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Investigating the Effects of Pre-Laboratory Videos with Associated Questions on the Performance and Overall Laboratory Experience of Organic Chemistry Students

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2017 Final Capstone Paper: Investigating the Effects of Pre-Laboratory Videos with Associated Questions on the Performance and Overall Laboratory Experience of Organic Chemistry Students

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Abstract

Introduction: *Background:* Teachers struggle communicating ideas to students (Moreno et al, 2001). One of the aspects of teaching that's most concerning is when students experience cognitive overload: the total effort exerted by working memory to grasp new information (Mayer, et al, 2002). The educational community found that introducing multimedia in learning minimizes cognitive overload (Mayer, et al, 2002). Little research has related to undergraduate chemistry classes, specifically the relationship between organic chemistry pre-laboratory multimedia and student learning. *Purpose:* The purpose of this capstone is to investigate the subjective efficacy of integrating pre-laboratory videos for lab preparation in an undergraduate organic chemistry laboratory setting. *Research Question*s: Do organic chemistry students find pre-laboratory videos with corresponding questions to be useful in a laboratory setting? Methods: All undergraduate students enrolled in Organic Chemistry II who attended class the day the investigator arrived to class listened to a verbal announcement and were provided an informed consent form. Students were categorized into four laboratory sections. Sections A and B were given the first pre-lab video with 5 pre-lab questions for the first lab experiment, while sections C and E didn't receive anything. For the second consecutive lab experiment, sections C and E were given the second pre-lab video with 5 pre-lab questions while sections A and B didn't receive anything. Consenting students were then provided an anonymous survey asking for their subjective feedback on how effective they thought the MM treatment was. Collected data was organized and analyzed by looking at the number and percentage of students who responded "Highly agree, Agree, Neutral, Disagree, Highly Disagree" to the survey questions. Results: The data shows that 34 of the 44 students enrolled in Organic Chemistry II (77%) consented to take part in the study, and 24 students responded to the survey, representing 54.5% of the total population and 70.6% of the consenting students. 4-11 students answered “Highly Agree” to questions in the survey, 10-16 students answered “Agree”, 1-7 students answered “Neutral”, and 1 student answered “Disagree”. The average scores of the questions ranged from 4-4.39, with the standard deviation ranging from 0.59-0.83. Discussion: The data supported and added to past research in that multimedia is effective using narration, text, pictures, and videos together, using an appropriate level of educational and entertaining components can be effective in a learning environment, multimedia is helpful with instructional type tasks and in science environments, students liked the videos/question combinations, and multimedia seems to lower cognitive load. This research suggests multimedia should be used in teaching/academia, and undergraduate science students benefit from using multimedia. Limitations included time constraints, as student academic performance wasn’t collected, students may have received videos on procedures they’re already familiar with, the survey wasn’t validated, and cognitive load wasn’t directly measured. Conclusion: Science undergraduate level educators are encouraged to utilize MM in their teaching methods. Future research should focus on extending the time frame of the study, and studying the effects multimedia plays on students in different subjects and in different levels of classes.

Literature Review/Introduction

Background:

Learning is all about gaining and acquiring knowledge, refining skills, enhancing performance, and improving one's understanding of a specific topic (Nazir, 2012). In order to more easily achieve these feats, instructors are called upon to teach students these ideas and concepts. However, all teachers have their own way of teaching while students have their own way of learning, the combination of which causes teachers of numerous subjects to struggle to communicate ideas and concepts to students (Moreno et al, 2001). In addition to this, all students come into a new class with their own unique backgrounds and experiences which dictate how well and how quickly they understand subject material (Alhassan et al, 2012). Some students require visual presentations, hands on activities, and one-on-one attention in order to better grasp a certain idea (Dalacosta et al, 2008), while others need only be told once. These differences between students' learning styles makes the learning process very difficult (Alhassan et al, 2012). Due to this, researchers have been trying to better understand the learning process by discovering certain theories that could shed light on how to make learning more effective.

Relevant theories in learning:

Many researchers have explored ways to make learning more effective. One recent theory which helps to explain how to more appropriately approach teaching is Chandler and Sweller's Cognitive Load Theory of learning (Haryono, 2016). A part of this theory relates to the idea that everyone learns a little differently from one another. This of course then dictates how students react to newly exposed material. Chandler and Sweller's theory suggests that instructional messages and new information must be presented to students in a way that minimizes their exposure to cognitive overload, more specifically extraneous cognitive overload. Extraneous cognitive overload refers to the amount of total effort exerted and used by one's working memory to 'digest' extraneous new information (Mayer, et al, 2002). When someone is exposed to cognitive load, three types can be generated: Intrinsic, Extraneous, and Germane cognitive load (Zhang et al, 2015). Intrinsic cognition is evident when the content becomes more difficult, thus increasing cognitive overload (Zhang et al, 2015). Extraneous cognition is mainly affected by the presentation of teaching materials, the design of teaching materials, and teaching activities themselves as supposed to the content (Zhang et al, 2015). Germane Cognition is the opposite from the other two and aims to prevent cognitive overload by enhancing learning by offering learners with information, requesting learners with learning activities, and guiding learners to focus on learning content (Zhang et al, 2015). The final aspect of the cognitive overload theory is the thought that the cognitive capacity in one's working memory is limited, meaning that if learning a task requires too much capacity, the process of learning will become more demanding (Haryono, 2016).

During a typical lecture where students are introduced to a lot of new words and concepts rather than being visually shown at a slower pace, their minds are constantly and very quickly trying to internalize each piece of information, visualizing and contextualizing it as they attempt to reflect on what's being said. When this occurs at a very swift pace, the brain has difficulty keeping up, therefore losing key pieces of information that very much so impairs the learning process. Not only that, but overexposure to cognitive overload may cause students to have a negative outlook on the subject matter, leading to a poorer learning experience, frustration and burning them out, which then can cause students to giving up (Arguel, 2008).

There are many other ways in which cognitive overload can be heightened, including presenting too much information at the same time, too many visual aids, unnecessary dynamic presentations, information in succession too quickly, distracting the learner with unrelated topics, explaining material inadequately, being monotone and mundane, and even using confusing supplemental material that makes the topic more difficult to grasp (Arguel, 2008). Ways to avoid extraneous cognitive overload include simply avoiding methods that increase cognitive strain, introducing helpful supplemental material, and keeping up with the technological times so that teaching a subject matter can be as effective to the intended audience as possible (Gilakjani, 2012). By utilizing these ways that engage students, rather than turning them off, meaningful learning occurs. This allows learners to engage in what is called active cognitive processing, causing them to pay better attention to relevant incoming information (Gilakjani, 2012).

Another theory that has been explored when understanding how to conduct effective teaching by means of avoiding extraneous stress on the learner's mind is Paivio's Two Codes Theory. This theory relates to the idea that the information processing system in the human's brain consists of the auditory, verbal, and visual or image tracts (Haryono, 2016). This means that in order for the human brain to process information properly without overloading their mind with cognitive stress, information must be presented in a manner than tends to these different tracts. Not only that, but there must be a sense of balance between the auditory, verbal, and visual components in order to engage the students and heighten their learning experience (Atkinson, 2002).

Now that these two theories have been explored, it is clear there is a distinct connection between the integration of auditory, verbal, and visual components with learning and how effective that is in the learning process. Again, it appears that these assist the human's information processing system by minimizing cognitive overload. Through much research, it is evident that the most widely used and effective mode of communication and teaching that utilizes all of these components is multimedia. However, what is the exact definition of multimedia?

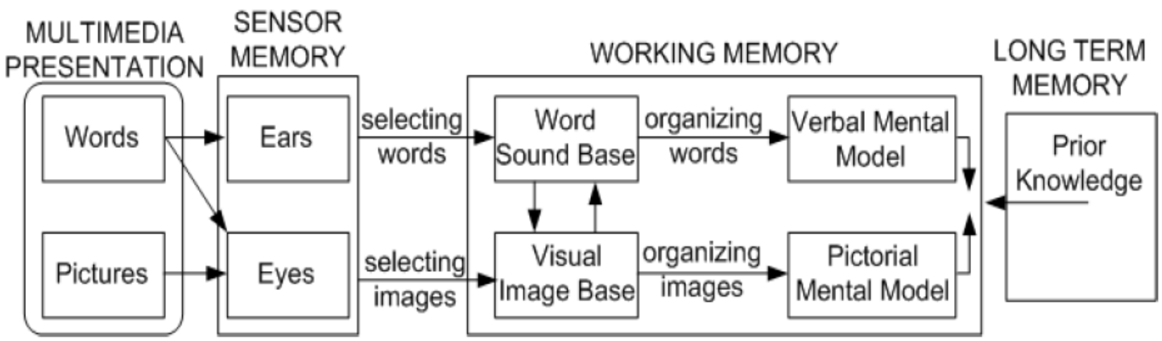
Definition of multimedia:

According to Nazir et al (2012) and Gilakjani et al (2012), multimedia is a medium of communication which provides a complex multi-sensory experience when exploring something through the use of text, graphics, images, audio, and video. With the use of multimedia that contains these different components, especially words and pictures, learning is enhanced as the student can dedicate their limited cognitive resources to processing important information which can then be used for problem solving (Dunsworth et al, 2005). However, how is this possible? What is exactly going on that allows these multimedia components to be so effective?

Multimedia and memory:

Figure 1 demonstrates the relationship between visual and auditory aspects of multimedia and learning, clarifying how these different components of multimedia affect sensory memory, working memory, and long term memory (Ljubojevic et al, 2014, pg. 277).

Figure 1: The Cognitive Theory of Multimedia Learning (Mayer, 2001).



This flow chart clearly shows how words and pictures interact with the eyes and ears to help the brain sift through an influx of information to retain the most important words, images and ideas that will then work themselves into working memory. At this stage in the learning process, this incoming information is then organized to create both a verbal and pictorial model. These can then come together to create a strong "video" feed that then interact with that person's prior knowledge, which has been obtained from past experiences, allowing the student to better contextualize this information. It is this interaction that helps a student to compartmentalize the info and store it into long term memory without causing cognitive overload or stress.

Multimedia and teaching:

There have also been many benefits to using multimedia for teachers. Lightbody et al (2006) and Priyambodo et al (2014) say the main purpose of Multimedia Based Learning (MBL) is creating a better teaching and learning process, one that is faster and fosters an independent learning attitude. By speeding up the teaching process while also making it more effective, students have the ability to learn more and become exposed to much more material in a significantly shorter period of time than would have been possible using a typical lecture teaching style. Additionally, by fostering an independent learning attitude promotes a type of learning that goes far and away beyond the classroom and can be one of the most useful tools in everyday life. Together, these help make the teacher's job easier.

In addition to this, Nazir, et al (2012) state that through MBL, teachers can deliver more innovative materials to motivate students to study harder. This creativity helps to show students ways to apply the topic in ways they never thought possible, allows them to think outside the box, and encourages them to become more engaged in the learning process. In addition to this, delivering teaching materials through MBL would clearly be much more effective than just the teacher delivering a lecture on course material (Osamah, et al, 2010), as it will allow the teacher's to have the students' attention for a longer period of time.

With all of this being said, it is clear in theory that the introduction of multimedia to learning is a great thing for both the student and the instructor. However, does it work in the real world? There are many things that theoretically should work but unfortunately do not perform in reality. Other questions that arise are, what kind of multimedia has been used in the classroom environment that has been researched? What are some of the ways in which they have and haven't worked? What is the exact intended population that has been targeted? These are all questions that must be answered, and can only be done so through a thorough review of recent literature.

Literature search identification:

An extremely thorough literature search was conducted using Merrimack College's

McQuade Library search engine to look for research articles conducted in this field. Articles were refined by narrowing the dates from 2000-present, choosing the 'available in library collection' option, and having access only to academic articles written in the English language. Examples of words searched to narrow down article results in this literature review include multimedia teaching, multimedia learning, effects of multimedia learning, multimedia: chemistry, multimedia: chemistry: pre-laboratory, multimedia: organic chemistry, and multimedia: organic chemistry: pre-laboratory.

Research articles analysis:

From this literature research, a total of 23 articles were analyzed, of which 16 were most pertinent. These 16 articles were analyzed by categorizing and looking at their similarities and differences in three different main categories: What are the articles investigating, what they did to reach their research objectives, and what did they find.

After having read all of the articles, it is clear that all of the articles looked at how multimedia (MM) effects teaching as well as learning, making this the largest commonality among all the research articles. Ljubojevic et al (2014) were the only researchers who investigated how the introduction of MM at different times during the lecture (before, during, or after) affected the learning process. They were also the only ones to investigate the difference between the efficacies of teaching using entertaining MM vs. educational MM. Additionally, Mechling et al were the only ones who investigated how good MM is in aiding independent pedestrian travel through unfamiliar territory. Although one may not associate navigation and pedestrian travel with learning, they certainly are related. When looked at more in depth, giving a person a procedure directing them to solve a simple algebra problem or how to build a simple

Lego structure is not much different than giving a person directions on how to go from point A to point B. In either case, a set of instructions are provided from one person to the other via some form of medium to help solve a puzzle or problem. It is this simple yet discrete comparison that makes this an interesting way to look at how versatile MM can be when it comes to learning new material.

Through research, it was found that introducing MM half way through a lecture was most effective when compared to introducing MM during other times of the lecture. This was evident when comparing the average number of questions answered correctly. Out of 18 total questions, those who were exposed to an educational video during the beginning of lecture answered 14 correct, compared to 15 when an educational video was presented during the middle of lecture, and 12 when an educational video was presented at the end of lecture (Ljubojevic et al, 2014). They also found that educational videos were more effective than entertaining videos when it came to student performance, even though both modes of MM were more effective than lecture without any MM aid. This was also evident by comparing the average number of questions answered correctly. Students who did not receive any videos answered 12 out of 18 questions correctly compared to 13 with an entertaining video in the beginning of lecture, 14 with an entertaining video in the middle of lecture, and 12 at the end of lecture (Ljubojevic et al, 2014). Finally, using MM as an aid for independent pedestrian travel was found to be very effective, especially with the use of a hand-held Personal Digital Assistant (PDA). This was concluded when the researchers found that pedestrians were able to find between 70% - 80% of certain landmarks and final destinations with as little as one searching session compared to 0% with 3 sessions (Mechling et al, 2011).

With this being said, it is also known through much research that using a combination of videos, still images, texts, and narrations were most effective when it came to learning new material. Research has shown that the MM with narration + multiple agent outperforms standalone text, with students answering 17.65 questions correctly vs. 14.71, which is a 20% increase (Dunsworth et al, 2007). It has also been found that there is a strong negative correlation between the introduction of MM in learning and cognitive load, with β values of -1.697 for internal cognition and -1.833 for external cognition. This means that the use of additional outside sources of MM in learning decreased cognitive load and stress in students, making them more capable to learn more material without being mentally overwhelmed. Additionally, it was also clear that introducing MM aids with too many stimulating agents, such as verbal, auditory and visual stimuli also hindered the students' ability to learn because it overwhelmed the students' cognitive abilities (Mayer et al, 2002). Again, this means that there needs to be a balance between the different MM aids in order for students to truly benefit.

These concrete conclusions have been determined through multiple areas of research in this field that have been thoroughly investigated including, but not limited to: comparing various forms of MM to lecture and how effective that is on learning (Dalacosta et al, 2008; Priyambodo et al, 2014; & Zhang et al, 2016), finding a correlation between using MM in a classroom and reducing cognitive load (Mayer et al, 2002; Moreno et al, 2000; & Zhang et al, 2016), finding the difference in efficacy of different modes of MM on learning (Atkinson et al, 2001, Dunsworth et al, 2007; Harskamp et al, 2007; Haryono et al, 2016; Ljubojevic et al, 2014; Mayer et al, 2002; Moreno et al, 2000; Shi-Jer et al, 2012; Supasorn et al, 2008; Wong et al, 2009), and the effects of narration coupled with text in MM on learning (Dunsworth et al, 2007; Harskamp et al, 2007; Ljubojevic et al, 2014; Supasorn et al, 2008).

In addition to this, many other comparisons were made in the articles that compared the efficacy of different modes of MM on learning to each other(Atkinson et al, 2001; Dunsworth et al, 2007); Harskamp et al, 2007; Haryono et al, 2016; Ljubojevic et al, 2014; Mayer et al, 2002; Moreno et al, 2000; Shi-Jer et al, 2012; Supasorn et al, 2008; Wong et al, 2009), since each research article was set in a different research environment which had slightly different goals. Some comparisons looked at the efficacy of different MM learning programs such as "Rosetta stone" (Japanese) vs. "Tell Me More Japanese" (Zhang et al, 2016), while others looked at MM with narration only, on screen text only, narration plus an agent vs on screen text, and narration plus an agent vs just narration (Dunsworth et al, 2007). With this being said, it is clear that the forms of MM which reduced cognitive overload the most and boosted student performance the best were those that used some combination of interactive videos, vivid pictures, beneficial text, and meaningful narration.

Through this thorough literature review, it is evident that there is still a relatively limited amount of research in this field when it comes to investigating the importance of MM and how it effects different aspects of learning. Research still needs to be conducted to analyze the effects of MM in all different kinds of settings that include but aren't limited to different undergraduate and graduate science classes, doctorate classes, pre-school, different museums worldwide, across different cultures, and even in everyday activities such as cooking and 'do it yourself' activities. Not only that, but there are some aspects to these studies that are not of interest for this research project. For example, Mechling et al's target population was high school students with moderate mental disabilities, which is a group of individuals that will not be of interest in this capstone project. In addition to these observations, Ljubojevic et al did not present videos that were both educational and entertaining, meaning it is still unclear as to how effective MM can be in learning when it is both educational and entertaining. Ljubojevic et al also did not look into presenting videos to students prior to coming to class, which is something that would be interesting, as this would theoretically help students be prepared for class. These are observations that would be taken into consideration when performing this capstone project.

In terms of research environments, 7 of the 16 articles were set in some sort of science type setting, whether it was general science classes for elementary school, anatomy, computer science, biology, or chemistry (Dalacoasta et al, 2008; Harskamp et al, 2007; Ljubojevic et al, 2014; Priyambodo et al, 2014; Shi-Jer et al, 2012; Supasorn et al, 2008; Wong et al, 2009). The settings of these research articles included middle school, high school, undergraduate classes, and even a chemistry laboratory. Since all of these articles were set in different research environments, they tended to different audiences and age groups. Despite their vast differences in settings, they all seemed to come to the same conclusion, the idea that integrating MM in a learning environment does help students increase academic performance while simultaneously decreasing cognitive overload. Only one article (Moreno et al, 2001) had a different conclusion, which found that the presence of multimedia agents had no effects on students' learning, although it did not hurt students' performance. However, when looked at more closely, it is clear that their research involved the incorporation of MM and visual aids that were not exactly appropriate for the intended application, meaning that their findings only reflected the outcome of the students' performance rather than the content of the visual aids provided to the students. This should be taken into account when considering methods for incorporating MM.

It is also important to analyze what the researchers did to reach these conclusions, as this will provide valuable information regarding what would be the best course of action when it comes to carrying out this capstone project. One of the articles (Gilakjani et al, 2012) was a meta-analysis, meaning that they drew conclusions based off of what other researchers had discovered. Another article changed when the videos were presented to the students (Ljubojevic et al, 2014), as previously discussed. Two articles (Dunsworth et al, 2007 & Ljubojevic et al) used only post subjective and objective assessments without any pre-test, which may not be as useful as using both pre and post-tests since there is no baseline data. 6 of the articles (Harskamp et al, 2007; Mayer et al, 2002; Priyambodo et al, 2014; Shi-Jer et al, 2012; Supasorn et al, 2008; & Zhang et al, 2016) used both pre and post objective tests, which was appropriate since they were interested in how the MM changed student performance. Also, 4 of the articles (Haryono et al, 2016; Harskamp et al, 2007; Mechling et al, 2011; & Wong et al, 2009) used only a post objective assessment, which again is not an ideal situation since they didn't have baseline data to see not only how different groups compared to each other, but also how much did they change as a result of introducing MM to them. In terms of the study design itself, 6 articles used randomization (Dunsworth et al, 2007; Harskamp et al, 2007; Priyambodo et al, 2014; Shi-Jer et al, 2012; Supasorn et al, 2008; Wong et al, 2009), which helps the researchers create better data, 7 used 2x2 designs comparing experimental groups to control groups (Dalacosta et al, 2008; Harskamp et al, 2007; Haryono et al, 2016; Mayer et al, 2002; Supasorn et al, 2008; Wong et al, 2009; Zhang et al, 2016), which allows researchers to compare and contrast groups to each other with different treatments, and 2 articles compared a single independent variable to several variations of MM interventions (Dunsworth et al, 2007 & Priyambodo et al, 2014), allowing the researchers to see how different variations of MM alter student performance.

With all this being said, it is clear from the literature that there is a lack of research looking at the effects of MM on learning the hard sciences, particularly in an organic chemistry laboratory at the undergraduate level, which is the audience and environment of interest for this capstone project.

After reviewing the literature, there was only one article (Shi-Jer et al, 2012) which took place in an organic chemistry laboratory. The purpose of this particular study was to explore the effects of three different forms of multimedia teaching materials (static pictures, video, and animation) on the achievements and attitudes of 54 eighth-grade students in Pingtung County, Taiwan in an organic chemistry laboratory. The researchers had three randomized groups, the first of which was supplemented with videos, the second of which was provided with animations, and the last of which was given just static pictures. All three groups took a pre-test then proceeded through their first experiment, took their first post test, went through a second experiment, and then took their second and final post-test. The researchers found that the integration of videos alone was more effective than the use of still images alone in terms of operating equipment, technical operation, and experimental procedures. The students indicated that video presentations best assisted them in understanding the experiments. Finally, their statistical analysis tests revealed that chemistry test grades of the video group and animation group were higher than those of the static picture group, presenting a moderate correlation between type of multimedia teaching material and test scores. Unfortunately, this article took place in a junior high school rather than at the undergraduate level, which isn't the target audience of interest for this capstone project. This means that there is a severe lack of research in this capstone project's environment and population of interest.

Additionally, none of the articles analyzed looked into how MM presented prior to entering class would affect student performance as well as cognitive stress. Also, some articles changed the entire teaching style of the class rather than just changing one variable to see how that effects the research results, which makes it difficult to reach certain conclusions. All of this criticism leads into the importance and necessities for carrying out this capstone in the identified setting

Need/Rationale:

It is clear from this literature review that very few research has investigated the effects of MM on undergraduate student learning, very little to no research has been done in laboratory settings, and even fewer research has been conducted to look at the subject of organic chemistry. Additionally, no research has analyzed how assigned pre-laboratory MM that is both entertaining and educational with narration, purposeful gestures, text, and still images with supplementary pre-laboratory questions affect students' subjective confidence, motivation and overall cognitive overload. These observations are important because, Merrimack College's organic chemistry professor has been teaching organic chemistry for the past 5 years and has been looking for new and innovative ways to better engage, prepare, as well as reduce the stress of undergraduate organic chemistry students, especially in the laboratory setting. He has always been interested in making pre-laboratory videos to help with these issues and felt these videos could be a great addition to the fields of education and organic chemistry. The creation of these pre-lab videos and the analysis of students' subjective feedback about the supplemental MM material in this research project would connect the educational field to organic chemistry, both helping students in the laboratory environment as well as adding significant information to both fields of research.

Research Objectives

The purpose of this capstone is to investigate the subjective efficacy of integrating pre-laboratory videos for lab preparation in an undergraduate organic chemistry laboratory setting. The research question for this capstone is: Do organic chemistry students find pre-laboratory videos with corresponding questions to be useful in a laboratory setting?

Methodology

Research Design: Consenting students were exposed to a post-test design. The consenting students were systematically divided into two groups and provided the treatment, or the pre-lab video and quiz combination, then asked to fill out a survey. This supplementary survey collected non-experimental quantitative data. The quantitative data collected from this post-test design research project was then analyzed.

Participants: The population of this study was all Organic Chemistry II students, a total of 44. All students in organic chemistry II who attended class the day the investigator arrived listened to a verbal announcement and were asked to take part in this study by signing a consent form. This means that this sample is an example of consensus sampling. The participants, or the final sample, in this study were 34 undergraduate organic chemistry students who consented to be part of the research. These 34 students represent 77% of the total population. Of these 34 students, 24 responded to the post-treatment survey. This means that the sample size of 24 students represents 54.5% of the total population and 70.6% of the students who consented to take part of the study.

<u>Instruments and Measurements</u>: The survey that was created to collect information regarding the students' subjective feedback regarding the videos' efficacy is presented in Appendix A. The survey that was created utilized similar assessment questions used by Ljubojevic et al (2014) such as "Did you find the quality of presenting a lecture sufficient?" and "Were you able to maintain the attention level during the session?" (Ljubojevic et al, 2014, 281). The survey was delivered to students via Google Forms. Responses to each question was presented to the investigator through Google Forms as bar charts, showing the number and percentage of students who responded Highly agree, Agree, Neutral, Disagree, and Highly Disagree. These values were then transferred to tables to also create pie charts, just so there are more visual aids to help contextualize and analyze the data.

<u>Procedures</u>: After having met with Merrimack College's organic chemistry professor, a work flow plan was created to help organize the individual steps of the process as well as to help keep the project running on time. Simultaneously, this project was approved by Merrimack's IRB. During this process, organic chemistry videos and questions were made, with the consultation of Merrimack College's organic chemistry professor, using an iPad, iMovie, Google Docs, the application 'Explain Everything', and a precision stylus pen. After having gotten IRB approval, and several videos and questions were made, the investigator went to the two organic chemistry classes to obtain student consent via paper consent. Only the students who consented to be part of the study would take part in this research.

At this point, an email with the assigned pre-lab video and 5 questions was sent to students who consented to be part of the study in two of the four laboratory sections for the first week of the study. Sections A and B were given these first pre-lab video with 5 pre-lab questions for the first lab experiment, while sections C and E received no videos or questions.

After this first week had passed, another email with the second assigned pre-lab video with 5 questions was sent to sections C and E for the second week of the study. Sections A and B received no videos or questions. Again, these videos were a requirement of the course and were mandatory for the students to watch in preparation for lab.

During the following week, students who responded that they would like to be part of the study were also provided an invite to respond to an anonymous survey asking for their feedback on what they thought of the videos and how effective they were to the laboratory experience. After having provided the students 1 week to respond to the survey, the data was collected. Upon completion of data collection, data analysis was possible.

No quantitative data regarding the students' academic performance on laboratory reports was collected due to time constraints.

The following figure presents the timeline of the events that took place during this procedure:

Figure 2: Events that took place during Procedure

Order	**Event**
1.	Work flow plan created
2.	Pre-lab videos and questions were made while obtaining IRB

	approval
3.	Investigator attended both organic chemistry sections to obtain student approval. Verbal announcement and consent forms were provided.
4.	1st email sent to students who consented to take part in the study in sections A & B with 1st pre-lab video/quiz combo (1st week of study)
5.	2nd email sent to students who consented to take part in the study in sections C & E with 2nd pre-lab video/quiz combo (2nd week of study).
6.	A survey with 9 questions asking for subjective feedback was sent to students who consented to take part in the study in (3rd week of study).
7.	Data collection and analysis was possible after survey was distributed. 1 week was provided to students to respond to survey.

This figure presents the events that took place during the procedure in this capstone project.

Data Analysis: Information regarding subjective feedback of the videos from the students was collected via the Likert scale in the survey using Google Forms. The scale was ranked from 1-5 with corresponding responses of ‘Highly disagree’ to ‘Highly agree’, respectively. The data was first analyzed by looking at the number of students who responded to the survey as well as to each individual question. Then, the data of the students' responses was transformed into bar charts, presenting the number and percentage of students who responded either Highly Agree, Agree, Neutral, Disagree, or Highly Disagree to each question. These figures were then categorized in a table then used to create pie charts to help further contextualize the information for analysis. The data was then analyzed by looking at the percentage of students who responded either Highly Agree, Agree, Neutral, Disagree, or Highly Disagree. Finally, the average and standard deviation of the ratings for each question were calculate and analyzed to help determine the overall view the students had on each question and how consistent they were in their responses. These responses were not analyzed by section, but by the class as a whole, since all of the students were exposed to similar treatments.

Results

After having conducted this study, the following results were collected:

The following table presents the number of students who responded Highly Agree, Agree, Neutral, Disagree, or Highly Disagree to the survey questions that are presented in Appendix A.

Figure 3: Number & Percentage of students who answered Highly Agree, Agree, Neutral, Disagree, or Highly Disagree to Survey Questions

Questions	Number of Responses per category				
	Highly Agree	Agree	Neutral	Disagree	Highly Disagree

Were the pre-lab videos clear, informative and useful?	11 (47.8%)	11 (47.8%)	1 (4.3%)	0 (0%)	0 (0%)
Did the pre-lab videos relate well to material taught and methods used in that corresponding lab experiment?	11 (47.8%)	10 (43.5%)	2 (8.7%)	0 (0%)	0 (0%)
Were the pre-lab questions helpful?	7 (30.4%)	11 (47.8%)	5 (21.7%)	1 (4.3%)	0 (0%)
Did the pre-ab questions correspond well with the provided video?	9 (39.1%)	11 (56.5%)	1 (4.3%)	0 (0%)	0 (0%)
Were you more engaged to learn	6 (26.1%)	12 (52.2%)	4 (17.4%)	1 (4.3%)	0 (0%)

while watching the videos?					
Were you more motivated to learn and go to lab while watching the videos?	7 (30.4%)	10 (43.5%)	7 (30.4%)	0 (0%)	0 (0%)
Were you more prepared for laboratory experiments with the aid of these videos?	6 (26.1%)	12 (52.2%)	5 (21.7%)	0 (0%)	0 (0%)
Were you more confident when conducting lab experiments?	4 (17.4%)	15 (65.2%)	4 (17.4%)	0 (0%)	0 (0%)
Would you like to have more pre-lab video/pre-lab question combinations for	6 (26.1%)	16 (69.6%)	1 (4.3%)	1 (4.3%)	0 (0%)

future labs?					

Figure 3 presents the questions in the post treatment survey as well as the number and percentage of students who responded Highly Agree, Agree, Neutral, Disagree, or Highly Disagree to the survey questions. These numbers show that 4-11 students (17.4-47.8%) answered "Highly Agree" to questions in the survey, 10-16 students (43.5-69.6%) answered "Agree", 1-7 students (4.3-30.4%) answered "Neutral", 1 student (4.3%) answered "Disagree", and no student responded "Highly Disagree".

From these values, it was also clear there were some discrepancies in the number of students who answered each question. From the data that was collected, it became apparent that all of the 24 respondents answered to questions 3, 6, and 9, 23 of the respondents answered to questions 1, 2, 5, 7, and 8, and 21 of the respondents answered to question 4.

These numbers are important to present, however it is important to also present these numbers in visual format to help improve and complete the presentation of the data. Figures 4-12 present the data in figure 3 in percentage format for questions 1-9 from the survey.

Figure 4: Responses of Students to Survey Question 1

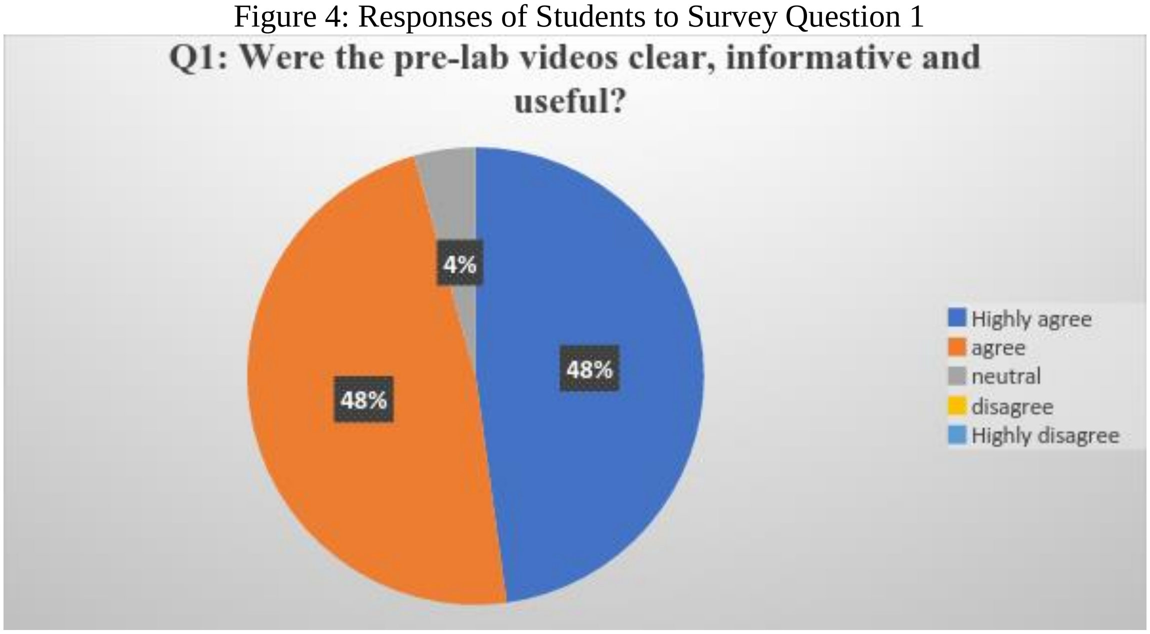


Figure 4 is a pie chart presenting the percentages of students who responded Highly Agree, Agree, Neutral, Disagree, or Highly Disagree to survey question 1. This shows that the majority of the student's points of view at least agree with the question.

Figure 5: Responses of Students to Survey Question 2

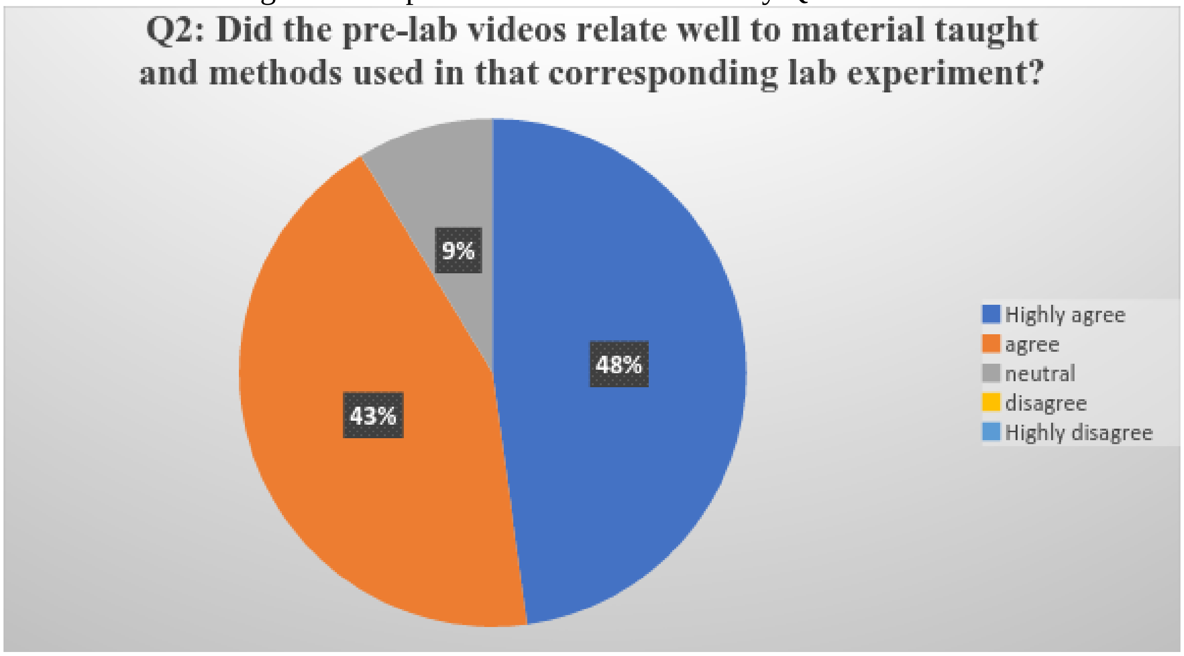


Figure 5 is a pie chart presenting the percentages of students who responded Highly Agree, Agree, Neutral, Disagree, or Highly Disagree to survey question 2. This shows that the majority of the student's points of view at least agree with the question.

Figure 6: Responses of Students to Survey Question 3

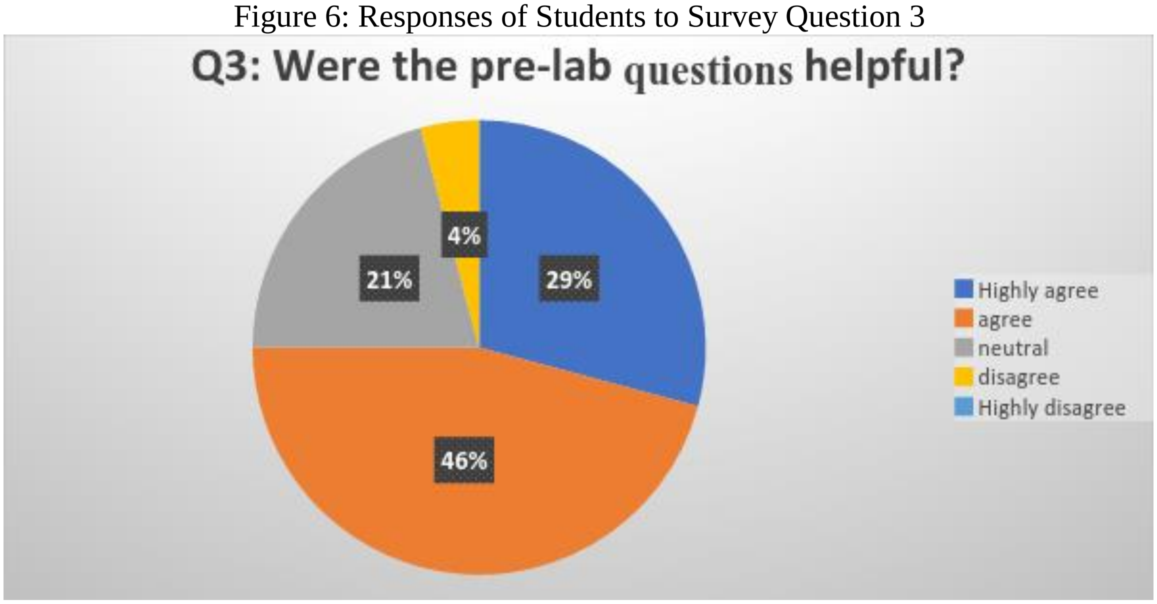


Figure 6 is a pie chart presenting the percentages of students who responded Highly Agree, Agree, Neutral, Disagree, or Highly Disagree to survey question 3. This shows that the majority of the student's points of view at least agree with the question.

Figure 7: Responses of Students to Survey Question 4

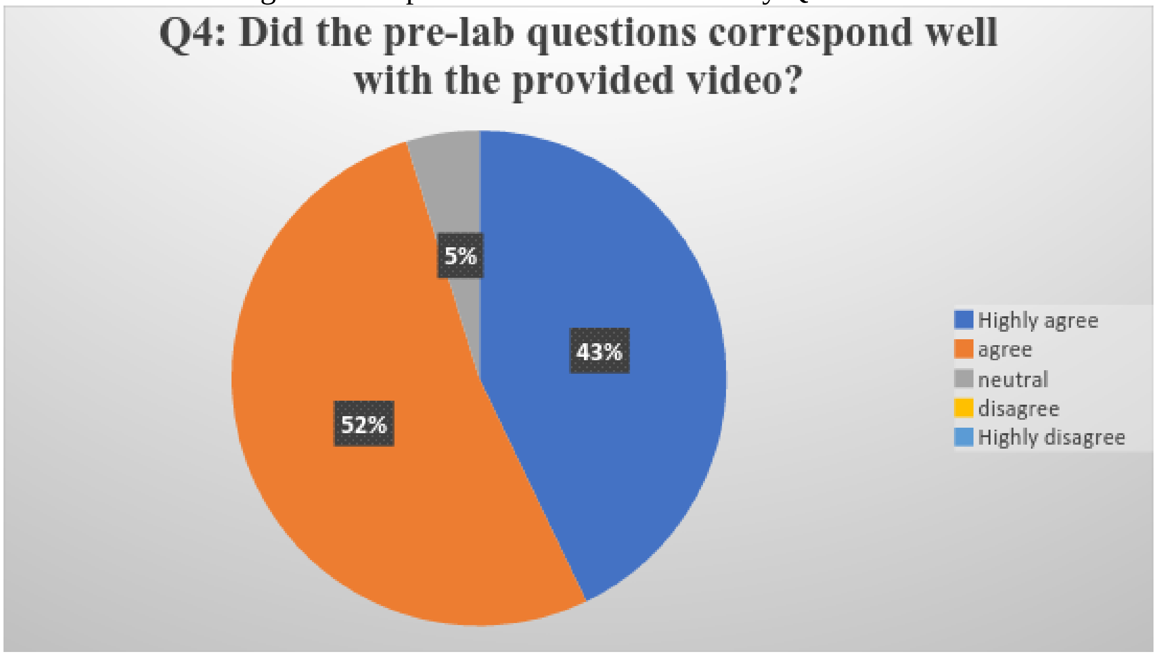


Figure 7 is a pie chart presenting the percentages of students who responded Highly Agree, Agree, Neutral, Disagree, or Highly Disagree to survey question 4. This shows that the majority of the student's points of view at least agree with the question.

Figure 8: Responses of Students to Survey Question 5

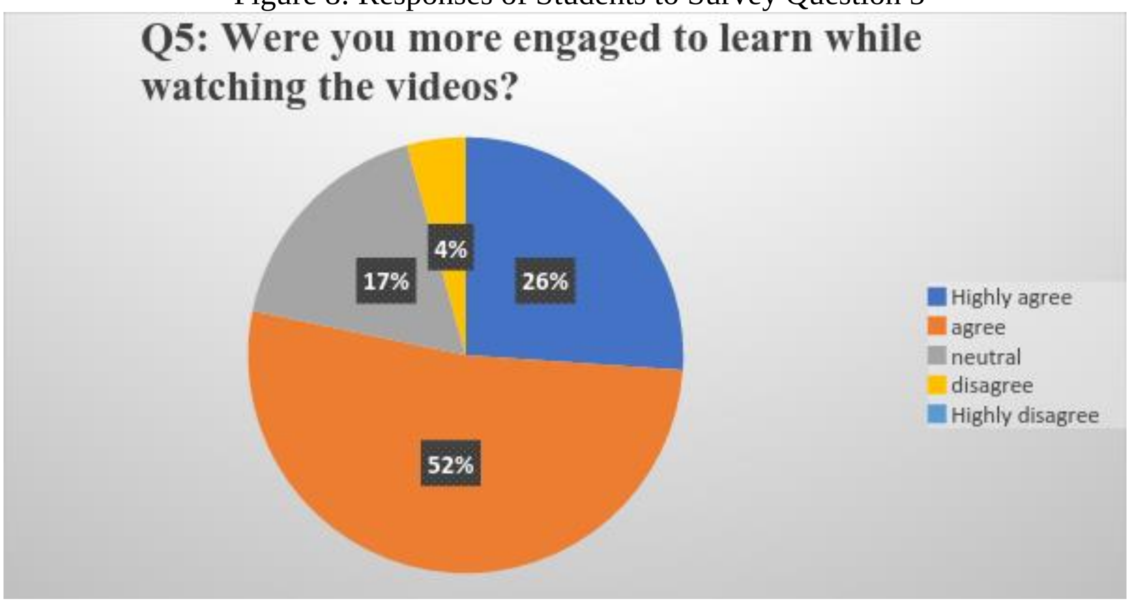


Figure 8 is a pie chart presenting the percentages of students who responded Highly Agree, Agree, Neutral, Disagree, or Highly Disagree to survey question 5. This shows that most of the students responded positively about their engagement to learn while watching the videos.

Figure 9: Responses of Students to Survey Question 6

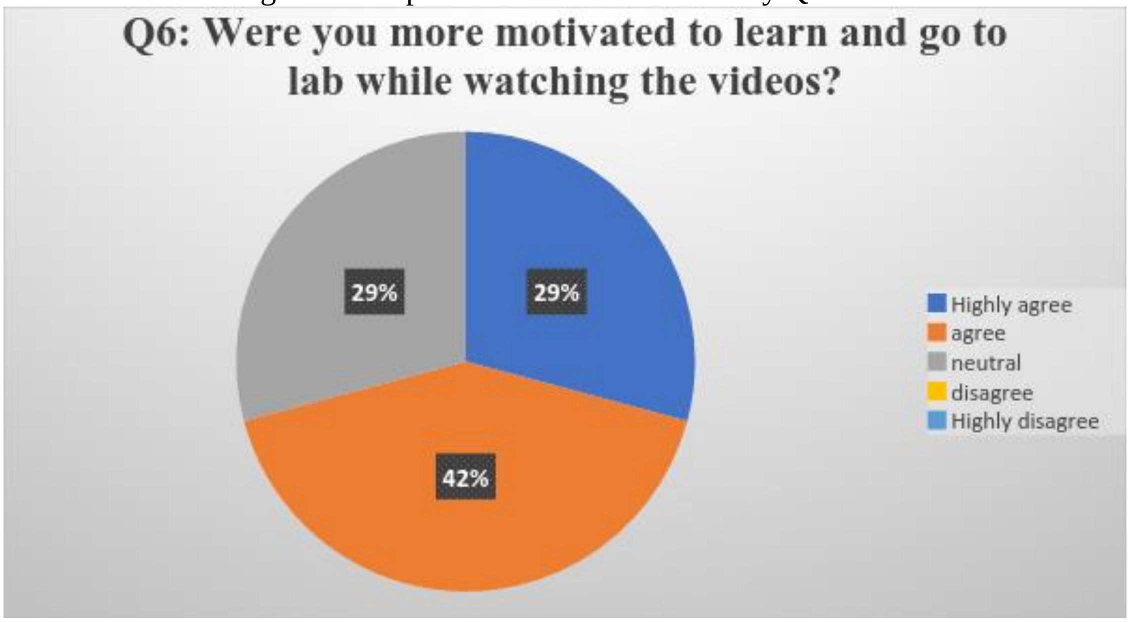


Figure 9 is a pie chart presenting the percentages of students who responded Highly Agree, Agree, Neutral, Disagree, or Highly Disagree to survey question 6. This shows that the majority of the student's points of view at least agree with the question.

Figure 10: Responses of Students to Survey Question 7

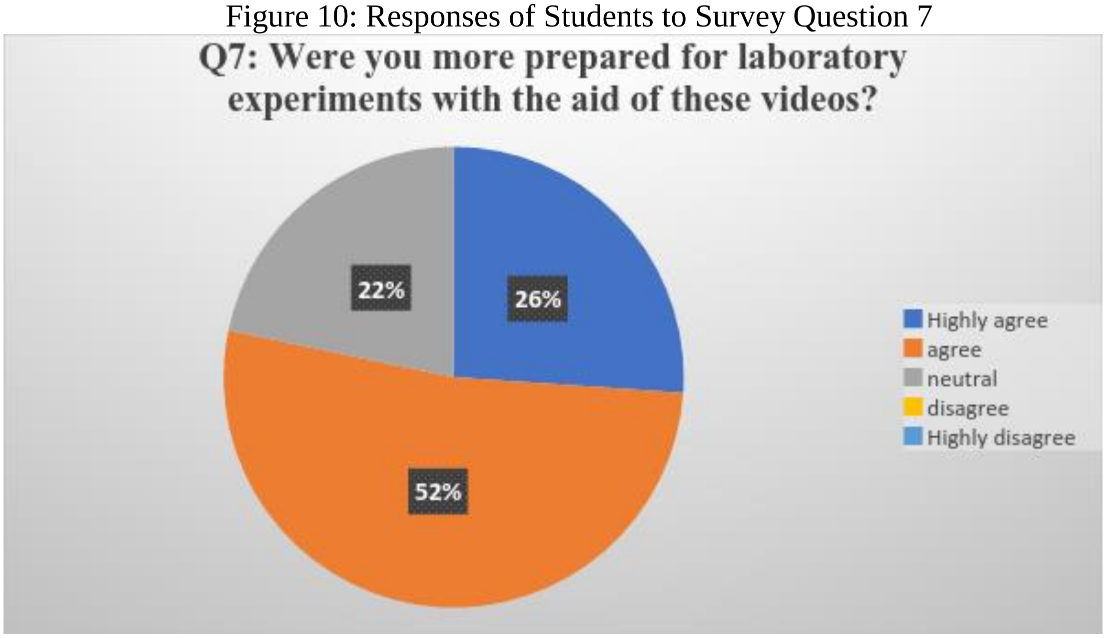


Figure 10 is a pie chart presenting the percentages of students who responded Highly Agree, Agree, Neutral, Disagree, or Highly Disagree to survey question 7. This shows that the majority of the student's points of view at least agree with the question.

Figure 11: Responses of Students to Survey Question 8

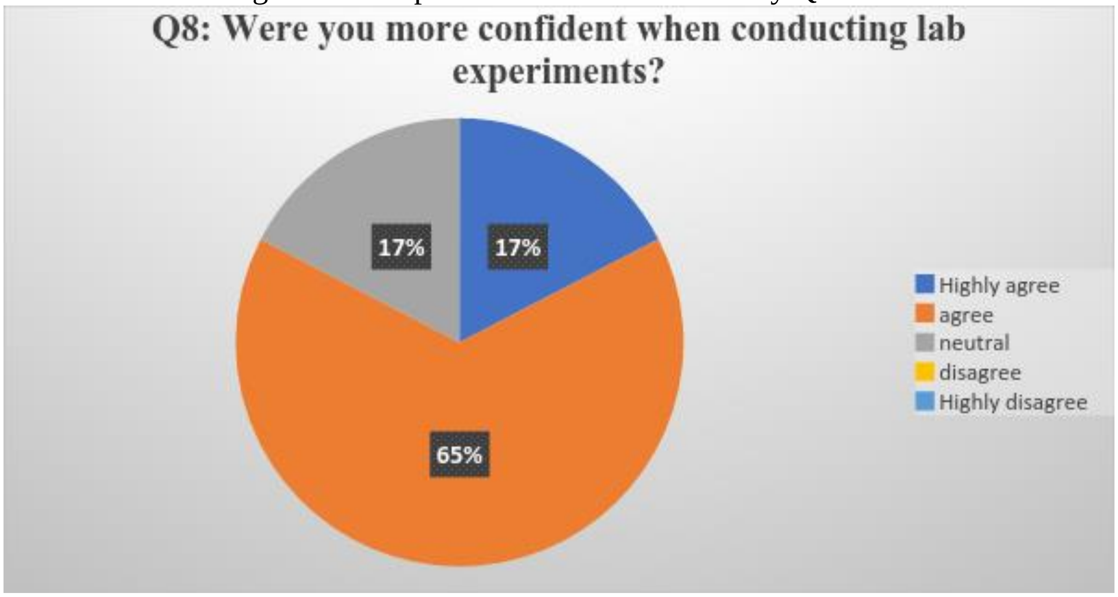


Figure 11 is a pie chart presenting the percentages of students who responded Highly Agree, Agree, Neutral, Disagree, or Highly Disagree to survey question 8. This shows that the majority of the student's points of view at least agree with the question.

Figure 12: Responses of Students to Survey Question 9

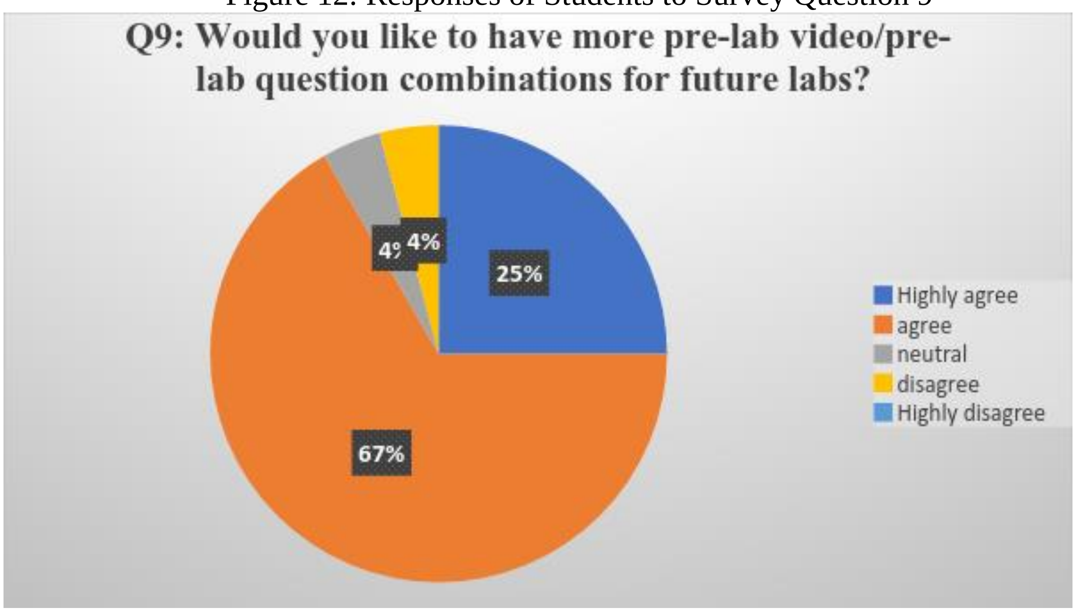


Figure 12 is a pie chart presenting the percentages of students who responded Highly Agree, Agree, Neutral, Disagree, or Highly Disagree to survey question 9. This shows that the vast majority of the student's points of view at least agree with the question.

The means and standard deviation for the scores for each question are presented here. The scale was a 1 to 5 scale, with 1 being strongly disagree and 5 being agree. Figure 13 presents this data.

Figure 13: Mean & Standard Deviation (SD) of score ratings for survey questions

Questions	Mean	Standard Deviation (SD)
1. Were the pre-lab videos clear, informative and useful?	4.43	0.59
2. Did the pre-lab videos relate well to material taught and methods used in that corresponding lab experiment?	4.39	0.66
3. Were the pre-lab questions helpful?	4.00	0.83
4. Did the pre-lab questions correspond well with the provided video?	4.38	0.59
5. Were you more engaged to learn while watching the videos?	4	0.80
6. Were you more motivated to learn and go to lab while watching the videos?	4	0.78
7. Were you more prepared for laboratory experiments with the aid of these videos?	4.04	0.71
8. Were you more confident when conducting lab experiments?	4	0.60
9. Would you like to have more pre-lab video/pre-lab question combinations for future labs?	4.13	0.68

Discussion

Findings & Connection to Research:

Data presented in Figure 3 reveals that nearly 75%, or 3 out of every 4 students, thought the pre-lab videos were clear, informative, and useful, they related well to material taught and methods used in that corresponding lab experiment, the pre-lab questions were helpful, the questions corresponded well with the provided video, they were more engaged to learn while watching the videos, more motivated to learn and go to lab while watching the videos, more prepared for laboratory experiments, more confident when conducting lab experiments, and they would like to have more pre-lab videos/pre-lab question combinations for future labs. These findings support those Shi-Jer et al found in 2012 in that “videos and animations have a more significant effect on promoting students’ learning achievements in a chemistry laboratory context in terms of operating equipment, technical operation, experimental procedures, and observation performance” (Shi-Jer et al, 2012).

In addition to this, the average scores for the questions ranged from 4-4.38, with an overall average score of 4.15, which equates to a rating between “Agree” and “Highly Agree”. This is a good indication that the students liked the pre-lab videos and questions. Not only that, but the standard deviation (SD) for these scores was between 0.59 and 0.83, with an average SD of 0.69. The value of the SD is small, meaning that the scores the students gave these survey questions were consistent. This means that not only did the students like the pre-lab videos and questions overall, but there is was not a lot of variance in the sample, meaning that there weren't a lot of outliers in the ratings students gave the questions. This data supports Ljubojevic et al who also tested for Quality of Experience (QOE), which was their term for subjective feedback from students regarding how they felt towards the provided treatment. They found that "positive feedback from students about enhancement of their learning motivation…confirmed positive effects of the use of videos in teaching" (Ljubojevic et al, 2014).

This data also suggests that these the pre-lab videos and questions had an overall positive impact on the students learning of laboratory techniques, they helped prepare the students for laboratory activities, and they inspired confidence and motivated these students to learn as well as go to lab, which as previously mentioned, supports Ljubojevic et al. This data also suggests that videos that are created well, cover the appropriate material, and do so in an effective manner do foster the learning experience in students, which supports Dunsworth et al in that "incorporating an animated pedagogical agent…into a science-focused multimedia learning environment can foster learning" (Dunsworth et al, 2007).

The collected data agrees with previous research in that educational MM which uses video feed, still images, text, narration, and meaningful gestures helps to positively contribute to the learning experience of students (Dunsworth et al, 2007; Harskamp et al, 2007; Ljubojevic et al, 2014; Shi-Jer et al, 2012 & Supasorn et al, 2008). Not only that, but the data shows that the use of videos that utilize appropriate levels of both educational and entertaining components can improve the educational experience for students, especially in a science related field. This finding adds to the literature, as none of the research in the literature used videos that were simultaneously entertaining and educational. Researchers claimed that entertaining videos were not as effective as educational ones (Ljubojevic et al, 2014), meaning that they studied how videos that were either educational or entertaining affected students' learning, but they never studied videos that were both entertaining and educational. Additionally, since these videos presented instructional information regarding how to perform certain laboratory techniques, it can be determined that the collected data agrees with previous research in that MM is helpful in delivering instructional type information to accomplish certain tasks (Mechling et al, 2011). It can also be said that this data supports previous research in that MM does in fact help foster students learning in classes that are science related (Dalacosta et al, 2008; Harskamp et al, 2007; Ljubojevic et al, 2014; Priyambodo et al, 2014; Shi-Jer et al, 2012; Supasorn et al, 2008; & Wong et al, 2009).

It’s important to mention that there was only one article that looked at the effects different forms of MM had on learning in an organic chemistry laboratory (Shi-Jer et al, 2012). Since this is the same setting this research took place in, that means that findings from this research adds a lot of valuable information to this particular topic of research.

Finally, the collected data also suggests that introducing effective MM in an educational setting may in fact play an important role in lowering cognitive stress or overload. This agrees with previous research which has determined that MM does play a role in lowering cognitive overload (Mayer et al, 2002; Moreno et al, 2000 and Zhang et al, 2016). Although this data does not directly measure levels of cognitive stress or overload, it does help suggest that there seems to be a negative correlation between using effective MM and levels of cognitive overload in students. Again, this was done by measuring how the introduction of MM effects aspects that contribute to lower cognitive stress such as confidence in performing tasks and solving problems, engagement to learn, as well as motivation to learn.

Applications and Implications:

With this being said, the findings of this research have several applications in academia, especially in chemistry. This research suggests that students studying chemistry seem to like the integration of technology with learning. As already mentioned, previous research has supported the use of effective and appropriate kinds of MM in education, and with the data collected in this research, it is clear that educators in chemistry should be highly encouraged to utilize this very valuable resource of mode of communication.

With this being said, these teachers should be highly encouraged to find more ways to incorporate MM in their educational schemes, both continuously providing students with different forms of effective MM as well as assigning students to create their own while critiquing each other's MM creations. Research has shown that MM improves teaching and learning processes, making it not only faster but also by fostering an independent learning attitude (Lightbody et al, 2006), and assigning students to make their own form of MM while also conducting constructive peer review would also improve their understanding and mastery of subject material, which in this case is chemistry.

Strengths and Limitations:

This research has certain strengths including the high response rates (54.5% of the total population and 70.6% of the students who consented to take part of the study responded to the survey), the simple research design that maximized response rates, and the level of control/freedom the investigator had in creating effective pre-lab videos along with their associated questions.

The major limitation of this study was that time constraints did not allow for the collection or analysis of student academic performance. This information would have provided much stronger supportive information regarding the effects the provided MM had on the students learning. Additionally, this research took place half way through the semester when students were already enrolled in Organic Chemistry II. Since these students have already taken Organic

Chemistry I and have already covered half of the course's material, there is the chance these students may have already learned techniques presented to them in this MM treatment. This limitation may have drawn away from the experience the students could have had if this material was presented earlier on, which effects their subjective feedback on the videos.

In addition to these limitations, the study did not utilize a validated tool to measure levels of cognitive overload, as there isn't a tool that has been created for this purpose. Due to this, this study did not directly measure levels of cognitive load, but rather looked at indications of cognitive overload.

Suggestions for Future Research:

Future research in this field should be highly encouraged, as there is a lack of research currently available. Suggestions for future research include: conducting studies that take place over longer periods of time to help tend to the limitations in this study, similar studies should be performed in other subjects such as Biology and other branches of Chemistry to see if similar results would arise, similar studies should take place at different levels of courses including introductory, intermediate, and higher level courses to see if there are similar trends among the different levels of students, and research should also look into the levels of cognitive overload as well as levels of understanding students who make these videos have.

Conclusions

In conclusion, this study shows that students like MM as a means of learning new information and techniques, especially in a laboratory setting. This study also shows that MM does seem to help lower cognitive overload in students, which adds to already established research in the field of MM and education. Data from this research also found that MM is effective when there's a good balance between narration, text, pictures, and videos, and that MM is a useful tool when it comes to instructional type tasks, both of which add to already established research in this field. Also, the effects MM have on learning are promising when there is an appropriate balance of entertainment in educational videos, which is a contribution to the literature in this field. Finally, this study has collected data that highly encourages educators at the undergraduate level to utilize MM as a mode of communicating information to their students.

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Appendix

Appendix A: Post-Videos Survey

How much do you agree with these statements? (rank from 1-5)

1. Were the pre-lab videos clear, informative, and useful?

Highly disagree	Disagree	Neutral	Agree	Highly Agree
1	2	3	4	5

2. Did the pre-lab videos relate well to material taught and methods used in that corresponding lab experiment?

   1 2 3 4 5

3. Were the pre-lab questions helpful?

   1 2 3 4 5

4. Did the pre-lab questions correspond well with the provided video?

   1 2 3 4 5

5. Were you more engaged to learn while watching the videos?

   1 2 3 4 5

6. Were you more motivated to learn and go to lab while watching the videos?

   1 2 3 4 5

7. Were you more prepared for laboratory experiments with the aid of these videos?

   1 2 3 4 5

8. Were you more confident when conducting lab experiments?

   1 2 3 4 5

9. Would you like to have more pre-lab video/pre-lab question combinations for future labs?

   1 2 3 4 5