time to think about the data, or connect new data to their previous understanding of the topics. A 1994 study showed that laboratory experiences did not provide sufficient gains in scientific understanding by students (Chang & Lederman, 1994). In 1998, Fisher et al. found that student laboratory experiences focused their attention on step-by-step procedures and gave little time for reflection of the purpose of the experiment.

In 2006, the National Research Council identified several goals of laboratory experiences and these goals are listed as follows: enhancing mastery of science material; developing scientific reasoning; understanding the complexity and ambiguity of empirical work; developing practical skills; understanding the nature of science; cultivating interest in science; and developing teamwork abilities. The committee identified the new goal of "understanding the complexity and ambiguity of empirical work" to reflect the uniqueness of laboratory experiences (National Research Council, 2006, p. 3). Improving students' ability to develop strategies is the goal of laboratory experiences and is unlike the other goals that can be learned through lectures (National Research Council, 2006).

A review of the evidence on achieving the goals set forth by the National Research Council in 2006 found a shift away from laboratories that were focused on traditional stand-alone activities. In fact, the study found that the laboratories were disconnected from the flow of the classroom lessons as they did not seem to promote mastery of science knowledge. Instructors often conducted science experiments and then assessed the student's understanding of that concept. It was found that most laboratory experiences were not any better than other forms of science instruction (National Research Council, 2006). Stand-alone laboratories, whether they are traditional or inquiry-based, do not seem to be effective for students as far as mastering science knowledge. Cognitive research has shown that immediate feedback opportunities, such as those that can be completed online, are important to student learning together with formative self-assessments that assist student advancement toward the goals of the laboratory experience (Singer et al., 2005).

Many educators who study science laboratory education have changed their focus to include integrated instructional units that connect students to the activity by using lectures, readings, and discussions along with computer technologies. Using integrated instructional units, "students are engaged in framing research questions, making observations, designing and executing experiments, gathering and analyzing data, and constructing scientific arguments and explanations." (Singer et al., 2005, p. 4). Students are given more time to revisit their experiences in the laboratory as they connect what they learn in the laboratory with the science content. Laboratory experiences can be designed in a way that can result in successfully attaining science education goals such as those outlined by the Committee on High School Science Laboratories (National Research Council, 2006).

Inquiry-based activities that encourage critical thinking skills are replacing the traditional laboratory exercises in many laboratories (Hofstein & Lunetta, 2004), although, traditional laboratory exercises that reinforce a concept taught in the lectures are also important. A blend of the two methods, traditional and inquiry-based, could be the solution for some laboratory curricula. In a study of New York high school students, Lauren Goldenberg examined students' perceptions in learning science in her article, *What Students Really Want in Science Class* (2011). Goldenberg stated that students like the same goals and same principles of learning that were outlined previously (Singer et al., 2005), where students valued meaningful activities with more interactive learning that included hands-on activities, opportunities to communicate with other students, and real-life examples that were relevant to their lives. They also prefer fun and visual digital resources and stories that illustrate science concepts (Goldenberg, 2011).

Methods blending new technologies that are now readily available to most students together with laboratory exercises that pertain to the concepts being taught in the classroom, and that are also relevant to their lives, are increasingly being developed and implemented in science classrooms and laboratories. An analysis of flipped learning in science, technology, engineering, and mathematics (STEM) classes, which included 58 peer-reviewed research studies found that there was an increase in flipped classroom methods. The findings were overwhelmingly positive. One finding, in particular, was the importance of the flipped approach to improving students' control of their own learning and the value of life-long learning skills in the workplace (Huber & Werner, 2016). Students in the STEM fields felt that they improved their independent learning strategies and, were more on-task and engaged when learning through a flipped approach (McLean et al., 2016). Of 80 students enrolled in a large, undergraduate engineering class, 74% felt the flipped classes were helpful to understand the concepts. Approximately half of the students preferred to listen to a face-to-face lecture rather than watching the video, while the other half felt the videos allowed them to just watch and absorb the material. Students were also less willing to listen to videos that were an hour long and preferred videos around 20 minutes in length (Zappe et al., 2009).

Science instructors in the laboratory often present information using a traditional approach similar to teaching a lecture class. Most instructors expect students to read the course material for initial exposure to the content before class to have students engage in a more meaningful discussion and prompt their higher-level learning skills. However, most students do not follow this study method (Cummings et al., 2002). A study of 45 students given multimedia learning modules scored significantly better than students given the textbook only. Comparing the two groups, they found that 75% of the students that used the multimedia approach scored above the average grade on the exam while 75% of the students that used the textbook scored below the average grade on the exam (Stelzer et al., 2009).

Flipped-learning Classes

Customarily, students primarily receive information by listening and notetaking. Yet, numerous research studies have shown that students need to be more actively engaged in the course material to better understand the concepts. Chemistry teachers, Jonathan Bergmann and Aaron Sams decided that the best use of class time would be to have students spend their time with hands-on activities instead of using class time sitting and listening to a long lecture (Bergmann & Sams, 2012a). Consequently, Bergmann and Sams flipped their classroom in a way that students watched recorded videos of the lecture at home giving the teacher time for hands-on activities in class. Presenting the material in such a format gave ownership to the students for their own learning and prevented students from getting behind; whereas before, if they had missed a class, it might have been more difficult to get the material from the lecture (Bergmann & Sams, 2013). Interestingly, the original purpose of providing the videos was to help those that had missed material because they had missed class and they soon found that even students that had already heard the material in class, used the videos to review. Eventually, this format became a self-paced method that the students used and they could move on to the next lesson as they completed the material (Bergmann & Sams, 2013). The online portion of the class is not meant to replace the teacher but instead allows the student and the teacher to interact more when they are in the classroom. Numerous guidelines have since been written, however, Bergmann and Sams felt that there were many ways to flip a classroom, and that it didn’t fit just one definition or format (Bergmann & Sams, 2012b). Even though their intent may have been to use this in a classroom setting, the concept works well in many situations including laboratories.

Students entering college are met with many different lecture classes, all of which proceed at a very fast pace, and until recently, most college-level classes relied on lecture methods to teach students. Although some students thrive in this type of setting, other students have difficulty learning with this style of teaching. A flipped-classroom, where the students can learn at their own pace by taking the lecture in part or replaying it as many times as necessary, reaches many more students that learn differently (Bart, 2013). In November of 2013, a survey by the Center for Digital Education and Sonic Foundry of higher education faculty members found that 29% of faculty are using a flipped classroom approach, while 27% are planning on using it in the next year. The survey had a total of 309 responses collected from members of the Education Exchange. This survey data revealed that flipped classrooms provide a better learning experience for students and 83% of faculty agreed or strongly agreed that the model has a positive impact. Although they felt it took more time to prepare, the benefits outweighed the challenges (Bart, 2013).

The majority of the research studies on flipped-learning focuses on the classroom. A small percentage of the literature in comparison was applied to science laboratories. A study by Tang Teo in 2014, found that flipped teaching was suitable for laboratory learning. The study of 33 students found that, according to the students, the practical procedures and theoretical concepts were more understandable and the students were more confident (Teo et al., 2014). A study consisting of 230 students in 2012, compared laboratory exercises using a flipped-learning method versus the traditional method. Students found the visual instructions to be very helpful and were more prepared for the laboratory exercise. The study showed an increase in learning outcomes and in time management skills (Gregory & Trapani, 2012). Another laboratory flipped-learning study found that students were more engaged when using the flipped learning model. The students completed more of the two undergraduate chemistry laboratories during the laboratory session. Instructor and student opinions were mostly positive (Donovan & Lee, 2015).

As we progress through the 21st century, the roles and goals of laboratory experiences are changing with the focus on acquiring critical thinking skills, and the application of experimental design (Hofstein & Lunetta, 2003). The use of technology in a flipped laboratory, which requires the student to preview the class material and procedures online before the laboratory encourages students to take on a more active role and accept more responsibility for their learning, while providing instructors time to deliver more meaningful laboratory experiences, more discussions, and online assignments with immediate feedback before the student attends the class.

METHODOLOGY

Demographics

Richard Bland College of William and Mary (RBC) is a degree-granting, residential junior college in the state of Virginia in the rural part of Dinwiddie and Prince George counties, on the outskirts of the City of Petersburg, located about 30 miles south of Richmond. RBC awards Associate of Arts and Associate of Science degrees to students that complete 60 credit hours with all the necessary required courses, and ideally those students transfer to a 4-year college or university. Although the COVID-19 pandemic may have created some variances from 2019 to 2020, the following statistics stayed relatively consistent from year to year. According to the National Center for Education Statistics, RBC had an enrollment of 2315 students in the Fall of 2020, which is nearly identical to the Fall of 2019. Residential housing is available on campus, however, the majority of the students commute to campus. In the Fall of 2020, the student population was 47% (50% in 2019) white and 25% (25% in 2019) black, 18% (15% in 2019) Asian, and the age of 97% of the student body was 18-22 in the Fall of 2020 (98% in the Fall of 2019). In Fall 2020, 64% (63% in 2019) of the students were part-time students and 62% (61% in 2019) were female (Fall Headcount, 2021). In Fall 2020, nearly 30% of all students transferred to 4-year colleges and universities via RBC's guaranteed transfer agreements. The student-to-faculty ratio was 27 to 1 in both Fall 2019 and Fall 2020 (College Navigator, 2021).

Treatment

Research was conducted over a period of three years and included data from five semesters containing 542 first and second-year students. The research was conducted over the course of 14 laboratory exercises during the Spring semester of 2018, the Fall semester of 2018, the Spring semester of 2019, the Fall semester of 2020, and the Spring semester of 2021. Data was not available for the Fall semester of 2019 and the Spring semester of 2020 was excluded because of the mid-semester changes due to the COVID-19 pandemic, which made the data incomparable with other semesters before and after. A mixed methods research design was used to gather data for analysis, to measure percent changes, and for survey responses, before and after changes to the pedagogy. Semesters before the Fall of 2020 will be called "pre-treatment" where the laboratory course material and procedures were delivered through in-class lectures and demonstrations even though students were assigned a pre-laboratory online homework assignment. The Fall semester of 2020 and the Spring semester of 2021 will be referred to as "post-treatment" where students were presented with a flipped-learning model that did not include in-class lecture or in-class procedure explanation (Table 1).

Table 1. Summary of pre-treatment and post-treatment semesters, (N=542).

Semester	Spring 2018 n=146	Fall 2018 n=138	Spring 2019 n=116	Fall 2020 n=99	Spring 2021 n=43
Pre-treatment	X	X	X		
Post-treatment				X	X

Students attended two laboratory sessions per week for seven weeks. Each laboratory exercise consisted of a pre-laboratory homework assessment and a procedure video assessment. Students were assigned technologies that included narrated PowerPoints and instructor generated procedure videos, both of which had an online assessment, which were due before attending the laboratory (Table 2). In addition, there were two laboratory exercises during the 7-week session that were exclusively online. Students watched the completed online laboratory exercise and recorded the results. Attendance for each laboratory session was mandatory.

Table 2. Summary of assigned technologies, (*N*=542).

	Pre-treatment			Post-treatment	
Semester	Spring 2018 *n*=146	Fall 2018 *n*=138	Spring 2019 *n*=116	Fall 2020 *n*=99	Spring 2021 *n*=43
Pre-laboratory Assessment	X	X	X	X*	X*
Procedural Video Assessment				X	X
Proctored Online Exams				X	X

*Narrated PowerPoints

The instructional strategies used in the post-treatment BIO101Ls were changed from in-person to online laboratory and lecture experiences. In addition, students performed all of the laboratory exercises before the material was taught in the lecture, which was different from previous semesters in which much of the material was taught in the lecture after students had completed the laboratory exercise. Students were provided with a narrated PowerPoint of the material, which was not available in prior semesters (pre-treatment), and were given an online pre-laboratory homework assessment. Pre-laboratory homework had been assigned in previous semesters with students using their laboratory manuals to complete the online assessment, without access to a narrated

PowerPoint that replaced the laboratory lecture. There were not any in-class lectures conducted in the laboratory during the post-treatment semesters. And the intent behind having students complete the pre-laboratory assignments and assessments was that most students would come to class prepared. Students were given opportunities to ask questions before and during the laboratory session. The research study concentrated on the effects of flipped learning and the pace of the course on students and faculty.

The pre-laboratory online quiz varied in length from 30 to 60 matching, multiple-choice, and True/False questions. Students were typically able to complete the video and quiz within 45 minutes. Procedural videos were a new methodology for delivering guidance with the experiments to be conducted during the lab session, and students answered a short quiz before coming to the laboratory session. The procedural video online quizzes were less than 10 questions and students typically completed the video and quiz in less than 30 minutes. The majority of students completed the assessments before arriving at the laboratory.

The topics taught in each of the semesters were essentially the same with a few minor changes or additions. For example, meiosis and photosynthesis were added and plant characteristic objectives were not taught in the Fall semester of 2020 or the Spring semester of 2021. These changes were considered minor in relation to the rest of the course.

Due to the differences in the pedagogy and the pace of the course, the answer to the main question that was explored as part of this study was whether or not the learning outcomes were affected. While the learning outcome information was necessary for

SACSCOC and SCHEV reporting, our goal was to show that students performed as well or better using the flipped classroom technique, which would provide evidence that this format will be a good model to consider using in future semesters. Interestingly, the use of the delivery techniques may not have been attempted had it not been for the COVID-19 pandemic.

The research methodology for this project received an exemption from Montana State University's Institutional Review Board and compliance for working with human subjects was maintained (Appendix A).

Data Collection and Analysis Strategies

The instruments used included scores from the assessments taken by the students, a student survey, faculty interviews, and a teacher journal. The exams were given at the mid-term of the course and at the end of the course and the second exam was not cumulative for all the semesters assessed. Information as to the learning outcomes of the students was extracted from these exams (Appendix B). In prior semesters, there were also proctored quizzes that were fused as part of the data collection. The anonymous student survey was sent to the students through RBC's Information Technology Department (Appendix C). Another instrument used was interviews with the faculty members that taught the biology laboratories both post-treatment (in the Fall semester of 2020 and the Spring semester of 2021) and pre-treatment (who also taught this course many times previously) (Appendix D). The final instrument was a teacher journal Observation Sheet in the Spring semester of 2021 (Appendix E).

The first data collection instrument included the data from the learning outcomes of the two exams given to students at the mid-term and the end of the semester. Student levels of achievement for the learning outcomes were gathered from the answers to questions on the exams. Typically, there are 80 -150 students each semester in BIO101L with fewer students in the Spring semesters. The number of students for the Fall semester of 2020 and the Spring semester of 2021 saw a decrease with a total of 142 students total for both semesters. Before the Fall semester of 2020, the scores of quizzes as well as the exams were used to calculate whether a student was meeting the learning outcomes. Due to the laboratory time of only one hour, students did not take the four proctored laboratory quizzes in the Fall semester of 2020 or the Spring of 2021. Slight modifications to the exams were made due to COVID-19 restrictions for both semesters, but the questions were the same or very similar, even though the exams were not given as a hands-on practical. For example, laboratory exams during prior semesters required the student to perform some tasks such as weighing something on a triple beam balance, but since having students move throughout the room to different stations would have interrupted physical /social distancing guidelines, a picture of the triple beam balance was provided as part of the exam, and students were asked to read the mass from the picture. Laboratory exams during all the semesters were proctored and thus should provide valid and reliable data for the comparison. Data was not collected in the Fall semester of 2019 and the data from the Spring semester of 2020 was not included due to changes made during the start of the pandemic.

Learning outcomes were established for SACSCOC accreditation in the Spring semester of 2017, and student progress is tracked each semester according to whether they exceed, meet, approach, or do not meet the standards. In general, the students are usually different each semester, although some may be repeating the course. For this action research project, learning outcome assessment was streamlined by creating two categories: ‘meeting’ the learning outcome or ‘not meeting’ the learning outcome. Students that have an average of 70% or above were counted as meeting the learning outcome and those with an average of below 70% were counted as not meeting the learning outcome.

Three questions in this project were addressed through the learning outcome portion of the data collection. The instruments used to collect the learning outcome data were two exams with a total of 110 questions. Each question was assigned a learning outcome. An average for each of the learning outcomes was calculated from this data which was used to determine if the learning outcome achievement was met or not met.

There were four faculty members, including myself, that taught the biology laboratories and taught them for the past several years. All the faculty members used the same laboratory exercises, materials, and assessments so this information provides a large enough number of students and faculty to make a comparison of the differences before and after the format changes.

There were slight adjustments made to a few of the laboratory exercises over the last few semesters but those differences are small and will not affect the consistency of the data. Although students were not the same each semester, and the project was using different sections and different years to compare, the previous year groups were not a control group. The learning outcome data from previous years and interviews with the faculty that taught the laboratories provided a comparison to evaluate the positive or negative effects of the changes that were made due to COVID-19.

A mixed-methods design for this study used both qualitative and quantitative data sources to answer the questions in this action research project (Table 3). The primary question of the research will use the data from the two exams to assess learning outcomes, learning outcome data from previous semesters, the student survey, the teacher journal, and the faculty interviews. The question, "*What are the effects of changing the pedagogy in an undergraduate biology laboratory course with respect to learning outcomes and student success?"* is a relatively broad question that will use data from three years to compare changes in the learning outcomes assessments among the students, providing quantitative data.

Table 3. Data Triangulation Matrix A, (*N*=542).

Focus Questions	Learning outcomes	Student survey	Faculty interview	Teacher journal
Primary Question	X	X	X	X
Sub-question 1	X	X	X	X
Sub-question 2	X			
Sub-question 3		X		
Sub-question 4			X	X

Qualitative and quantitative data for this study is provided with student responses to the scheduling and pace changes and will provide a student perspective as to the effectiveness of shorter laboratory times and the increased pace (i.e., 7-week session with two laboratories per week). Faculty interviews included questions about the ability to complete the work in one hour instead of two hours and the preparedness of the students when they arrived to the laboratory. In the Spring semester of 2020, the laboratory exercises were concurrent with the lecture material. Faculty responses regarding the laboratory exercises not running concurrently with the lecture were addressed in the interview questions.

Student surveys and faculty interviews were administered after completion each semester. The student surveys and the faculty interviews provide a mix of perspectives which should offer a clear indication of the effect of the shorter laboratory time and the increased pace from the faculty and students' points of view. The student survey was comprised of questions regarding student preferences toward the varied technology, resources, flipped learning model, shortened laboratory class time, working alone, critical thinking skills, faculty evaluations, and overall course rating. The student survey used the Likert scale with various responses such as *strongly agree, excellent* and *very easy* using a 5-category scale and these questions used for the post-treatment were not the same questions asked as part of the pre-treatment semesters. The questions asked about the flipped learning and other student preferences applied only to the post-treatment students. The faculty interview questions focused on faculty preferences, scheduling changes, student preparedness, understanding of the material, the effectiveness of the varied technologies, and correlations with the lecture course. The first interview was conducted in person with the other three faculty that taught BIO101L. The second interview in the Spring of 2021 was conducted by email together with comments made throughout the semester. The teacher journal consisted of an observation sheet completed after each laboratory session to provide evidence of student engagement, behaviors, attitudes, and comments (Appendix E).

Triangulation was accomplished by using multiple methods such as learning outcome data, end-of-course student surveys (course evaluations), faculty interviews, and a teacher journal to help ensure the validity of the study (Table 4). The same faculty members have each taught this course over the entirety of the study and also in the years prior. Both the faculty interviews and the course evaluation data were a source of secondary data to aid in the understanding of the quantitative data.

Table 4. Data Triangulation Matrix B, (*N*=542).

	2018 *n*=248	2019 *n*=116	2020 *n*=99	2021 *n*=43
Learning outcome data	X	X	X	X
Student surveys			X	X
Faculty interviews (Observance)	X*	X*	X	X
Teacher journal (Observance)				X

X* - Questions will refer to previous semesters.

During the post-treatment portion of the research study, analysis were done on the collection strategies such as the learning outcome data, and the online anonymous course evaluations completed by the students. Questions used in the course evaluations were based on an informal, anonymous handwritten survey given to all students in the Fall semester of 2020 after their midterm exam. The data from the survey was compiled, disassembled, and reassembled into topics using the coding scheme described by Mertler (2016) and used to write the online course evaluation distributed to the students at the end of the post-treatment semesters. Data from the Fall semester of 2020 was analyzed at the end of the semester to check for unforeseen problems or questions. The method of collecting the data was valid according to a review by a professor that has taught the course for over 10 years, and also by the RBC Natural Science and Mathematics Department Director, Dr. Shawn Holt, who has also taught the course for in the past. Both professors were instrumental in setting up the RBC learning outcome assessments used since 2017.

The conclusions made from this study regarding the learning outcome assessments were entered into Microsoft Excel, and analyzed for patterns and trends. Graphical displays were made from the learning outcome data collected at the end of the course from four faculty members of the course and the student course evaluations, which were voluntary and anonymous. Approximately one-half of the students completed the course evaluations. The qualitative data from the faculty interviews and the teacher journal were organized by semester and used to reinforce the findings of the quantitative data. Students' comments that were included in the course evaluation were organized by the topic of the question. To ensure the validity of this study related to the accuracy of the results, many data sources were triangulated and checked for corroboration. The results gathered and the conclusions from the data analysis were used to evaluate the new pedagogy of the flipped learning model and compressed scheduling that will be used at RBC in the future.

DATA ANALYSIS

Results

The results from the learning outcome data showed a sharp increase in learning outcome 1 (LO1) from 66% of students in the Fall semester of 2018 (pre-treatment) to 85% of students in the Fall semester of 2020 (post-treatment) meeting the learning outcome, an increase of 19% (*N*=542). A 22% increase in students meeting learning outcome 2 (LO2), 1% increase in learning outcome 3 (LO3), and 8% increase in learning outcome 4 (LO4) was found for the same semester comparisons (Figure 1). All learning outcomes increased in the Fall semester of 2020, and while an overall comparison is warranted, it is necessary to compare Fall semesters to Fall semesters and Spring semesters to Spring semesters for consistency.

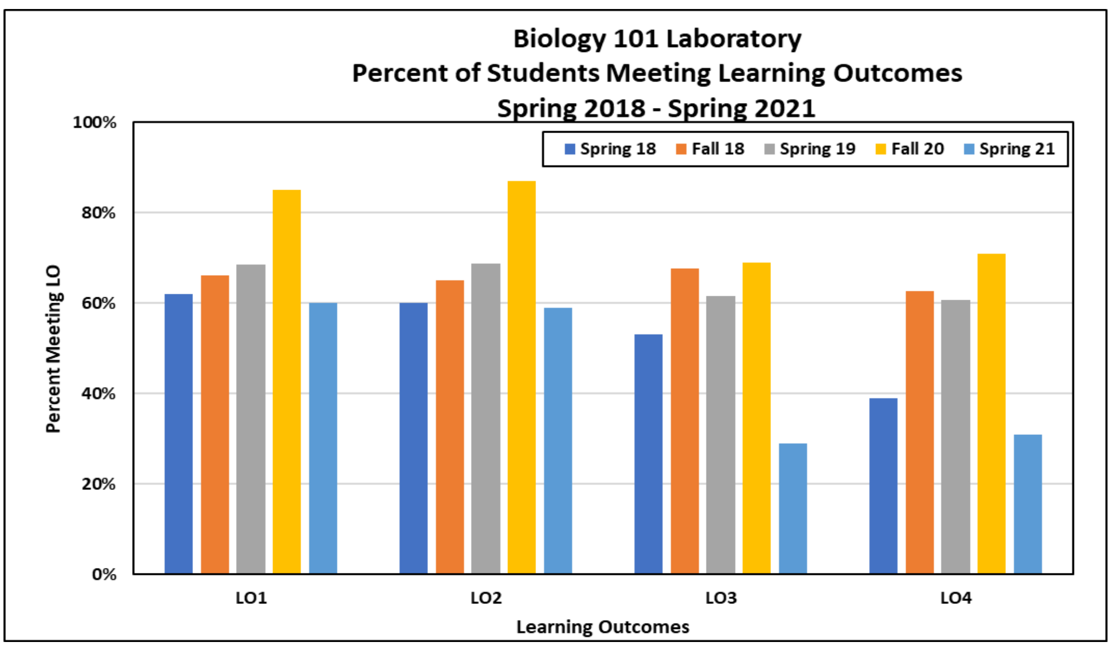

Figure 1. Spring 2018 – Spring 2021 Biology 101 laboratory learning outcomes. Spr18 (*n*=146), Fall18 (*n*=138), Spr19 (*n*=116), Fall20 (*n*=99), Spr21 (*n*=43), (*N*=542).

A definite change in the Fall semester of 2020 compared to the Fall semester of 2018 can be seen in Figure 1 for all four learning outcomes, which is consistent with the comments of three of the faculty that remarked that the students appeared to be more prepared when they came to the laboratory than they did in previous semesters. One of the faculty stated during the interview at the end of the Fall semester, “With the exception of one or two students, they have completed the pre-laboratory assessments before coming to the lab session.”

The laboratory exercises, except for a few minor changes, are the same each semester. Students in the Fall semester of 2020 were instructed to watch a narrated PowerPoint and answer questions online before coming to each of the laboratory classes. Before the Fall semester of 2020, students were instructed to use their laboratory manual to complete the online questions. In addition, students in the Fall of 2020 were allowed two attempts at the online questions, while students in prior semesters were only allowed to take it once, which may have contributed to their better performance during the Fall semester of 2020. Instead of just answering the questions and only having one opportunity to do so, they were allowed to correct their missed answers. This immediate feedback could have contributed to their better understanding of the material when they came to the laboratory and thus would have likely carried over to the increase in the number of students mastering learning outcomes. What’s more, prior to the Fall semester of 2020, the PowerPoint for the lecture was not narrated and was presented in the laboratory while the faculty taught the material for that laboratory exercise. Due to the time constraint of a 1-hour laboratory time, the laboratory lecture portion was flipped and the students were responsible for viewing and listening to the PowerPoint before they came to the laboratory session. The PowerPoint was not intended to stand alone when it was originally made as it was intended to be used with the faculty discussing each slide in-person during the lab session. Some of the faculty chose not to use the PowerPoint during the laboratory session and preferred to use handwritten notes on the board. A narration of the PowerPoint would have allowed the students to listen and learn smaller portions at a time, or possibly replay a part they did not understand.

The results from the learning outcome data for the Spring semesters showed quite different data. LO1 increased from 62% to 69% from the Spring semester of 2018 to the Spring semester of 2019 (pre-treatment), however, it decreased to 60% in the Spring of 2021 (post-treatment). Similarly, LO2, LO3, and LO4 showed the same phenomenon. LO2 increased in the Spring semester of 2019 to 69% from 60% in the Spring semester of 2018 (Pre-treatment) but dropped to 59% in the Spring of 2021 (post-treatment). LO3 increased in the Spring semester of 2019 to 69% from 68% in the spring semester of 2018 (pre-treatment) and dropped to 29% in the Spring semester of 2021 (post-treatment). The results of LO4 were equally as dramatic as LO3, as the increase from the Spring semester of 2018 to the Spring semester of 2019 went from 39% to 61% (pre-treatment). The post-treatment decreased to 31% in the Spring semester of 2021 (post-treatment). One faculty member stated, “The students seem burned out this semester more so than other Spring semesters.” In an observation in my teacher journal written in the Spring semester of 2021, I noted that “Students lacked enthusiasm and did not ask questions.” on more than one occasion.

A comparison of the number of students meeting LO1 and LO2 versus LO3 and LO4 for the Fall semester data versus the Spring semester data shows a pattern. The number of students meeting LO3 and LO4 decreased in comparison to the number of students meeting LO1 and LO2 for both sets of data. The laboratory exercises associated with LO3 and LO4 are much more difficult for a non-major undergraduate student, and, the material is presented at a much faster pace. A large portion of the lab exercises for LO3 and LO4 deal with evolution and concepts involving the classification of animals such as the development of the blastopore and the number of germ layers. These concepts may or may not have been taught to some of the students in their high school biology course yet the topics in LO1 and LO2 are commonly taught in high school biology courses. Students may have been more familiar with the topics in LO1 and LO2 and therefore did not have as much difficulty meeting those learning outcomes or moving at a fast pace during those laboratory sessions. This could account for the lower scores. In an interview, Dr. Peters, stated, “at the end, they were a little overwhelmed”, and other faculty and I feel the same way. Students had to digest a lot of information about evolution, the fate of the blastopore, the coelom, and the body plan among other things, and relate those to each phylum. Many of the terms and names were unfamiliar to them. We all agreed that we need to look at those laboratories at the end of the course and keep in mind that these students are not biology majors.

A pre-treatment and post-treatment summary of the learning outcome assessment data uses a weighted approach that factors in the number of students each semester indicates that LO1 and LO2 were greatly impacted while LO3 decreased slightly and

LO4 increased slightly (Figure 2). This method of evaluating the data considers the fact that in the Fall semester of 2020 there were 99 students and in the Spring semester of 2021, there were only 43 students. The percent of students meeting the learning outcome in the Fall semester of 2020 was weighted more due to the 99 students in the course versus 43 students in the Spring of 2021. Thus, a better indication of the differences in the learning outcomes for the students can be seen. Learning outcome 1 had a percent change increase of 19%, LO2 percent change increase of 23%, LO3 percent change decrease of 7% and LO4 percent change increase of 9%. There is a statistically significant difference in LO1 and LO2. Although LO4 does not indicate a statistically significant change, it did increase and overall, there is an indication that the changes made to the pedagogy of the course had a positive impact on three out of four student learning outcomes.

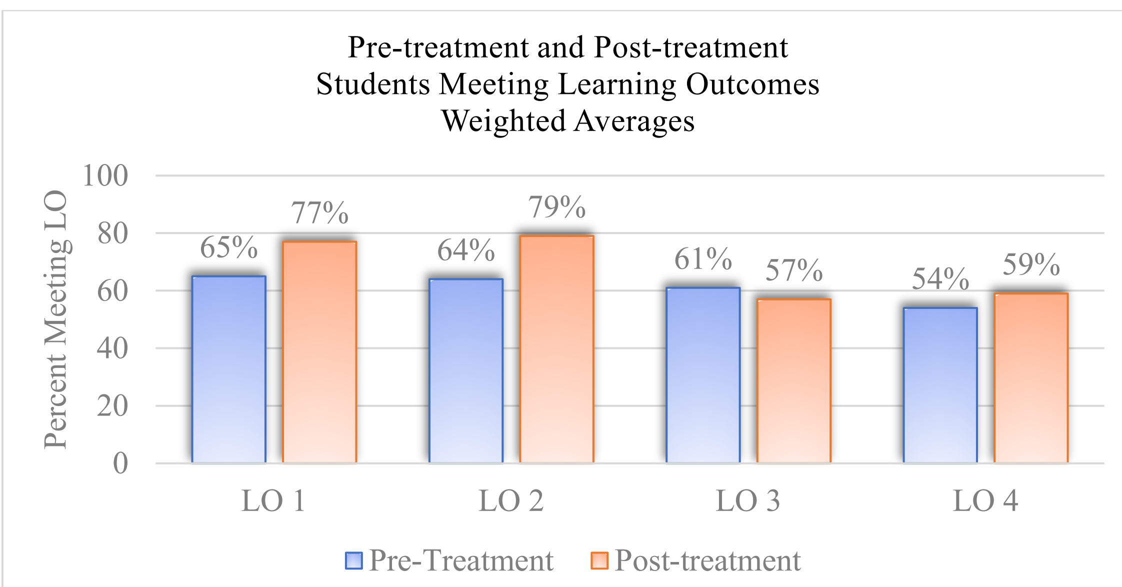

Figure 2. Summary of pre-treatment and post-treatment percent of students meeting each learning outcome, (*N*=543).

The results from the Student Course Evaluation Survey regarding student preferences showed 54% of the students prefer two laboratory sessions per week for 7 weeks versus 19% that preferred one laboratory session per week for 14 weeks (Figure 3). One student commented on the survey, “I like being done with the labs halfway through the semester, however, the pace can be overwhelming.” Another student commented, “(It) helped feel more streamlined and helped retain information for the test easier.” Students that preferred the flipped learning model were more evenly spread out with 40% agreeing, 27% neutral, and 33% disagreeing with the use of the flipped learning model. A student comment on the survey was, “I like doing the pre-lab work at my own pace and knowing what to expect when I go to lab class.” Students overwhelmingly agreed that having a laboratory partner was preferred with 51% versus only 12% that would rather work alone. There were pros and cons to working alone, although the consensus among the faculty was that students working without a lab partner to rely on made each student accountable. Each student had to understand and complete the laboratory exercise by themselves, which probably helped them retain the information better rather than watching their lab partner perform the work. It was discussed that one of the reasons for laboratory partners is the cost of lab equipment for a pair of students. Another reason for having laboratory partners is for students to learn to work together and help each other, which can often help students better understand the material.

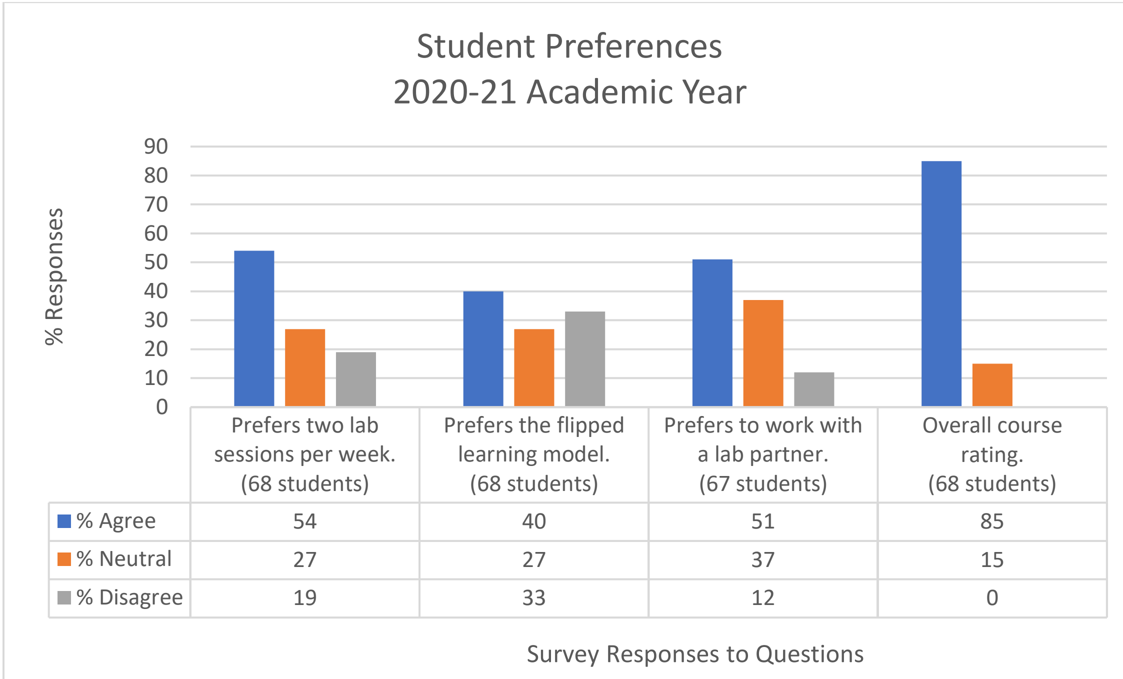

Figure 3. Student Course Evaluation Survey preferences at the end of the course for the 2020-21 academic year, (*N*=68).

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CLAIMS, EVIDENCE AND REASONING

Claims From the Study

In regards to my focus question on the effects of changing the pedagogy of the laboratory course, I found that the student learning outcome assessments increased 19% (LO1), 23% (LO2) and 9% (LO4), while LO3 decreased 7%. Eighty-five percent of the students gave a very high overall course rating. In regards to my question on how student learning outcome assessments were impacted quantitatively, I found that there was an increase in three out of four students learning outcomes when comparing pre-treatment to post-treatment with two out of the three positive changes being statistically significant.

A comparison of LO assessment for the Fall semesters 2018 (pre-treatment) and 2020 (post-treatment) showed a significant increase. A comparison of LO assessment for the Spring 2018, and Spring 2019 (pre-treatment) showed an increase in LO assessment, however, there was a drop in all LOs in the Spring of 2021. This could be possibly be attributed to the lack of enthusiasm by students as the isolation due to COVID-19. Faculty noted that students seemed less engaged, over-whelmed and depressed. There were also far fewer students in the Spring of 2021 (43) as compared to Spring of 2018 (146) and Spring of 2019 (116). There was not any data available to compare demographics of each semester for each class so this was not known.

According to the student survey results, there was a preference by students to have two labs per week at an accelerated pace of seven weeks to complete the course instead of 14 weeks. Several comments from students said it was easier to remember the material for the exam at the faster pace, however, some felt it was too much material in such a short time. In regards to the response from faculty interviews, the overall feeling was positive. The faculty members felt the students were able to accomplish the student goals in the one hour in-person lab time, ask questions, and, by completing the pre-laboratory assignments, they were able to understand the material when they arrived to the laboratory session better than before the changes were made.

Value of the Study and Consideration for Future Research

This paper focused on the overall effect of the schedule changes and a flipped-learning format of instruction on the student learning in the biology laboratories, on the students and the faculty. The format change of a flipped-learning model had not been discussed as a laboratory teaching method for the BIO101L before we were mandated to do so by the restrictions due to the COVID-19 pandemic. The purpose of this project and my interest in the results stemmed from the events of the pandemic on the students, faculty members, and the school. The fact that it was not planned makes it all the more surprising discovery that could be something positive that comes out of the vast amount of changes made because of the pandemic. Despite the masks and plastic physical barriers between lab benches, student attitude seemed upbeat. Students showed resilience in their resolve to make the best of the situation. One possible reason for the overall positive attitude of the group could be attributed to the fact that they were glad to be around people instead of sitting in their dorm rooms or homes. Whatever the reason, students were generally engaged and were willing to learn the material independently and at their own pace. The quantitative and qualitative data gathered thus far somewhat support the flipped model of learning to have positive effects on attitude and learning.

The students seemed more motivated and prepared when they came to the laboratory session.

The results of the learning outcomes for the Spring semesters showing a decline in students meeting the learning outcomes could be due to the low numbers of students used in the comparison, 146 students in the Spring semester of 2018, 116 students in the Spring of 2019, and only 42 students in the Spring of 2021. In addition, students may have felt depressed due to the length of time they have been isolated even though the laboratory sessions were in person.

If this format is to be used in the future, it is not only important for the students to achieve the same or better levels of understanding concerning their learning outcomes, but it is also important to know if the students and faculty members prefer the flipped learning model format. A problem exists for students that are not able to learn using the flipped model and how will we be able to help them. Part of the survey asks what methods were most helpful and what improvements can be made. This information will be used in the future to help students that may struggle with this learning model.

Combining the data from the learning outcomes together with the feedback from the students and faculty answers the primary question of the effect of the changes that were made on student learning. Students prefer the flipped learning model and the accelerated schedule. The data from the learning outcomes for the Fall semesters, which are more representative of students that are on track, shows that student learning outcomes increased. This would indicate that the flipped learning model and compressed laboratory sessions were successful. Faculty members agreed that the addition of 15 or

20 minutes would help a great deal in some of the laboratory exercises so the students are not rushed. The solution to this was to schedule the labs with at least 30 minutes between sessions. The students liked having the course completed in seven weeks and according to their comments, they were able to remember the material better for the exams due to the material still being fresh in their minds.

The response of the laboratory faculty in regard to the scheduling changes, their teaching strategies, and the impact on student learning was very positive. Overall, they felt the students were more engaged and prepared for the laboratory. The laboratory faculty members overwhelmingly felt that the changes were positive and successful. Other than feeling rushed to make the changes to the format, online material, and Canvas settings due to the pace and the decision at the last minute to use this format, they felt the laboratories went better than expected during the Fall semester of 2020, and that the students performed the same if not better than in previous semesters.

Originally, this change to a one-hour laboratory with the flipped learning model was intended to only be temporary. The plan was to go back to the traditional schedule of one laboratory session per week for 14 weeks. However, I think everyone was surprised at the success of the change from the student and the faculty point of view, and it appears this will be a permanent format. The doubled-up pace of the laboratories will be duplicated in the Fall semester of 2021 but instead of having one seven-week session, there will be two seven-week sessions. This would benefit students due to scheduling or even allow students to repeat the course, if necessary, in the same semester and not get off track.

A future project might include using the same flipped model but changing the laboratories to be more inquiry-based. Incorporating more critical thinking into our laboratory exercises is strongly encouraged. The problem will be logistics. Faculty only have so many hours in a day and with over 125 students on average, this would be a challenge. Possibly, a slight modification to existing laboratories could be tried. Another project might involve just comparing having a lab partner to not having a lab partner. Half of the students preferred working with a lab partner, while 37% were neutral. I feel the student performance increased partly due to working alone. Even though some students prefer a lab partner, and there is the benefit of learning from each other, when students work alone, they are solely responsible for the work. This may or may not be a significant factor and student personality would play a large part in the results meaning that what works for some may not work for others. This study could show that, if possible, students could be given the choice to have a lab partner or not instead of making students work in pairs.

Another important area of research that would be useful is the approach to flipped learning. I feel that more work needs to be done to include all levels of students when using the flipped-learning method. Students that struggle with motivation or have different learning styles need to have methods that are geared towards their needs. Research as to altering and/or modifying the resources we have available to reach all students is very important.

Impact of Action Research on the Author

I began teaching middle school and high school 30 years ago, and over the past 30 years I have made numerous, countless attempts to encourage, coerce, reward, and yes, bribe students to come to class prepared for the days lesson. Students, for the most part, did not have a problem doing homework for the lesson that had been taught that day, but trying to get them to teach themselves the material before they came to class was next to impossible. “Read the material for tomorrow! There’s going to be a short quiz!” - I would remind them on their way out. Only the rare student would be prepared. The greatest impact this action research project has had on me as a teacher is realizing how technology is what has made this a reality. Technology has allowed flipped teaching and flipped learning to become a platform that uses various pedagogies that will engage students outside the classroom in a self-directed way. I think my excitement shows through to my students when I see them come to class knowing what we are going to do and able to ask questions because they are prepared. Gone are the days of walking into the room unaware of what we will be doing in the lab that day. I noticed a change in student attitudes as they felt more confident knowing what to do and what to ask. The interactions between me and the students, despite wearing face masks, were enjoyable and made the experience much more relaxed, in my opinion. Technology has made this method of instruction possible in way that was not possible before.

In addition, this action research project has inspired me to formally reflect on observations in the classroom. I have always reflected on my teaching instruction but never made a point of writing notes at the end of class on my observations. I see the value and importance of doing this now and it is something that I will put into practice. Gathering quantitative data also is invaluable in order to see correlations and reason the cause. When I first began to learn about action research, it threw me because I didn't understand how it could be done with so many, what I called, variables, and strict controls. I understand now the important role action research plays in education and how it can be used to make changes that improve the experience for students based on the research, instead of just a hunch.

REFERENCES CITED

Armstrong, H. E. (1910). *The teaching of scientific method and other papers on education*. Macmillan and Co.

Bart, M. (2013, November 20). *Survey confirms growth of the flipped classroom*. Faculty Focus | Higher Ed Teaching & Learning.

Bergmann, J., & Sams, A. (2012a). Before you flip, consider this. *Phi Delta Kappan*, *94*(2), 25.

Bergmann, J., & Sams, A. (2012b). Flip your classroom: Reach every student in every class every day. *International Society for Technology in Education.*

Bergmann, J., & Sams, A. (2013). Flip your student's learning. *Educational Leadership*, *70*(6), 16-20.

Champagne, A. B., Gunstone, R., & Klopfer, L. (1985). Consequences of knowledge about physical phenomena. *Cognitive Structure and Conceptual Change*, *163-187*.

Chang, H.-P., & Lederman, N. G. (1994). The effect of levels of cooperation within physical science laboratory groups on physical science achievement. *J. Res. Sci. Teach*., *31,* 167-181.

College Navigator - Richard Bland College. (2021). https://nces.ed.gov/collegenavigator?id=233338#outcome

Cummings, K., French, T., & Cooney, P. (2002). Student textbook use in introductory physics. Paper presented at Physics Education Research Conference 2002, Boise, Idaho.

Donovan, J., & Lee, S. (2015). How we flipped student and instructor reflections of a flipped-class model in a sensory evaluation laboratory course. *NACTA Journal, 59*(4), 335-342.

Fall Headcount. Higher Ed Info for Virginia. (2021). https://research.schev.edu/info/Reports.Guide-to-the-Fall-Headcount-Enrollment-Reports

Fisher, D., Harrison, A., Henderson, D., & Hofstein, A. (1998). Laboratory learning environments and practical tasks in senior secondary science classes. *Research in Science Education 28,* 353-363.

Goldenberg, L. B. (2011, September 01). What students really want in science class. *Science Teacher, 78*(6), 52-55.

Gregory, S., & Trapani, G. D. (2012). A blended learning approach to laboratory preparation. *International Journal of Innovation in Science and Mathematics Education, 20,* 56-70.

Hofstein, A., & Lunetta, V. (1982). The role of the laboratory in science teaching: Neglected aspects of research. *Review of Educational Research*, *52*(2), 201-217. https://doi.org/10.2307/1170311

Hofstein, A., & Lunetta, V. N. (2003). The laboratory in science education: Foundations for the twenty-first century. *Sci. Ed.,* 88, *28-54*. https://doi.org/10.1002/sce.10106

Hofstein, A., Kipnis, M., & Abrahams, I. (2013). How to learn in and from the chemistry laboratory. *Teaching Chemistry – A Studybook, 153–182.* https://doi.org/10.1007/978-94-6209-140-5_6

Huber, E., & Werner, A. (2016). A review of the literature on flipping the STEM classroom: Preliminary findings. In S. Barker, S. Dawson, A. Pardo, & C. Colvin (Eds.), Show Me the Learning. Proceedings ASCILITE 2016 Adelaide (*pp. 267-274).*

Kingsley, C. (1846). *How to study natural history*. Lecture.

Mann, C. R. (1910). The present condition of physics teaching in the United States. *Broad Lines in Science Teaching*. Macmillan.

McEvoy, J. G. (2021, March 10). Joseph Priestley. *Encyclopedia Britannica.*

McLean, S., Attardi, S. M., Faden, L., Goldszmidt, M. (2016). Flipped classrooms and student learning: Not just surface gains. *Adv Physiol Educ. 40*(1), 47-55. https://doi.org/10.1152/advan.00098.2015. PMID: 26847257

Mertler, C. A. (2016). *Action research improving schools and empowering educators* (5th ed.). SAGE.

National Research Council. (2006). *America's lab report: Investigations in high school science.* The National Academies Press.

Newbury, N. F. (1934). *The teaching of chemistry*. Heinemann Educational.

Otero, V. K., & Meltzer, D. E. (2017). The past and future of physics education reform. *Physics Today*, *70*, 50-56. https://doi.org/10.1063/PT.3.3555

Packard, J. C. (1903). Physics for the boys and girls: An introductory course. *NEA Proceedings*. https://doi.org/10.1037/e597402010-168

Romey, W. D. (1968). *Inquiry techniques for teaching science*. Prentice-Hall.

Rosen, S. (1954). A history of the physics laboratory in the American public high school (to 1910). *The American Journal of Physics, 22*(4), 194-204.

Rosen, S. (1979). Rise of laboratory work in high school chemistry. *Journal of Chemical Education*, *56*(6). https://doi.org/10.1021/ed056p404

Science Masters' Association. (1953). *Secondary modern science teaching: A report on the teaching of science in secondary modern schools*. Murray.

Singer, S., Hilton, M., & Scheingruber, H. (2005). Laboratory experiences and student learning. *America's Lab Report: Investigations in High School Science*. The National Academies Press. https://doi.org/10.17226/11311

Stelzer, T., Gladding, G., Mestre, J., & Brookes, D. (2009). Comparing the efficacy of multimedia modules with traditional textbooks for learning introductory physics content. *The American Journal of Physics*, *77*(2), 184-190. https://doi.org/10.1119/1.3028204

Tamir, P., & Iowa University, Iowa City. Science Education Center. (1976). *The role of the laboratory in science teaching. Technical Report 10*.

Teo, T. W.; Tan, K. C. D.; Yan, Y. K.; Teo, Y. C.; & Yeo, L. W. (2014). How flip teaching supports undergraduate chemistry laboratory learning. *Chemistry Education Research and Practice, 15*(4), 550-567.

Zappe, S., Leicht, R., Messner, J., Litzinger, T., & Lee, H. W. (2009). "Flipping" the classroom to explore active learning in a large undergraduate course. *ASEE Annual Conference and Exposition, Conference Proceedings*.

APPENDICES

APPENDIX A

INSTRUCTIONAL REVIEW BOARD EXEMPTION

INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 00000165

MONTANA STATE UNIVERSITY

2155 Analysis Drive
c/o Microbiology & Immunology
Montana State University
Bozeman, MT 59718
Telephone: 406-994-4706
FAX: 406-994-4303
E-mail: cherylj@montana.edu

Chair: Mark Quinn
406-994-4707
mquinn@montana.edu
Administrator:
Cheryl Johnson
406-994-4706
cherylj@montana.edu

MEMORANDUM

TO: Laura Camp and Walter Woolbaugh

FROM: Mark Quinn *Mark Quinn CJ*
Chair, Institutional Review Board for the Protection of Human Subjects

DATE: August 17, 2020

RE: *"The Effect of Reading and Discussing Current Event Science Articles on the Ability of Students to Understand Its Validity and to Better Understand Other Points of View" [LC081720-EX]*

The above research, described in your submission of August 13, 2020, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

_X_ (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

_X_ (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation; and (iii) the information obtained is recorded by the investigator in such a manner that the identity of the human subjects can readily be ascertained, directly or through identifiers linked to the subjects, and an IRB conducts a limited IRB review to make the determination required by section 16.111(a)(7).

___ (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.

___ (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.

___ (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.

___ (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.

APPENDIX B

LEARNING OUTCOMES

RBC Biology 101 Laboratory Learning Outcomes

	BIO101L Learning Outcomes
1	Explain and apply the Scientific Method.
2	Acquire basic scientific skills and common biological laboratory practices.
3	Explain and integrate fundamental biological concepts related to cell and molecular biology.
4	Understand and discuss the comparative anatomy of plants and lower eukaryotic organisms.

	Exceeding	Meeting	Approaching	Not Meeting
Learning Outcome Average	90-100%	70-89%	60-69%	<50%

APPENDIX C

STUDENT SURVEY QUESTIONS

Question 18

Fall 2020 Lab Specific Questions

Question 19

The online resources provided the information I needed to complete my assignment.

(5) Strongly Agree	(4) Somewhat Agree	(3) Neutral	(2) Somewhat Disagree	(1) Strongly Disagree
○	○	○	○	○

Comments:

- Reversed Options

Question 20

I prefer to have one lab session per week for 14 weeks instead of two lab sessions per week for 7 weeks. (1hr each for Biology, 2hr for Chemistry)

(5) Strongly Agree	(4) Somewhat Agree	(3) Neutral	(2) Somewhat Disagree	(1) Strongly Disagree
○	○	○	○	○

Comments:

- Reversed Options

Question 21

I prefer to learn the material and procedures on my own when it is convenient rather than having more time in the lab for the instructor to teach the material and explain the procedure.

(5) Strongly Agree	(4) Somewhat Agree	(3) Neutral	(2) Somewhat Disagree	(1) Strongly Disagree
○	○	○	○	○

Comments:

- Reversed Options

Question 22

I was able to understand the material in the lab even though some topics had not been covered in the lecture yet.

(5) Strongly Agree	(4) Somewhat Agree	(3) Neutral	(2) Somewhat Disagree	(1) Strongly Disagree
○	○	○	○	○

Comments:

- Reversed Options

Question 23

I prefer to work with a lab partner.

(5) Strongly Agree	(4) Somewhat Agree	(3) Neutral	(2) Somewhat Disagree	(1) Strongly Disagree
○	○	○	○	○

- Reversed Options

Question 24

The at-home lab exercises were clear and understandable.

(5) Strongly Agree	(4) Somewhat Agree	(3) Neutral	(2) Somewhat Disagree	(1) Strongly Disagree
○	○	○	○	○

Comments:

- Reversed Options

Question 25

Did you take Biology 101 Lab this semester?

(1) Yes	(2) No
○	○

- Question has branched logic

Question 26

How helpful were the following online resources and assignments?

	(5) Very Easy	(4) Easy	(3) Difficult	(2) Very Difficult	(1) Never Attempted
Online Pre-lab Homework	○	○	○	○	○
Online Pre-lab Procedural Video/Homework	○	○	○	○	○
Narrated PowerPoints/Notes	○	○	○	○	○
Phylum Chart Review Video	○	○	○	○	○
Practice Exam	○	○	○	○	○
Quizlet	○	○	○	○	○

• Question is referenced by branched logic • Reversed Options

Question 27

Please comment on the ratings in the question above: "How helpful were the following online resources and assignments?"

• Question is referenced by branched logic

APPENDIX D

FACULTY INTERVIEW QUESTIONS

Biology 101 Lab Instructor Interview Questions

1. In general, what aspects of the scheduling changes made to the biology labs did you like? Why did you like those aspects?

2. In general, what aspects of the scheduling changes did you dislike?
   Why did you not like those aspects?

3. Do you feel the students were able to complete the same amount of material as in previous semesters? Why or why not?

4. Students had to learn the material and the procedures prior to coming to the lab. Did you see any differences in student preparedness compared to previous semesters? Can you give some examples.

5. Do you think the student was able to understand and therefore retain more from the lab by having to know the specific lab material before they came to the lab? What do you base this on?

6. What do you think are the advantages and disadvantages to not explaining the material and the procedures in person as opposed to an online video?

7. Did you feel the labs were the appropriate length of time needed to complete the procedures? If not, what would you recommend?

8. Since the lab exercises that correlate with the lecture were done before they had the material in the lecture, did you see a difference in the understanding of the lecture material among your students? Can you give some examples?

9. What differences did you see in the students when they performed the lab procedures alone versus prior semesters when the lab exercises were done in pairs or groups?

10. What would you do differently in the future?

APPENDIX E

OBSERVATION SHEET

Teacher Journal Observation Sheet

Date: ________________________ Laboratory Exercise:__________

1. Are students on task and engaged for the majority of the laboratory sessions?

2. Are the students asking questions related to the laboratory exercise and/or procedure?

3. Do the students appear to be interested in the laboratory exercise?

4. Do the questions include information that was provided in the pre-laboratory assignments?

5. Were there any comments or concerns pertaining to the pace of the course or the length of time in the laboratory?

6. Other: