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Analyzing the Effectiveness of Remote Laboratories at WPI During the Coronavirus Pandemic

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Analyzing the Effectiveness of Remote Laboratories at WPI

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I. Executive Summary

With the spread of the coronavirus in the United States forcing universities across the nation to emergency remote learning, **our project explored how the effects of this pandemic have impacted laboratory classes at WPI**. We focused on three objectives: (1) understanding the **faculty experience** in transitioning traditional laboratory classes online through interviews, (2) gathering **student perceptions** about the remote laboratory experience through a survey, and (3) completing an **analysis about the overall effectiveness of remote labs**. With six faculty interviews and about 200 student survey responses, we were able to gather a variety of opinions and experiences about the transition to online laboratories.

Of the classes we surveyed, we grouped them into the **three categories of chemistry, physics, and engineering** to protect the privacy of the instructors we worked with and reduce per-class bias in analyzing trends. Variables we investigated in our student survey included the ability to learn material, work in a team, focus, and the motivation to complete assignments. We found that the chemistry and physics classes we investigated had an average result that was more positive than that of the engineering classes for our performance variables. However, while chemistry and physics were more positive, they still had an overall negative response to the variables. **Chemistry classes had a relatively positive response to these variables, specifically in learning material and teamwork**, which is most likely due to the collaborative nature of chemistry laboratories. **Physics classes also had a relatively positive response to all variables, specifically in learning material and ability to focus**. This is likely because of the engaging delivery method of physics laboratories, which is an online simulation. **Engineering classes had a noticeably negative response to every variable**, nearly ranking extremely negative for each one. We believe this is due to the fact that the engineering classes we investigated are higher level and more major specific than the chemistry and physics classes. This makes it harder to perform the laboratories remotely for these classes, along with the fact that they are less theory-based than the chemistry and physics classes.

The interviews we performed with laboratory instructors also provided insight into the transition from the faculty perspective. We learned that they are struggling just as much as the students, they are missing the in-person connection of face to face classes, and they are working hard to be accommodating to all their students.

Based on all our findings from the survey and interviews, we came to a **recommendation** that if WPI were to use a phased reopening to bring students back to campus, it would be advisable to give **preference to students in higher level classes to have opportunities for in person labs**, since they have a harder time learning their material remotely. Introductory classes such as the chemistry and physics classes we investigated are successful online, but still not ideal when compared to in-person laboratories.

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1. Introduction

Our team aims to highlight the difficulties of the transition to remote learning because of the novel coronavirus, which originated in Wuhan, Hubei, China and has spread across the globe. This virus, known as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), causes COVID-19, a disease that has now infected a confirmed 4.3 million people around the globe as of 05/13/2020 (DOMO, 2020) in what the World Health Organization classifies as a pandemic (World Health Organization, 2020). COVID-19 is characterized by flu-like symptoms, including fever, cough, and shortness of breath (Center for Disease Control and Prevention, 2020). It can be especially devastating for certain demographics, most notably people over the age of 65 and people with pre-existing conditions such as diabetes, hypertension, and cancer. The pandemic has caused many countries to take such action as to close borders, enforce lockdowns of cities, advise residents to avoid groups of over 10 people, and stay 6 feet away from other people. These actions have caused the closure of businesses considered "non-essential," meaning that only businesses such as grocery stores, gas stations, and pharmacies remain active. The COVID-19 pandemic is having an enormous impact across the globe, along all walks of life, and is not something that has been taken lightly by the leaders of the world.

The United States of America is currently the country in the world with the most confirmed cases of COVID-19, with over 1.38 million citizens who have tested positive [as of 05/13/2020] (DOMO, 2020). The leaders of the fight against COVID-19 have advised against social gatherings and have even put certain areas on mandatory lockdown. The president, Donald Trump, has declared a national emergency, so that more resources can be used to fight this virus. Many states have called for a closure of non-essential businesses and issued advisories to ban social gatherings and advise or require people to cover their faces and wash their hands. Due to these actions, many Americans who do not work at an essential business have been forced to work remotely at home if possible, limiting the spread of the disease. Nearly all public and private schools, from elementary to university, have made the transition to remote learning. This has introduced a multitude of difficulties in communication and assessments of material.

At Worcester Polytechnic Institute (WPI), the effects of COVID-19 began when students abroad began to come home early from their C-term travels to Thailand. On March 4th, after Governor Baker's recommendation that universities cancel international travel, WPI decided to suspend university-sponsored international travel. This grounded 284 students and 23 faculty who had planned to complete global projects during D-term. We were among these students as we had originally planned to complete a research project in Denmark.

On March 11th, with the impact of the pandemic moving towards the United States, the WPI administration made the decision to delay D-term classes by a week and a half to allow faculty to prepare for remote delivery of classes for at least the first two weeks of D-term. It was announced that a decision would be made regarding the reminder of the term as well as

commencement by the end of March. Then, on March 18th, WPI made the decision to move D-term entirely to remote learning.

Faculty and staff have worked tirelessly to transition their classes online, something many of them never imagined. WPI's motto stresses Theory and Practice, an approach seen in our project-based curriculum and our emphasis on hands-on laboratory experiences. Transitioning classes to a remote format has proved to be a challenge at WPI and college campuses across the nation.

As a campus, WPI is reliant on online resources such as Canvas, Echo360, and other resources available to each professor. Canvas is a platform that enables professors to disseminate information to students via modules, files, and online quizzes. Echo360 allows professors to post recorded lectures to Canvas. A significant percentage of classes already utilize these tools, and they continue to be valuable in WPI's transition to remote learning. However, online learning has proven to need more than just these existing resources to be effective. As a staple of WPI, first-hand experience is essential, but in the age of COVID-19 exposing students to hand-on learning is nearly impossible.

While these online resources can be effective for lecture-based classes, laboratory classes need a different set of tools to transition to remote. Most of the information in a lab is discussed with students while they conduct experiments in person. This leaves a gap in practical knowledge, such as the trial and error process or team collaboration, once these laboratories are moved to a remote setting. While professors can stream or record experiments to the class, there is no guarantee the information is absorbed by those watching in the same way as if they were there doing it themselves. Fundamental questions regarding online labs remain: what are effective methods in teaching hands-on skills in a remote setting? What needs to be changed in order to have a more effective learning experience?

After our plans for international travel were cancelled, our team decided to seek answers to these questions. To determine the effectiveness of remote laboratory learning, we examined different ways in which online labs are delivered at WPI and how students perceived these different methods. WPI does not have extensive experience in delivering the practical aspect of Theory and Practice remotely, so we hope our project will inform the community and others on practices efficient for remote learning.

The goal of this project was to examine how the transition to online and alternative teaching methods during the coronavirus pandemic has affected students' learning and faculty's teaching in laboratory courses.

2. Methodology

We analyzed the effectiveness of remote laboratory style learning in several subject areas at WPI using surveys and interviews. To accomplish our goals, we had the following objectives:

1) Understand challenges faced by faculty transitioning their material into alternative formats
    i) Faculty at WPI did not have much time to adjust to delivering course material online, particularly courses with laboratory component. We conducted interviews with relevant faculty to determine how they were able to adapt their courses to an online environment. Questions can be found in Appendix A.
2) Gather student feedback and perceptions of the remote laboratory classes.
    i) The central aspect of this project is gauging how students have responded to the transition from in-person to online laboratories. Feedback was gathered regarding student attitudes and experiences using the survey questions found in Appendix B.
3) Analyze effectiveness of remote labs.
    i) Once the faculty interviews and student surveys were collected, they were analyzed to determine trends and commonalities among groups.

This project took place over the period of March 25th to May 13th, 2020, remotely due to the COVID-19 pandemic. This project studied the use of online laboratory experiences at Worcester Polytechnic Institute (WPI). “Online laboratory” in this sense refers to the transition of in-person classes with a laboratory section to remote learning due to the COVID-19 pandemic. The following chapter describes the methods used to accomplish our objectives.

For this project, we specifically investigated how the online format affected the following laboratory classes:

- CH 1020 - Chemical Reactions
- PH 1120/1 - Electromagnetism
- PH 1140 - Oscillations and Waves
- ME 1800 - Manufacturing Science Prototyping and Computer-Controlled Machining
- BME 3111 - Physiology and Engineering, and
- ME 3902 - Project-Based Engineering Experimentation

We selected these classes because of their larger enrollment as well as covering a range of subjects and course levels. While our focus was on connecting with professors and students from these specific classes, we gathered data from anyone taking a course with a lab component in D-term. Through surveys and interviews, we determined different challenges laboratory professors and students faced compared to lecture-based classes.

2.1. Interview Design

Our existing connections within our advisors allowed us to establish connections with the laboratory instructors and gain a basis for discussion. We looked to interview many of the laboratory instructors about their experience transitioning their lab classes online. We looked to further develop our understanding about how faculty responded to the remote learning of laboratories. Our interviews were conducted using Zoom, a video chat platform that allows recording of meetings. The interview questions varied slightly between faculty, but they shared the same basis of questions in each interview. Interviews become useful when the idea or answer of the subject is not simple. Open ended questions are used in interviews where participants' answers may need more context or personal experience. For open-ended questions to be correlated to quantified data, there must be solidified trends to determine if responses can be categorized without bias. In order to make interviews effective, we must consider a balance between questions with simple answers that will help support the answers of more complex questions later in the interview.

The most efficient way for us to gather this information is by using semi-standardized open-ended interview questions. The article, *Qualitative Interview Design: A Practical Guide for Novice Investigators* (Turner, 2010) describes a structured form of interviewing where the wording of the question is just as important as the answers themselves. The difficulty with these forms of interviews is bias, as words must have value but cannot hint towards the interviewer's hypothesis or belief. The questions will be consistent throughout all interviews and some deviation from the structure is allowed but should be noted by the interviewer. This will allow the interviewee to express their viewpoint in full, while giving the interviewer the option to dig into pieces of their responses they feel is important to the project. For our methods to be effective, the design of the questions was a crucial component in collecting the necessary information during our interviews. While the laboratories all have different components, we wanted to keep the questions consistent throughout. This allowed us to determine similarities between different laboratories. Our interview questions can be found in Appendix A.

When presenting the data from our interviews in our reports, we omit any identifiable data and refer to each interview by numbers. We asked for consent to record interviews for later reference and the recordings will be deleted after the report is complete.

2.2. Survey Design

This project used a survey to collect information from students in the WPI community. We gathered opinions about the transition from in-person laboratory experiences to remote ones. In order to ensure that the questions on these surveys are effective, we followed a guide from Chase Harrison at Harvard University (Harrison, 2007) There are many considerations when making a survey, from general qualities to types and wordings of questions.

Some considerations for surveys are how it will be administered, the length of the survey, the order of the questions, and which questions should be asked to whom. Our survey was administered online due to the remote nature of the pandemic. We focused on understanding how students would be filling it out, regardless of their prior technological experience. The length and wording of our survey needed to be short and concise. Participants needed to understand what the questions were asking while not dragging on so long they lost interest. We aimed to keep the survey at about ten questions or less to help our participants focus on each question and be more likely to complete the survey. The order of the questions in our survey is essential to the impact each question has on the following question. Some important factors for this are to start with a clear introduction, place questions with topics we want to enforce at the start and keep any sensitive questions near the end. Finally, filtering our questions based on who should answer them will be important to our survey. For this, we use "skip logic," a feature of Qualtrics which allows participants to answer questions that correspond based on their previous answers. If a participant of our survey has more information that we can use, we might want them to answer more questions, or questions with more detail.

Our next consideration for surveys is how the questions should be formatted. Because of the large number of anticipated responses, the survey questions should be standardized and easy to sort. Because of this, we concluded that a five-option Likert scale would be the most effective because it can easily separate those who feel strongly about a specific part of the transition.

Our final consideration for surveys is the wording of each question. Harrison cites three main guidelines when writing questions. He states that a question should measure the underlying concept it is intended to tap, should not measure other concepts, and means the same thing to all respondents. These points are critical to keep in mind when developing a survey, and there are some techniques to make sure each question accomplishes them. Avoiding excessive technical language helps each respondent completely understand what a question is asking. Maintaining concise wording specifies the intent of the question and will help reduce confusion about expected responses. Asking about two topics in one question, also known as double-barreled questions, can confuse respondents. It is important that each question is only asking about one specifically highlighted topic. Finally, a critical quality of a survey question is that it is not leading, allowing for the respondent to think about the question without being pressured to answer in a specific way.

When designing our survey, we consulted these recommendations to ensure that our survey remained clear and unbiased to the user. We focused on the flow of the questions to ensure that our respondents understood what each question was asking while maintaining a continuity throughout the entire survey.

When distributing our surveys, we identified faculty members who were teaching the selected laboratory classes this term and asked for their cooperation in sharing our survey with their students. We gave them an option to add their own questions to the survey so that they are

able to receive feedback from their students specific to their course. However, no instructor-specific questions were requested. We requested the instructors to distribute our survey link through either their email alias for the class or WPI's Canvas platform and the survey questions can be found in Appendix C.

2.3 Analysis of Interviews and Surveys

We looked through interviews and pulled out common themes and trends faculty were struggling with this term during the transition. When asked about student concerns, we investigated how their responses compare to the student trends seen in the survey.

The primary focus of our analysis is to determine how various online laboratory classes are received by students. Responses will be categorized into Chemistry (CH 1020), Physics (PH 1120/1 and PH 1140), and Engineering (ME 1800, ECE 2010, BME 3111, and ME 3902) to reduce bias from individual classes to better generalize trends as well as protecting the identity of professors. We will also investigate the effect that previous lab experience has on satisfaction with online labs by segregating responses based on class year and number of previous lab classes taken. Keywords and repeated information will be analyzed based on the results from interviews and short answer questions to determine trends.

3. Results and Discussion

Based on almost 200 student survey responses and six faculty interviews we were able gather a variety of opinions and experiences about the transition to online laboratories. Our results were able to gather a number a statistically significant trends from the students and in our analysis, we provide potential correlations to how the instructors developed these classes. The sections below discuss the results we gathered from faculty interviews as well as the student survey. The student survey breaks down our findings based on class subject: chemistry, physics, and engineering.

3.1. Faculty Interviews

Our interviews with WPI's faculty have informed us of the general perceptions among laboratory instructors during the transition to a remote setting. Interview questions can be found in **Error! Reference source not found.**. The most apparent trend was that while their students are managing remote learning the best they can, the instructors are struggling with keeping students engaged and connecting online.

When transitioning to remote learning, instructors lose the aspect of human interaction that is so prevalent during laboratory courses. They are unable to connect with their students on the same level as they can in person. Rudra Kafle, a professor we interviewed in the physics department, mentioned that two weeks into a typical term he usually knows the names of all 72 students in his lab. However, after four weeks of online learning, he can only name a handful. One of the pieces to creating a quality course is making a connection with students but this is not as easily done through Zoom or other online forms of delivery. Every professor we interviewed mentioned that the transition to online classes has greatly affected the relationships they build with their students.

This lack of connection has also made it difficult for instructors to perceive how much of the information is being received and retained through online classes. When asked if they believe that students are retaining the same amount of information as in person classes, many of them said they did not know. This makes assignments the only way to accurately measure the retention of material in their class. We have noticed that for many classes this causes the instructor to create more assignments, which in turn affects the motivation and focus of the students.

While the loss of in-person and hands-on time spent in lab is affecting students and instructors alike, they point out that the most fundamental piece of laboratories is missing: the ability to fail and respond to those failures. The chemistry department restructured their labs in recent years to highlight the true trial-and-error process that comes with laboratory experiments. They ask students to design their own procedure and then spend lab time attempting the experiment, under the guidance of the lab professor, and learning from the failures they have. By switching these labs to the online format and showing a recording of a lab instructor doing the experiment flawlessly, the element of failure has been eliminated and takes away students' ability to learn from failure.

Many professors we spoke with believe that when students struggle with the material, they are more likely to understand the larger concepts surrounding the topics. Recorded videos supplemented by sample data prevents students from experimenting with the process themselves. However, recorded lab experiments take up significantly less class time than true experimentation, so instructors can focus on larger concepts surrounding the lab, such as course objectives and the reasons behind the procedure. This extra time has proven to be beneficial as instructors have seen the quality of lab reports increase during the transition to remote learning.

Another aspect that many instructors emphasized was the rising awareness of their students' mental health. This situation has made some of them more attentive and compassionate to different scenarios that their students may be struggling with. For instance, professors are teaching students who are in different time zones, from the U.S. West Coast, all the way to China. Some students do not have a quiet space to work at home. Others might be struggling with a parent losing a job or family members passing away. It is more difficult for students to communicate with their professors about their situations when video cameras are turned off and the student-professor relationship has not been established.

Even communicating with professors to have course-related questions answered is much more time-consuming. Instead of just raising a hand in class, students need to take it upon themselves to tune into office hours or draft an email. Both things happen on campus, but when the element of in-class questions disappear, students are no longer able to learn from each other's questions and must take the time to express their lack of understanding. Remote communication complicates how students are able to learn.

Another difficult piece of the transition to online learning for the professors and instructors has been the amount of time required to prepare for this term quickly and efficiently. The time professors are putting in to create a meaningful experience online is significantly more due to the restructuring of labs.

3.2. Student Surveys

Class	2023	2022	2021	2020	Total
Chemistry	39	10	0	1	50
Physics	52	5	4	3	64
Engineering	7	20	25	14	66
Other	18	9	14	8	49
Total	116	44	43	26	229

Table 1. Class Year per Subject Area

Our survey gathered feedback from about 200 students across a large subsection of the undergraduate population. Table 1 is a breakdown of the responses from the selected classes by class subject and class year. Responses are categorized by subjects of chemistry, physics, and

engineering classes to reduce bias from individual classes, to better generalize trends, and to protect the identities of professors.

Subject Area	Pre-Recorded Labs	Online Simulations	At Home Labs
Chemistry	X		
Physics		X	X
Engineering	X		X

Table 2. Lab Delivery Method by Subject Area

Specific lab delivery methods were strongly associated with classes, depicted by **Error! Reference source not found.**, so determining the significance of each method on its own is difficult. While we initially wanted to investigate the effectiveness of various delivery methods, separating the methods from the material proved to be a challenge, as each class was distinctly linked with its specific delivery method. For instance, physics classes typically used online simulations, while chemistry classes used pre-recorded lectures with little crossover between classes. Each subject had its own delivery method so we cannot assume that results for a class are based solely on the delivery method; it is a combination of the class material and delivery method.

3.2.1. General Response

Overall, students were not very satisfied with the quality of remote learning or remote laboratories. When asked about their opinion on the transition to remote learning in general, they swayed slightly negative. As seen in Figure 1, with 51% of respondents saying they had a somewhat or extremely negative experience, compared to 29% with a positive perspective. This yields an average of 2.73 on a 1-5 scale, where 1 is "Extremely Negative" and 5 is "Extremely Positive". They hold a more negative opinion of the transition to remote labs, specifically, increasing to 55% of respondents having negative feelings, wielding a 2.54 out of 5 (Q6 & Q7 in Appendix C) and only 26% responding somewhat or extremely positive. As shown in Figure 1, the negative feelings were

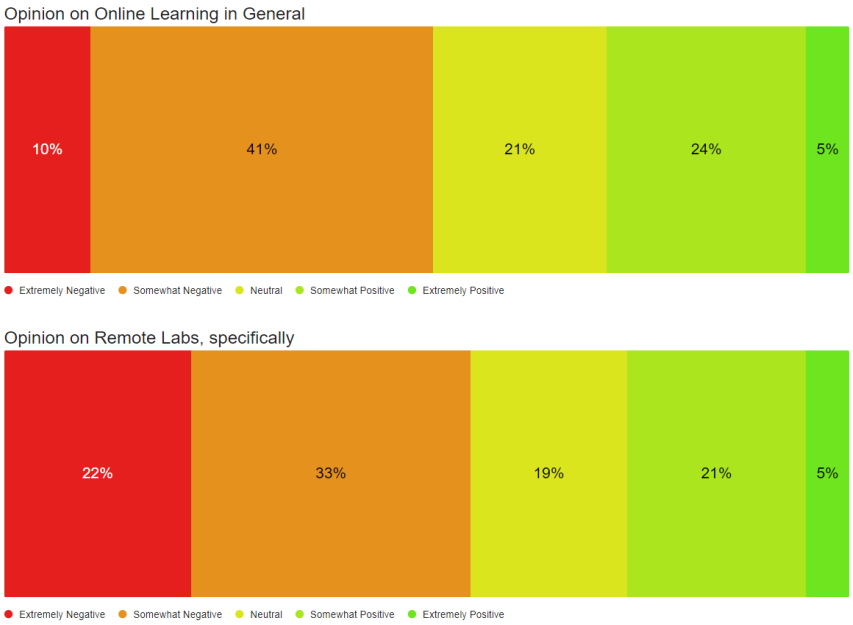

Figure 1. General Opinion on Online Classes and Remote Labs

noticeably stronger towards labs with double the percentage of "Extremely Negative" responses compared to general remote learning. The percentages of "Neutral", "Somewhat Positive", and "Extremely Positive" were approximately the same for both questions, slightly lower for labs than in general.

Those who held positive or negative opinions of online classes or labs specifically (Q6 & Q7, Appendix C) held similar negative views when asked how remote labs affect their ability to learn, work in a team, focus on schoolwork, and their motivation to complete assignments (Q8). Answers to Q6 & Q7 were strongly correlated with responses to Q8, with the lowest, but still significant confidence in "Ability to Work in a Team". However, those with neutral responses to Q6 & Q7 tended towards negative answers for Q8 rather than remaining neutral or becoming positive. Additionally, those who were initially positive were less likely to maintain their stance in following questions than those with initially negative responses. Overall, most of the respondents' answers shifted more negative when asked about more specifics of their

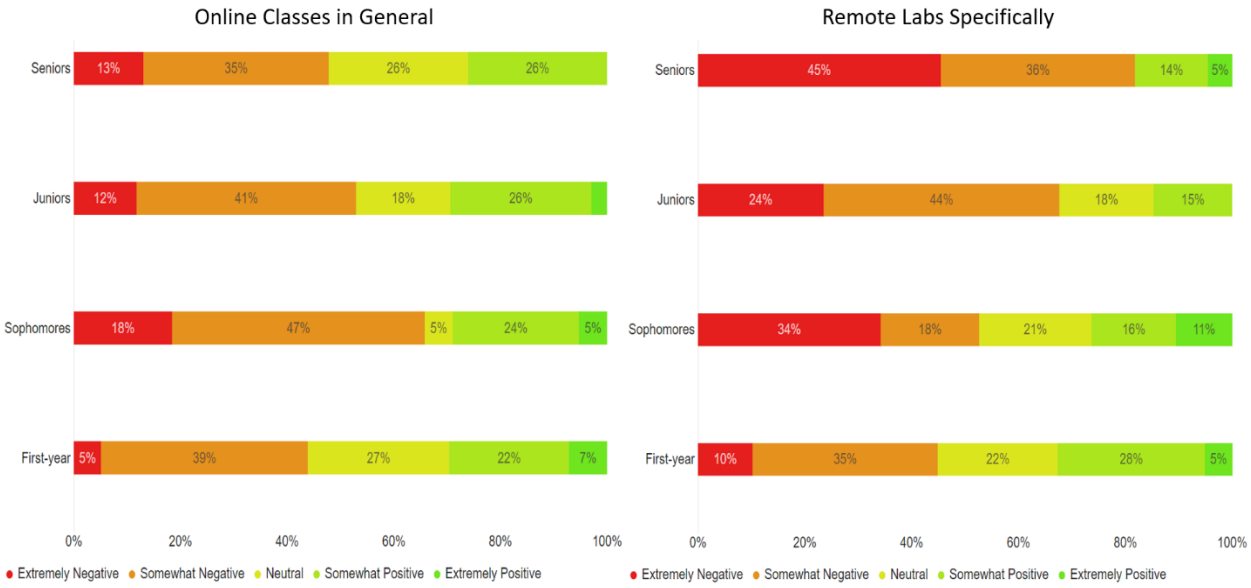

Figure 2. Opinion on Online Classes and Remote Labs by Class Year

experiences. The answering percentages, averages, and deviations can be found in Appendix D.

When looking at the responses based on class year (Figure 2), we noticed the further along in their education the students became more dissatisfied with their remote lab experience. Seniors were not only in more classes with lower average satisfaction, but also had lower than average satisfaction for those classes. We can speculate that higher-level students and students with more experience have a better sense of what missing by not having in-person labs. They may also be taking labs more specific to their majors and may therefore be more invested in the learning outcomes of their laboratory classes. As seen in Figure 3, students who have taken more than two lab classes in any subject (i.e. more experience) responded 46% negatively to online classes in general but 68% negatively to labs. This result may also be from the type of classes higher-level

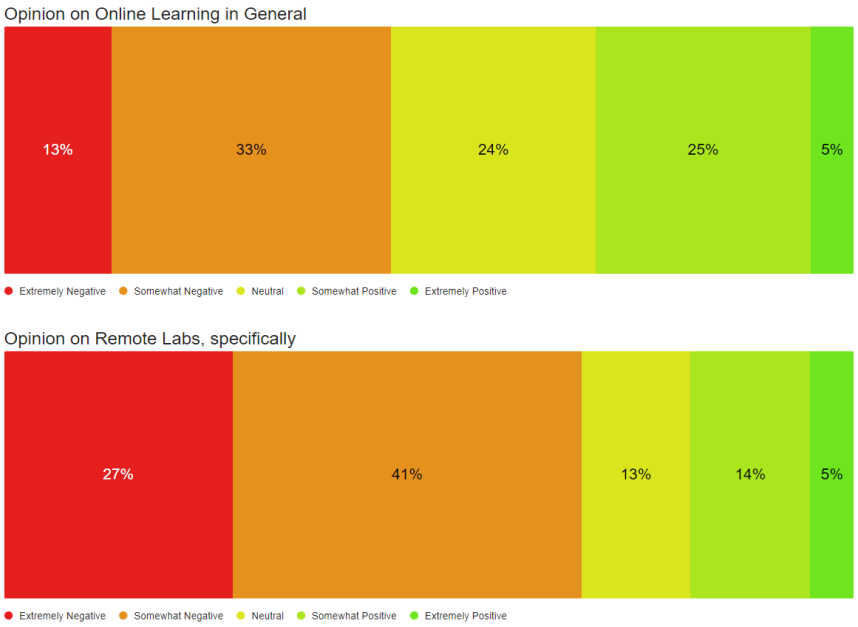

Figure 3. Experienced Students' Opinion on Online Classes and Remote Labs

students take but given that seniors were more dissatisfied than juniors for a given class, that is unlikely. The difference between the general opinion of online learning and online laboratories, as compared to the level of experience the students has at WPI, is much larger than that for the overall pool of respondents.

As seen in **Error! Reference source not found.**, the least positive category in Q8 was "Ability to Work in a Team" with 6% positive responses. The most negative was "Ability to Focus" with 67% negative responses. Establishing communication and collaborating with team members can be difficult even when there is the opportunity to meet face to face first, so it is not surprising that so few respondents do not feel positive about remote learning's impact on their teamwork.

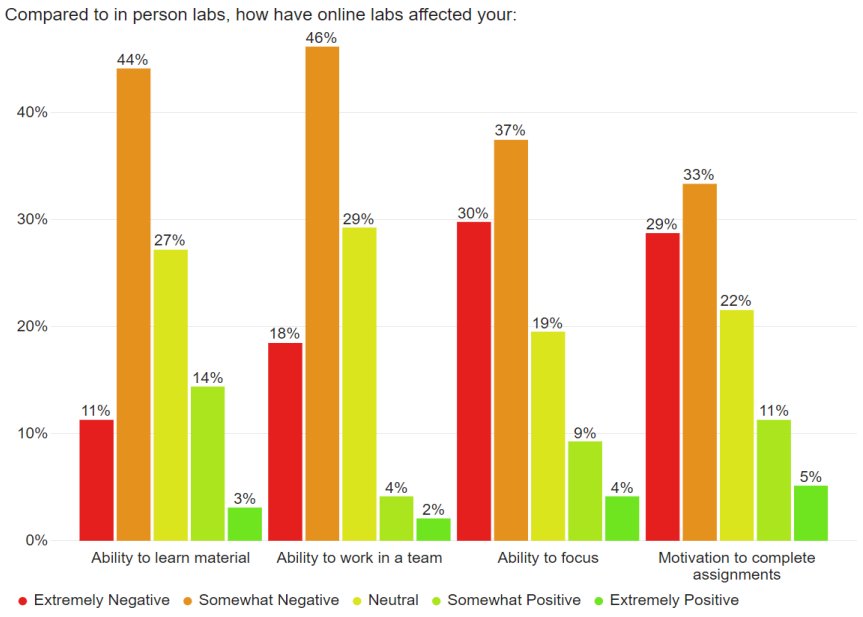

Figure 4. General Opinion on the Impact of Remote Labs

As for ability to focus, some students may fall into less productive habits when at home or be more prone to distractions at home for other reasons. There is also the general difficulty surrounding the pandemic, causing students to be unable to concentrate on their work as they worry about friends, family, and the future.

In terms of time commitment, students feel generally inconsistent regarding the time it takes them to complete remote labs, with a slight skew towards agreeing in-person and remote labs take them same time. An increase or decrease in time spent is not specified in the question,

making a conclusion difficult; however, if there is any result from this question, it is inconclusive if time spent on labs varies depending on in-person vs remote delivery.

How students view the material covered by remote labs is more conclusive, with an average response of 2.85/5 indicating slight disagreement that the material covered is equivalent. Engineering students brought down the average, but the overall average is relatively close to a neutral response, indicating chemistry and physics classes were able to transition to online with minor impacts to material delivered through labs. Students had an overall favorable response to the communication of remote lab objectives with an average of 4.4/5 agreeing they were communicated clearly, although many of the student comments (Appendix D) noted communication as a particular difficulty.

3.2.2. Chemistry

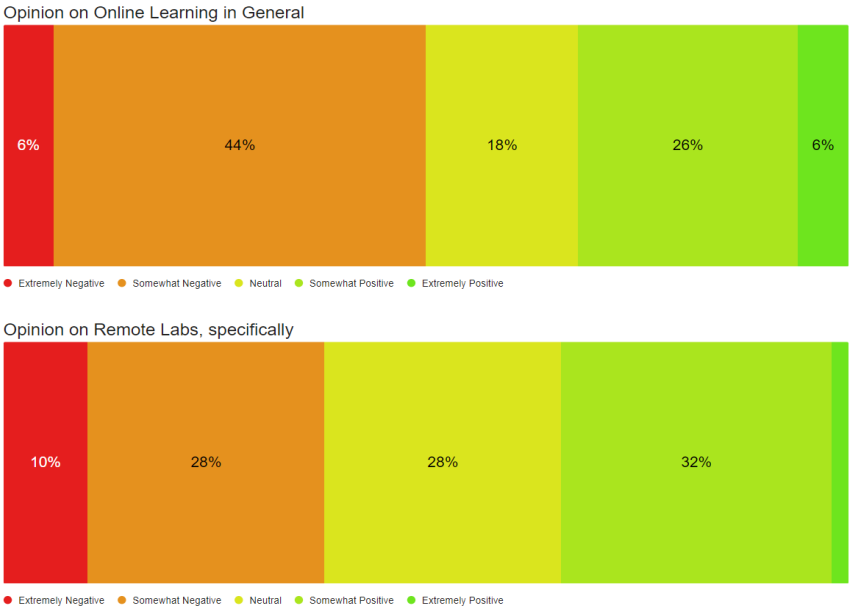

Figure 5. Chemistry Students' Opinion on Online Classes and Remote Labs

Students who responded to our survey from chemistry classes tended to have a positive response to the transition to remote laboratories. The laboratory component of this class is particularly hands-on, consisting of mixing chemicals and analyzing reactions. Instructors in this class made pre-recorded videos of themselves performing the experiments to show for the students in the class. Some instructors watched these pre-recorded videos live during class time, narrating over the video and pausing is so students can ask questions about the video. They then focused on allowing the students to use teamwork to draw conclusions from the demonstration and sample data.

The students in this class responded positively to this presentation method, working in teams to analyze the experiments and complete written reports based on their conclusions. The instructors for this class pointed out that there seemed to be an increase in the quality of the written laboratory reports using this presentation style. In chemistry, students had a positive response towards learning material from labs and working in teams, based on 26% responding positively and a further 26% remaining neutral regarding their ability to learn, and 16% positive and 30% neutral regarding teamwork, as shown in Figure 6. The students were showing an

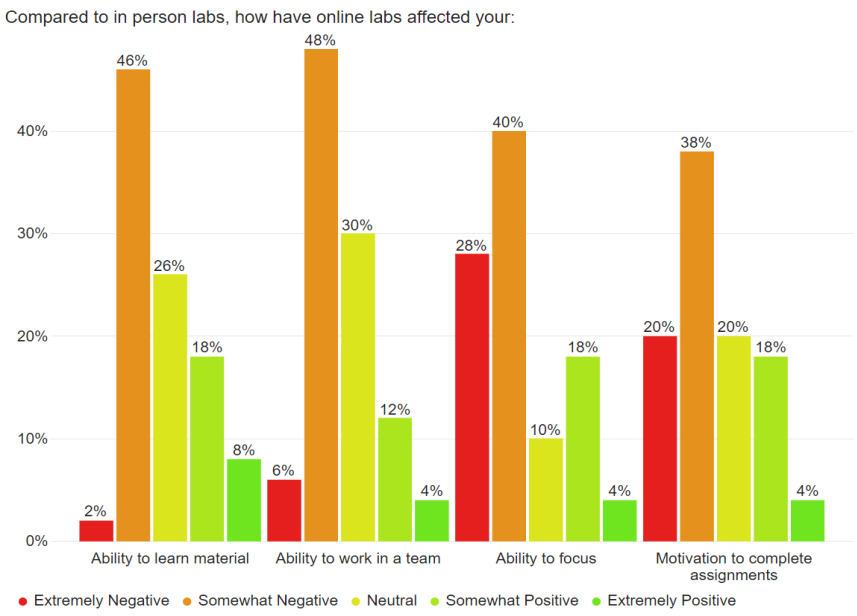

Figure 6. Chemistry Students' Opinion on the Impact of Remote Labs

increased knowledge of the concepts and how they apply to the laboratory experiments, 78% of students agreeing lab objectives are clearly conveyed.

The question here is whether the increase of report quality is due to a lack of difficulty in the laboratory or the ability to focus in a remote setting. Chemistry students showed an average response to their ability to focus, slightly positive 22%. Many instructors are giving extra assignments to make up for the lost experience in labs, hoping to drive home important concepts they would have learned in the lab. While giving extra assignments cause a positive response in conveying objectives, it may also increase the stress on students who expect less work compared to laboratory classes they have taken prior to this term, along with the other courses they are taking this term.

3.2.3. Physics

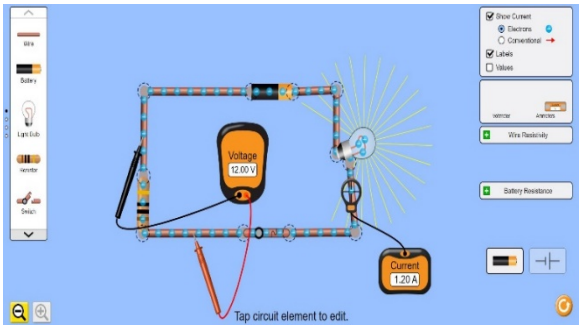

Figure 7. Example of an Online Physics Simulation

In Physics classes, instructors used online simulations to present laboratories. When on campus, these laboratories normally have students using physical circuits and magnets to conduct experiments. The simulations used allow students to drag wires, batteries, lightbulbs, and even electric charges around on their screen and use built in voltmeters to measure electric fields. An example screen of one of these simulations is shown in Figure 7 (Rouinfar, 2020). These simulations are more engaging for students compared to presentation techniques used in other classes, giving more of an experimental feel than watching someone complete the laboratory and analyzing their data. Students complete worksheets based on their findings, solidifying the concepts from lecture in practice.

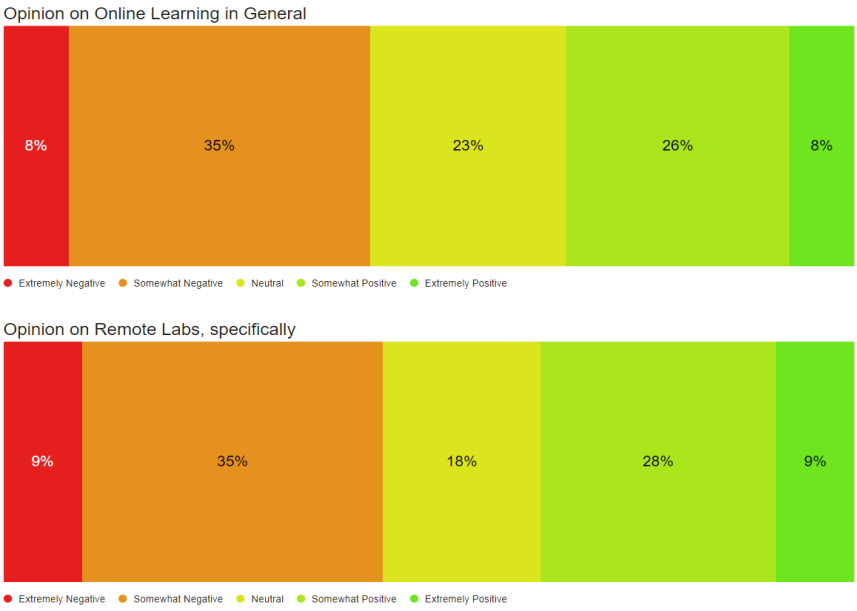

Figure 8. Physics Students' Opinion on Online Classes and Remote Labs

Students in these classes generally responded positively to this new presentation, specifically the ability to learn material and focus on the laboratory based on 21% positive with 38% neutral, and 15% positive with 29% neutral, respectively. However, they responded negatively to the ability to work in a team in these laboratories, as shown by the 69% responding negatively about their ability to work in a team.

Physics students tended to respond more positively to this transition than the overall average, with a score of 2.91 in general and a 2.9 for labs specifically according to Figure 8. They also averaged a score of 2.78 for ability to learn, a 2.46 for ability to focus, and a 2.4 for motivation to complete assignments, which are all above the survey average, seen in Figure 9. Physics Students' Opinion on the Impact of Remote Labs. They responded negatively to ability to work in a team, however, with a score of 2.08. Some other responses from physics students include 69% responding lab objectives were clearly conveyed and 72% responding software presented was easy to use.

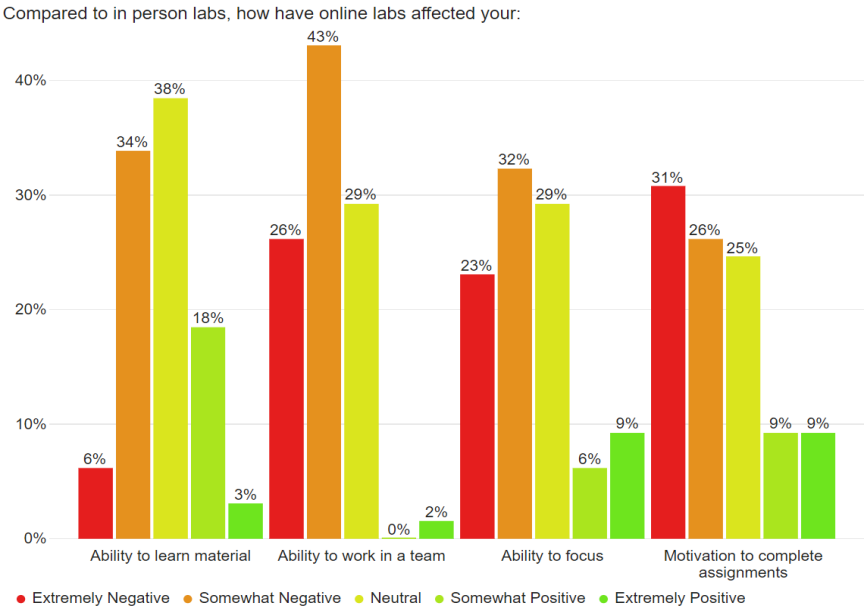

Figure 9. Physics Students' Opinion on the Impact of Remote Labs

3.2.4. Engineering

On campus, WPI's engineering laboratory classes are the staple of our project-based learning curriculum. Many of these classes focus on student-driven projects where faculty serve as both mentor and instructor. Transitioning these unique classes online has proved to be the most

challenging transition of any of the classes that we surveyed. Some classes began using online simulations and videos of how the project is supposed to be done. Others created unique at-home laboratory experiences to try to maintain the element of student run projects. These new presentation methods challenged students and faculty alike in the new remote environment.

Unfortunately, we were not able to interview any engineering professors to discuss their experiences, but we can still use student feedback to develop suggestions for future classes.

The engineering classes selected are very hands-on in their learning objectives, making it difficult to develop a meaningful experience for the students trying to comprehend complex concepts online. Many students look to these engineering classes, specifically the higher-level ones, to teach them skills they will need to know as engineers such as how to use equipment properly, gain understanding about the software they will be using, and how to implement an experiment properly. These specific concepts that are necessary in an engineering education struggle to pull through in a remote learning atmosphere.

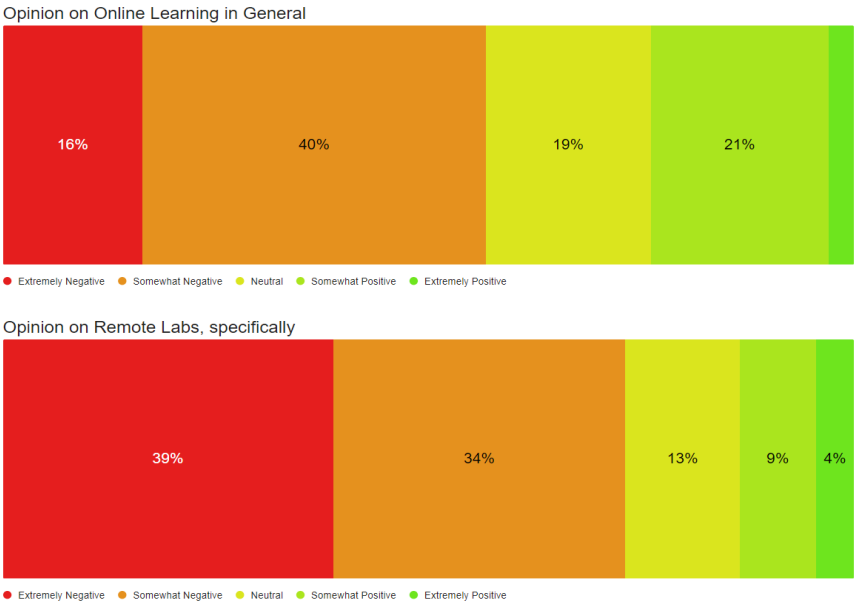

Figure 10. Engineering Students' Opinion on Online Classes and Remote Labs

Students in these classes have struggled more this term, giving an overall higher dissatisfaction from the average, as 56% felt negatively towards online learning and 73% felt negatively towards remote labs, specifically (Figure 10). As noted in Figure 3 above, the overall dissatisfaction was greater in the students who were more experienced with the process and expectation of WPI's courses. As these engineering classes are largely populated with upperclassmen students, the trends for these classes are more negative, as expected. General engineering trends based on ability to learn material, ability to work in a team, ability to focus, and motivation to complete assignments can be seen in Figure 11.

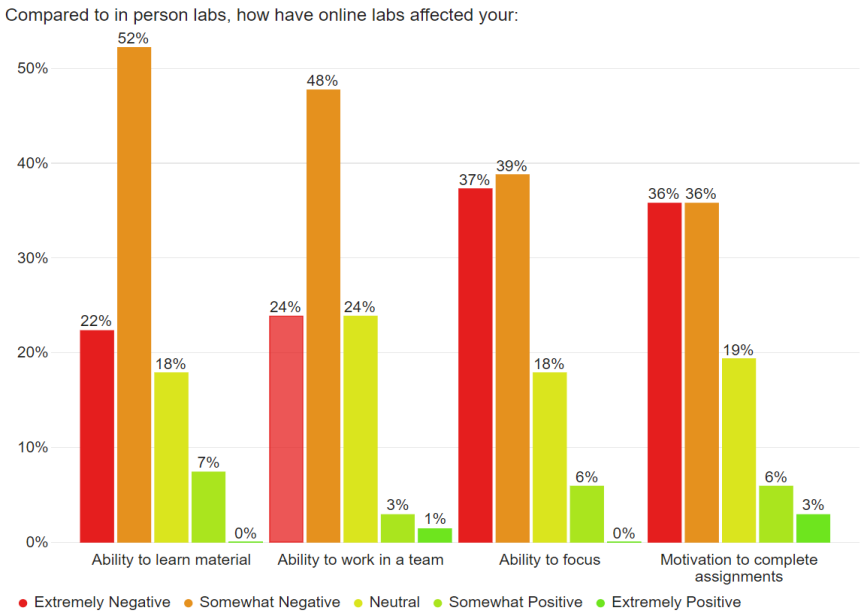

Figure 11. Engineering Students' Opinion on the Impact of Remote Labs

Negative trends continue when looking at introductory-level engineering courses, while they may not be as specific, the students expect more from these classes. These introductory-level classes followed the general trend of engineering students lacking focus and motivation. As this class serves as a beginner class for the rest of the engineering series, many students may have expected more from the class then they got.

An upper-level engineering class is heavily project- and lab-based. This turned out to be one of the more difficult classes to transition to an online setting, as it required more complex ideas and concepts for the students to apply as part of a group. As mentioned throughout other departments, the most difficult piece to the transition to online learning was getting the students to engage with the content and understanding what is expected of them. This is exceptionally difficult when it comes to team collaboration. Teamwork in laboratory classes had some of the worst scores in our survey, and as a teamwork heavy classes, the higher-level engineering classes suffered.

Another higher-level lab we studied was a particularly hands-on course and in the transition to remote learning, decided to use pre-recorded laboratories. Due to the nature of the course, the feedback from the students was generally negative. They were most unhappy with their ability to focus with 76% responding negatively. Their motivation to complete assignments was 72% negative. However, students in this course had a positive response to being able to work in a team, with a class average of 2.4, compared to the survey average of 2.3. Based on qualitative results from students in this class, they are using team projects to make up for the missing hands-on projects normally used for this course. This explains the positive response to teamwork, and the negative response to learning and motivation, since they are missing out on interesting in-person lab activities.

3.2.5. Other Classes

We wanted to take into consideration all courses, so we included a space for people to provide responses for any labs we may have not specifically listed. The presentation of other

classes outside the ones we selected had an even distribution through each delivery method. In the survey, these miscellaneous laboratories did have responses that heavily weighed positively or negative, but these are outliers that we did not look at specifically as the overall was close to the general perspective. Survey results from Other classes can be found in **Error! Reference source not found.**. These respondents allowed us to have a wider scope of responses and were useful to confirm student's overall opinion of remote laboratories.

3.3. Comparative Analysis

We decided to take our data from the three subject areas we surveyed and compare them based on the four areas of performance we investigated. **Error! Reference source not found.** is a graph which depicts this with a scale of 1 to 5 where 1 as extremely negative, 5 is extremely positive, and 3 is neutral. When looking at ability to learn material, chemistry has an average response of 2.84, and physics has an average response of 2.78. Engineering had an average response of 2.1. The survey average for this variable was a 2.54, meaning chemistry and physics had a response which was above average for respondents, but still an overall negative response to the question. We correlate this higher score with chemistry and physics performing laboratory exercises that are more related to concept material taught in lecture, whereas engineering classes have more focus on the procedures learned in lab and less on concepts. This may also be affected by the level of the course, since the chemistry and physics classes are introductory level, as

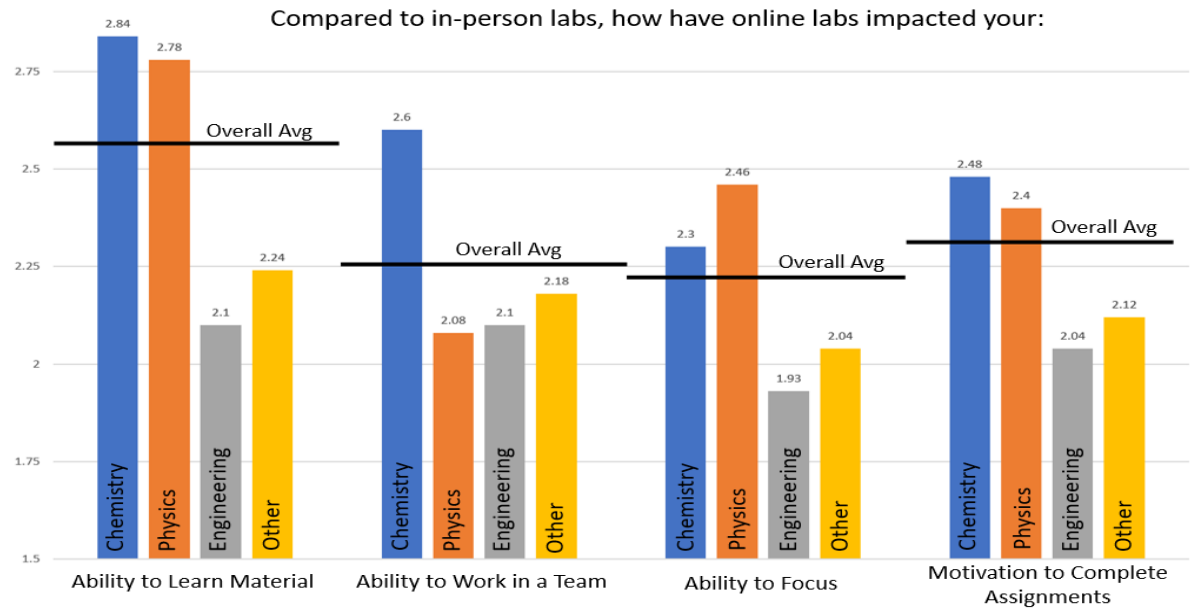

Figure 12. Opinion on the Impact of Remote Labs by Subject Area

opposed to the engineering classes being high level and more major specific. Next, in ability to work in a team, chemistry had a response of 2.6, physics had 2.08, and engineering had 2.1. The survey average for this question was 2.25. the only subject that was above average for this question was chemistry, and we think this is because chemistry has a more group-oriented focus

than the other subject areas. Chemistry also relies heavily on lab groups, so the students in this class have adapted more easily than the other subject areas.

Next is ability to focus, in which chemistry averaged 2.3, physics averaged 2.46, and engineering averaged 1.93. The survey average was a 2.21. In this category, chemistry and physics were both above average for the survey, but physics was noticeably higher than chemistry. This is most likely because physics laboratories use online simulations for their labs. These simulations are much more engaging than a pre-recorded procedure supplemented with given data, which is what many other classes used.

Finally, in motivation to complete assignments, chemistry averaged a 2.48, physics averaged a 2.4, and engineering averaged a 2.04. The survey average for this variable was a 2.31. This puts chemistry and physics just above the average, which is likely because they are introductory courses, meaning that their work is more related to the lecture portion of the course instead of the lab procedures themselves, putting less pressure on the students than a class more focused on procedures. A general trend shown by this data is that chemistry and physics students had a relatively positive response to their performance compared to our overall survey average while engineering classes fell well below the average in every category. However, as all scored remined below a neutral 3, online labs still fell below their in-person counterparts. Despite this fact, we believe chemistry and physics students had an easier time because the chemistry and physics classes we investigated are introductory courses and are typically taken by students of most majors. The engineering classes we investigated are higher level courses and are mostly major specific, meaning that the students taking them are more negatively impacted by the transition online.

4. Conclusion

This project was intended to understand challenges faced by faculty transitioning their material into alternative formats and gather student feedback and perceptions of the remote laboratory classes. The overall opinion of students involved with laboratory classes was negative but there were some laboratories that still succeeded in providing a beneficial experience online, specifically introductory chemistry and physics. Engineering classes struggled the most as many of them have more specific material and more specialized laboratory components. Students wanted to see classes balance the work more consistently through the term; many of them struggled with a higher concentration of work at the beginning of the term. Balancing the amount of work would also allow professors the opportunity to receive feedback from the students and potentially build rapport with the students. Instructors and students alike mentioned that the student-faculty connection is missing in the online format.

Transitioning hands-on laboratory classes to online proved to be a challenge many faculty and students were not expecting. Overall, the situation for many laboratories that did not perform as well seemed analogous to learning to drive a car by watching a simulation of someone else doing it. The hands-on experience for many classes is essential and without experiencing trial and error failure, students miss learning the hard and soft skills that they would get in a true laboratory experience.

4.1. Recommendations

If WPI must use remote learning again in the future, our study indicates that this format has a disproportionally negative impact on higher-level laboratory classes. Through our research, we were able to see that the general physics and chemistry classes, while not ideal online, can be more successful remotely. While WPI develops a plan for returning to campus in August, they should consider putting 3000 and 4000 level engineering lab classes at a higher priority so their students can continue to learn through theory and practice. While we are aware this term had a transition to emergency online teaching much quicker than everyone would have liked, it is evident that students and instructors are doing their best in these trying times. It has become obvious to us, through our research, online classes cannot compare to the actual experience of being in-person with the material. Being as WPI's motto is "theory and practice" we recommend that classes heavily related to the "practice" should take the higher priority in the event of a phased reopening of campus.

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Appendices

Appendix A - Interview Questions

1) What is your name and department? How many years of experience do you have at WPI?
2) What is the biggest challenge you faced in making the transition from in-person to online laboratory classes?
3) How did your department help you to make the transition from in-person to online labs?
4) What resources were most helpful to you (from within WPI or from other sources) in making the transition of your laboratory class to remote learning?
5) What do you think the key differences are between in-person laboratories and remote laboratories?
6) How do you think your students are handling the transition to online laboratories?
7) How do you think remote laboratory experiences affect the amount of material retained by students?
8) Based on your experience this far this term, are there changes you would have made to your plan for the transition to online labs?

Appendix B - Interview Notes

Interview 1

1) What is your name and department? How many years of experience do you have at WPI?
   - Answers omitted for privacy. 2 years at WPI. Chemistry Department.
2) What is the biggest challenge you faced in making the transition from in-person to online laboratory classes?
   - Coming up with ways to compensate for the lack of in-person experience
   - Maintaining the project-based lab experience that was transitioned to two years ago
     - These highlight the trial-and-error laboratory experience
   - Short period of time to create online substitutions
   - Attempted to re-create common errors in labs during video recordings
3) How did your department help you to make the transition from in-person to online labs?
   - Three lab instructors and lab managers meet weekly to discuss logistics and what is effective in practice and what is not
   - Coordinated with lecture professors to ensure more continuity between labs and lecture
4) What resources were most helpful to you (from within WPI or from other sources) in making the transition of your laboratory class to remote learning?
   - Existing videos of others doing labs while waiting for permission to film at WPI
   - Not much existing information about online chemistry labs
   - American Chemical Society (ACS) had web-based resources, not as applicable
5) What do you think the key differences are between in-person laboratories and remote laboratories?
   - Difficulty getting students interaction
   - Lacking communication in online setting
   - In-person, students are addressed as lab groups (3 students or so) so the move online has instructors addressing the class as a whole
6) How do you think your students are handling the transition to online laboratories?
   - Omitted from this interview
7) How do you think remote laboratory experiences affect the amount of material retained by students?
   - Would like to think material retained is equivalent
   - Missing hands-on experimental process and sources of error element of lab
   - Students are still able to learn overarching objectives with given data and processes
   - Actual content is clear, lecture and lab are working together more
8) Based on your experience this far this term, are there changes you would have made to your plan for the transition to online labs?
   - Slow material down – trying to fit too much into 7 weeks

- Lab course was too front loaded in first few weeks of the term – spread out assignments more
- Skills challenges are difficult to translate to online setting
- Splitting into smaller groups using breakout rooms on zoom would've helped earlier in the term
- Incorporate more group work

Interview 2

1) What is your name and department? How many years of experience do you have at WPI?
   - Answers omitted for privacy. 7 years at WPI. Physics Department.
2) What is the biggest challenge you faced in making the transition from in-person to online laboratory classes?
   - Interacting with students and maintaining their attention
   - Engaging students in both content and teaching style
3) How did your department help you to make the transition from in-person to online labs?
   - Using colleagues are resources
   - Responsibility to adapt classes fell on professors
4) What resources were most helpful to you (from within WPI or from other sources) in making the transition of your laboratory class to remote learning?
   - Online simulations from CU Boulder and American Physical Society (APS)
   - Using poll everywhere as tool in classes
5) What do you think the key differences are between in-person laboratories and remote laboratories?
   - All labs are simulations, students are missing the hands-on aspect
   - Students missing connecting laboratories to practical applications and what experiments are capable of achieving
   - Believes that a combination of hands-on and simulation is needed for labs
6) How do you think your students are handling the transition to online laboratories?
   - Students appreciate the magnitude of the situation and that it is out of their control
   - Students are concerned for next year and how things will change due to pandemic
   - Overall very understanding of the situation
7) How do you think remote laboratory experiences affect the amount of material retained by students?
   - No, remote learning makes it easy for students to get distracted
   - Engaging with students is a challenge
   - Students are trying to get by, not as focused on learning the material and its larger concepts
8) Based on your experience this far this term, are there changes you would have made to your plan for the transition to online labs?

- Gotten more comfortable in remote environment throughout the term
- Has more experience interacting with students in a team format, not necessarily lecture style labs
- More prepared to deliver content if this were to happen again, understands potential challenges
- Maintain balance with content, new material, and lecture
- Attempt a more interactive-based approach

Interview 3

1) What is your name and department? How many years of experience do you have at WPI?
   - Answers omitted for privacy. 5 years at WPI. Physics Department.
2) What is the biggest challenge you faced in making the transition from in-person to online laboratory classes?
   - Time consuming to transition labs online to be compatible with new simulations
   - Needed to re-train TAs and PLAs with new labs
   - Simulations were already an aspect of class on campus
   - Home life conflicting with time management
3) How did your department help you to make the transition from in-person to online labs?
   - Brought attention to online resources and other existing independent research
   - Rely on Tas and PLAs to deliver laboratories
4) What resources were most helpful to you (from within WPI or from other sources) in making the transition of your laboratory class to remote learning?
   - Focused on PhET simulation
   - Not much time to research resources
5) What do you think the key differences are between in-person laboratories and remote laboratories?
   - Cannot make individual connections with students, difficult to learn names and faces through the screen when there is no personal interaction
   - Still able to communicate content, but missing physical demonstrations
   - Online is good in this emergency situation, but not the ideal way to be teaching this material
6) How do you think your students are handling the transition to online laboratories?
   - Difficult to interact in person
   - Time zones are a challenge
     - Recording and posting lectures is helpful for students in alternate time zones
   - Students have difficulty asking questions
   - Basic software/internet issues are frustrating
7) How do you think remote laboratory experiences affect the amount of material retained by students?

- Grades are similar, so material is being received
- Nothing fails in simulations – students cannot break equipment
- Still using worksheets and labs as handouts asking for snips from the simulations
- Simulations are connected to the course material, but students can experiment on their own time

8) Based on your experience this far this term, are there changes you would have made to your plan for the transition to online labs?
   - Using the same set up for online E-term classes
   - Simulations are effective – can be used in the future
   - Will have continual improvement each time the course is taught
   - This experience opens opportunity to incorporate new technologies in teaching
   - Could incorporate videos in the future
   - Smartphones could be useful in the future, apps that would take measurements and could be used for at-home experiments

Interview 4

1) What is your name and department? How many years of experience do you have at WPI?
   - Answers omitted for privacy. 2 years at WPI. Chemistry Department.
2) What is the biggest challenge you faced in making the transition from in-person to online laboratory classes?
   - Trying to provide a valuable experience
   - Missing student driven learning and lack of critical thinking
   - Handling mental health in conjunction with teaching
3) How did your department help you to make the transition from in-person to online labs?
   - Department has been supportive
   - Collaborated with lab managers to develop and film curriculum
4) What resources were most helpful to you (from within WPI or from other sources) in making the transition of your laboratory class to remote learning?
   - Looked for outside resources, not much could be found
   - Used Khan academy and similar simulated lab experiences
   - Used silent experiments and spoke over the videos in recorded class
   - Learning from other's presentation styles
5) What do you think the key differences are between in-person laboratories and remote laboratories?
   - Students are not getting any mechanical lab experiences
   - Missing critical thinking aspect of the labs and learning from failures
   - It is hard for students to understand potential errors when they are not committing them
   - Have more time to go through concepts with short lab videos

6) How do you think your students are handling the transition to online laboratories?
   - Student have been doing their best to remain engaged
   - Mentioned that this experience has made them more aware and sympathetic to mental health struggles
   - Had to handle few technical difficulties throughout the term
   - More difficult to engage the class, shifting teaching style to accommodate online
   - Not many students are speaking up in class, using breakout rooms to mitigate
7) How do you think remote laboratory experiences affect the amount of material retained by students?
   - Better chance to solidify material and concepts this term
   - Not many assessments to test amount retained
     - Has seen better written work, not necessarily about the amount of material retained though
   - Not much feedback in class about material retained
   - Letting students annotate is helpful when teaching them
8) Based on your experience this far this term, are there changes you would have made to your plan for the transition to online labs?
   - Learning to present material differently and incorporate more teaching styles
   - Isolating alone and adapting has been a challenge
   - Learning to be more understanding and compassionate with students

Interview 5

1) What is your name and department? How many years of experience do you have at WPI?
   - Answers omitted for privacy. 4 years at WPI. Physics Department.
2) What is the biggest challenge you faced in making the transition from in-person to online laboratory classes?
   - Recording labs and uploading them has made teaching less personable
   - More time for students to pick up details and ask simple questions
   - Software issues have been prevalent
   - Missing general lab announcements and timely information
   - Low engagement with students
3) How did your department help you to make the transition from in-person to online labs?
   - Bi-weekly meetings to share helpful recourses and methods
   - Rolling feedback from Tas and PLAs when testing modified labs
4) What resources were most helpful to you (from within WPI or from other sources) in making the transition of your laboratory class to remote learning?
   - American Association of Physics Teachers (AAPT)
   - PhET simulations

- List server of physics department heads around the country to share best practices and resources

5) What do you think the key differences are between in-person laboratories and remote laboratories?
   - Lack of direct contact for quick questions has made communication harder and longer
   - Higher focus on analysis of data, not the data collection piece
   - Course objectives have shifted to accommodate remote learning
   - Removes experimental aspect of labs
6) How do you think your students are handling the transition to online laboratories?
   - More procedural questions than in-person
   - Communication is difficult – lack student to student communication that typically happens in the lab
     - Gives reflection time on how instructors communicate in-person
7) How do you think remote laboratory experiences affect the amount of material retained by students?
   - "I have no idea"
   - Only using test and lab reports as understanding of material retained
8) Based on your experience this far this term, are there changes you would have made to your plan for the transition to online labs?
   - Reflecting on specific learning outcomes and how better preparation may help in the future
   - Framework for time differences could increase attendance and engagement, specifically for office hours

Interview 6

1) What is your name and department? How many years of experience do you have at WPI?
   - Answers omitted for privacy. 2 years at WPI. Chemistry Department.
2) What is the biggest challenge you faced in making the transition from in-person to online laboratory classes?
   - Has experience teaching online classes, transition was smooth
   - Recording videos took time
   - Zoom helps with its multiple functions
3) How did your department help you to make the transition from in-person to online labs?
   - ATC gave intro to zoom
   - Department has been supportive
4) What resources were most helpful to you (from within WPI or from other sources) in making the transition of your laboratory class to remote learning?
   - No virtual laboratories

5) What do you think the key differences are between in-person laboratories and remote laboratories?
    - Students miss hands-on aspect
    - Missing problem solving and trial-and-error piece of labs that helps solidify understanding
    - Using polls and questions to test understanding – also doubles as ways to engage students
    - Students struggle asking questions in zoom/online format
    - Using discussion boards so students can answer each other's questions
    - More time with recoded lectures to cover questions and concept topics
    - Using breakout rooms to get engagement
6) How do you think your students are handling the transition to online laboratories?
    - If students are struggling it is difficult to tell
    - Students in different time zones has been a challenge – being flexible with deadlines
    - Students missing their peers
7) How do you think remote laboratory experiences affect the amount of material retained by students?
    - Will not know until the end of the course
    - Labs and lectures are more integrated this term due to remote learning
    - Cannot do notebook checks to see how students are interacting and learning the material
8) Based on your experience this far this term, are there changes you would have made to your plan for the transition to online labs?
    - Provide pre-labs with detailed goals and procedures
    - Accommodate smaller groups of students

Appendix C - Survey Questions

1) Informed consent
2) Do you consent to participating in this survey?
    i) Yes/No
3) What is your class year?
    i) 2020/2021/2022/2023
4) What is your major?
    i) List of majors available at WPI
5) How many laboratory classes have you previously taken in each subject?
    i) 0, 1-2, 3-4, 5+
    b) Biology / Biomedical Engineering
    c) Chemistry / Chemical Engineering
    d) Civil / Environmental / Architectural Engineering
    e) Computer Science
    f) Electrical and Computer Engineering
    g) Math
    h) Mechanical / Aerospace Engineering
    i) Physics
    j) Robotic Engineering
    k) Other/Not Listed
6) How would you describe your opinion of the transition to remote learning in general?
    i) 1-5 Likert scale
7) How would you describe your opinion of the transition to remote lab experiences, specifically?
    i) 1-5 Likert scale
8) Compared to in person labs, how have online labs affected your:
    i) Extremely Negative/Somewhat Negative/Neutral/Somewhat Positive/Extremely Positive
    b) Ability to learn material
    c) Ability to work in a team
    d) Ability to focus
    e) Motivation to complete assignments
9) What lab classes are you taking this term?
    i) Checkboxes
    b) CH 1020
    c) PH 1120(1)
    d) PH 1140
    e) ME 1800
    f) ECE 2010
    g) BME 3111

h) ME 3902
i) Other
    i) Text box

10) Who is your lab instructor for [lab selected]?
11) Professor names omitted for anonymity
12) How are your labs for [lab selected] presented?
    i) Checkbox
    b) Live lab procedure
    c) Pre-recorded lab procedures
    d) Online lab simulations
    e) At-home / Household labs
    f) Cancelled
    g) Other
        i) Text box
13) Describe your experience with remote labs for [lab selected]?
    i) Disagree/Somewhat Disagree/Neutral/Somewhat Agree/Agree
    b) Material covered is equivalent to in-person:
    c) Lab objectives are clearly conveyed:
    d) Software/equipment is easy to use:
    e) Time required to complete online lab is equivalent to in-person
14) Do you have any additional comments or suggestion to improve the experience of online labs?
    i) Text box

Appendix D - Survey Results

Comparison of Opinions on Online Classes and Remote Labs

	Q6: How would you desc...e learning in general?				Q7: How would you desc...riences, specifically?			
	Total	Positive	Negative	Neutral	Total	Positive	Negative	Neutral
Positive (Ability to learn material)	17.4%	39.3%	10.1%	5.0%	17.5%	47.1%	3.7%	16.7%
Negative (Ability to learn material)	55.4%	28.6%	68.7%	60.0%	55.7%	15.7%	79.4%	41.7%
Neutral (Ability to learn material)	27.2%	32.1%	21.2%	35.0%	26.8%	37.3%	16.8%	41.7%
Positive (Ability to work in a team)	6.2%	10.7%	4.0%	5.0%	6.2%	11.8%	1.9%	11.1%
Negative (Ability to work in a team)	64.6%	57.1%	69.7%	62.5%	64.4%	47.1%	70.1%	72.2%
Neutral (Ability to work in a team)	29.2%	32.1%	26.3%	32.5%	29.4%	41.2%	28.0%	16.7%
Positive (Ability to focus)	13.3%	30.4%	5.1%	10.0%	13.4%	35.3%	1.9%	16.7%
Negative (Ability to focus)	67.2%	41.1%	81.8%	67.5%	67.5%	41.2%	84.1%	55.6%
Neutral (Ability to focus)	19.5%	28.6%	13.1%	22.5%	19.1%	23.5%	14.0%	27.8%
Positive (Motivation to complete assignments)	16.4%	30.4%	10.1%	12.5%	16.5%	35.3%	7.5%	16.7%
Negative (Motivation to complete assignments)	62.1%	35.7%	76.8%	62.5%	61.9%	25.5%	78.5%	63.9%
Neutral (Motivation to complete assignments)	21.5%	33.9%	13.1%	25.0%	21.6%	39.2%	14.0%	19.4%
Bucketed Overall Sta...y to learn material)	**< 0.00001**				**< 0.00001**			
Bucketed Overall Sta...y to work in a team)	0.37807				**0.01655**			
Bucketed Overall Sta...s (Ability to focus)	**< 0.00001**				**< 0.00001**			
Bucketed Overall Sta...omplete assignments)	**0.00002**				**< 0.00001**			
Average (Ability to learn material)	2.4	2.9	2.2	2.4	2.4	3.1	2.0	2.5
Average (Ability to work in a team)	2.2	2.4	2.1	2.3	2.2	2.5	2.1	2.2
Average (Ability to focus)	2.1	2.7	1.7	2.2	2.1	2.8	1.7	2.3
Average (Motivation to complete assignments)	2.2	2.8	1.8	2.2	2.2	3.0	1.8	2.2
Overall Stat Test of...y to learn material)	**< 0.00001**				**< 0.00001**			
Overall Stat Test of...y to work in a team)	**0.04686**				**0.00571**			
Overall Stat Test of Averages (Ability to focus)	**< 0.00001**				**< 0.00001**			
Overall Stat Test of...omplete assignments)	**< 0.00001**				**< 0.00001**			

Student Comments

Virtual labs are already used on campus for BME3111, so I do not understand why we are not doing those since we can't do it in real life. Watching pre-recorded videos is not the same.
Don’t have them online. You cannot have a hands on class online and get good results.
The online lab I have been has gone extremely badly. Communication has not been clear at all, and I find I usually have to repeatedly email the TAs to get clear instructions on what each lab entails. Additionally, the material we have been covering offers pretty much little to no actual value. The goal of the experiments is usually to gain exposure to handling live rats, and performing experiments with live data capture using LabView. We have had none of that, understandably so! Instead, we are just presented data and make an excel graph about it and call it a day. I completely understand that conducting an actual lab now is impossible. However, communication about the labs has been lacking, and the value gotten from the labs is very little.
Sometimes it’s hard to write lab reports when you haven’t done the lab yourself. Pre-recorded labs don’t allow you to ask questions WHILE the experiment is being conducted, like you could in a classroom. You have to send an email now to ask any questions.
Modifications to lab reports. Some of the BME lab classes I am in right now, not BME 3111, expect the same level lab report as if we were doing them in lab. It is hard to write about something you didn’t do and is hard to apply concepts you learned through a PowerPoint uploaded to canvas versus in person lecture.
State your expectations in full. we are just guessing at what material we need to cover in our lab reports.
I prefer hands on experience to help reinforce learning.
Make sure to have very clear instructions with professors and TA's with clearly outlined office hours for helping with the labs. The most difficult thing for me during this time is the lack of communication and instruction within the labs. I could never tell if I was on the same page with my professor and classmates while completing a lab. Additionally, I think that it would be helpful to create better guidelines and platforms to work with lab partners for online labs. My lab partner could not maintain consistent communication and it was always a struggle to make sure that we were both on the same page and both doing the same work.
I feel that if I saw a video of the professor/ lab TA making the lab set up and was able to see the entire data collection process, it would be easier to understand the lab.
physics labs online while using remote desktop are very confusing and hard to complete

Professors are making the most of the situation. I think the best way to assist would be more detailed lab instructions. Make the format clear. Maybe include an example lab report.
do the whole lab in lab videos so that we actually get the data we need
There needs to be direct instruction on how to perform each lab along with the every code that is requiired!!
Just please talk to professors about only assigning the amount of work/lectures they would have been able to in person. I am so tired.
Explain how to use excel as many of us haven’t had to use it before.
The lab TAs are not very helpful in my experience as they would be in the classroom. When we are on zoom it is hard to get a response in a timely manner.
Online labs are better because they take up less time.
So far physics lab is going well for me.
I hate not being able to recieve in person help which I really learnt from lst term
I think that the online labs get the job done for the most part, but they just can't compare to being able to physically interact with materials.
Because labs are online, the procedures and objectives are way more clear, but they take a lot more time to complete.
We completed more of the skills labs since each recording is only 5-10 minutes long, as opposed to the 2 hours it can take to complete in person. Also, the post labs were a series of questions for skill challenges. The two bigger project experiment's pre and post labs are very similar online as in person
PLEASE don't penalize for late assignments -- it is UNETHICAL!! PERIODT! thank you for your time.
I really don't know how to improve them it's just a sort of unfortunate experience because we won't get the hands on skills that need to be practiced but there is not anything the professors can do to fix that, the only thi g that will fix the labs is being able to have them in person where they are hands on again.
Some ME3902 labs have changed slightly from C-2020, they now require a significant higher time allotment to complete.
It takes so much longer to complete. If we had a buddy system maybe that would help. It's hard to hold myself accountable to spending time on the lab because I'm not physically there and it takes time to set up and clean up but other classes it's faster to get started on. Also it's

harder to ask for help because everything is through video so it's hard for the person I'm asking to see what's wrong and for me to understand what they are saying to fix.
Clearly state all objectives and always provide videos of each lab objective being set up and/or completed
Professor Lagasse is doing a wonderful job! I feel like I am getting more from the labs than I would in person! I do not like the assignments being broken up into smaller assignments because it is difficult to keep track of.
This can't be improved but one big struggle is amazon literally is out of every component i wanted for my open ended project
Be lenient with due dates because everyone is still adjusting and struggling
Getting materials on time has been hard due to slower deliveries. Luckily, my teacher is understanding and accommodating, giving loose deadlines instead of being super strict.
Class bad
There is a lack of instruction on how to complete the labs, I have to rely on YouTube tutorials to learn how to use the materials
Any amount of cooperation or organization from the professor would be awesome (shout-out to the TAs though they're doing an awesome job trying to adapt to this and provide their help despite the Prof not giving them anything)
Doing more reflection about how your prelab procedure is different from what was done in the demonstrations and if your procedure would have been insufficient or still resulted in similar results with similar precision.
conferene should be tied to lab material not additional assignments, so that the understanding and support for the students is really there
I feel like the transition has had a minor negative impact on my ability to focus on the classes but the transition itself was not difficult or a negative experience.
There is almost no way to make the online lab as beneficial to learning as in person would be.
I am just luckily to not be a chemistry major because I do not really know how to use any of the instruments.
The instructors are more available for office hours
Online labs shouldn’t be a thing
This is the second week in a row where we have had four lab assignments due in a week. I have so much lab work that it is like im taking 5 classes, not three (2 classes worth of work

from lab). I do not get good sleep because of the amount of work I have from labs (and other classes). The lab work on top of relatively normal classwork from other classes (other classes have been giving a little extra work), I do not even have time for my "hour of solitary outdoor excersize." However, I do appreciate that these lab assignments take less time than their at-school counterparts, but because most of them are individual assignments rather than the at-school lab groupwork, it ends up being only slightly less work per assignment, with waayyyyyy more assignments than at-school labs.
Reduce the number of individual assignments and focus more on the group work
I think the addition of individual post lab and pre lab work is not very beneficial. It only adds more work that we would have done in groups anyway. My experience with online classes so far has been sitting in front of my computer for hours upon hours, and so I do not think additional work is necessary at a time like this.
I think they are doing as much as they can given the circumstances.
Assignments more spread out, too overwhelming and more work than in person
Not as bad as I expected
While I may not enjoy it, I understand that this is the first time this is being done. I hope that projects like this can better prepare us in case a similar situation arises.
I wish it would be possible for more collaboration since the learning from peers aspect has been taken away.
As much interaction as possible for students positively affects the overall level of understanding. Solely watching prerecorded videos isn't very interesting and is hard to learn from.
I don't think I have suggestions, they really are doing the best they can with the circumstances. I kind of wish my prof held formal office hours so I didn't have to reach out with questions through email, but otherwise, it's going okay.
I would like WPI to ship me a HASS Mini Mill in the future (jk... unless 😉....)
I don't have any ideas
At least have somewhat of a recorded lecture or zoom so we're not doing the labs completely by ourselves. Also good luck with this IQP :)