

Effectiveness of JoVE Videos in Improving STEM Students' Performance:

A Study in Undergraduate Biology Labs

By

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Study Summary

This study was conducted at two different universities with undergraduate biology laboratory classes to determine the effects on students' performance and learning experiences of watching videos pre-class that demonstrate scientific concepts and methods. For this purpose, we used four JoVE videos that demonstrate the scientific concepts and techniques included in four typical undergraduate laboratory classes in biological sciences.

The videos were assigned as a pre-lab watching requirement (in addition to reading a lab handout) for 50% of the lab sections; the remaining 50% of the lab sections did not watch videos and only read the lab handout. Both groups of students were tested on performance in pre-lab and post-lab exams and video group students were also surveyed about their learning experiences from the videos.

The obtained results reveal a significant positive impact of JoVE videos on students' performance and learning experience. In three out of the four laboratory classes, students who watched videos performed significantly better in both pre- and post-lab exams. For these students, we observed up to a two-fold increase in test scores on scientific concepts and techniques. For all four classes, 65-95% of the video group students reported that watching the video prior to lab helped enhance their confidence, comprehension of concepts, and understanding of how to conduct the lab.

The study results conclude that JoVE videos can be used as an effective resource in enhancing existing curriculum of undergraduate science courses and significantly improving students' performance.

Study Goals

This study was conducted to determine whether JoVE videos could influence student perceptions of engagement and confidence while conducting lab work, as well as impact their learning. The following research questions and indicators guided our work.

- ***To what extent do JoVE biology videos affect students' learning outcomes?*** We measured student knowledge overall and by two separate constructs:
 - conceptual ideas being studied through the labs;
 - experiment techniques and processes learned through the labs.
- ***To what extent do the JoVE biology videos contribute to undergraduate students' lab experiences?*** We measured student perceptions of their:
 - ability to conduct the labs;
 - sense of confidence during lab work;
 - sense that they understood the concept(s) being studied.

Study Design and Participants

The study was conducted at two universities, DeSales University and Clemson University, with undergraduate students. DeSales University is a small private university in Pennsylvania, with total enrolment of 3,309. Clemson University is a public research university in South Carolina, with total enrolment of 23,406. At DeSales University we

worked with Dr. Lara Goudsouzian, Assistant Professor in the Natural Science Department and at Clemson University we worked with Christine Minor, Senior Lecturer in the Biological Sciences Department. Each of them selected one course in which to conduct the study. Students in course sections, identified as the treatment group, were able to view JoVE videos, and thus, we will call them the *video group* throughout the rest of this report. Students in other course sections were the *comparison group*. They did not use videos.

- ***Description of the study at DeSales University:***

Students, Course, and Labs: Ninety four (94) students in a molecular biology course participated in the study. Most were sophomores who were part of the accelerated Physician Assistant program. About 25% of the students were majoring in biology. There were four course sections, all of which had the same professor. Each section served as the video group for one lab, and then as the comparison group for the other lab. Typically, participants don't change groups during a study. However, because of human subjects' requirements for this college, we allowed for this variation where students only had one video experience.

JoVE videos were used and data were collected from the following labs:

- [Plasmid Purification](#): Students watched the first 5:55 minutes of this video, as that portion provided an overview of the topic, principal components, and step-by-step procedures for plasmid purification that were relevant to their DNA and Enzymes lab.
- [Separating Protein with SDS PAGE](#): Students watched the first 5:45 minutes of the video, as that portion provided an overview of the topic, steps involved in sample preparation, and a demonstration of the step-by-step procedure on how to load and run the gel. All of these were relevant to their GFP Protein Denaturation lab.

- ***Description of the pilot at Clemson University:***

Students, Course, and Labs: Two hundred and fifty two (252) students in a biology course participated in the study. Students ranged from freshman to seniors, and all were taking the course to fulfill a core requirement, as none were majoring in a science field. There were 14 course sections with 18 students in each. Students in odd-numbered sections were part of the video group while students in the even-numbered sections served as the comparison group. We consider the large university study to fulfill random assignment criteria¹, as students signed up for sections solely based on their time preferences and scheduling needs.

¹Random assignment identifies the group of participants who will receive the intervention—in this case, will watch the video—and those who will not. Often, this is determined by a chance procedure (e.g., flipping a coin). Random assignment is important, because it helps to eliminate variables (like picking the high achieving students to watch the videos) that might influence the outcomes of the study.

JoVE videos were used and data were collected from the following labs:

- [*Introduction to the Spectrophotometer*](#): Students watched the first 5:07 minutes of the video, as that portion provided an overview of spectrophotometry concepts, and presented the components and operating procedures of a spectrophotometer that were relevant to their quantitative biology lab.
- [*Introduction to Light Microscopy*](#): Students watched the first 6:51 minutes of the video, as that portion provided an overview of the topic, and included basic principles, major components, and operating procedures of a light microscope that were relevant to their microscopy lab.

• ***Data collection from DeSales University and Clemson University students:***

Instrumentation and data collection were designed to be as similar as possible across both institutions.

Instrumentation:

- *Baseline survey-assessment* included: student confidence ratings about learning techniques and understanding course concepts, and student general knowledge assessment of three basic biology concepts that they might know prior to the course.
- *Time 1 assessment* included: 6-7 items about techniques and concepts covered in both the videos and lab work, tested before the lab.
- *Time 2 survey-assessment* included: the same 6-7 items from the Time 1 survey, and for those in the video group, questions about video watching and perceived support, tested after the lab.
- *Experiment 1*: Questions within the Time 1 assessment which tested students' knowledge on experimental techniques and processes pertaining to the specific lab.
- *Experiment 2*: Questions within the Time 2 assessment which tested students' knowledge on experimental techniques and processes pertaining to the specific lab.
- *Concept 1*: Questions within the Time 1 assessment which tested students' knowledge on conceptual ideas pertaining to the specific lab.
- *Concept 2*: Questions within the Time 2 assessment which tested students' knowledge on conceptual ideas pertaining to the specific lab.

(Experiment 1 and 2 are the same set of questions and Concept 1 and 2 are the same set of questions.)

Data Collection:

Before doing any work associated with the study, all students completed the baseline survey-assessment. The primary purpose of the baseline data was to ensure that the students in the video and comparison groups were the same, *overall*, in terms of their coursework confidence and general knowledge of basic biology concepts. While there was no obvious reason to expect these groups to differ, sometimes one group may be more experienced or knowledgeable just by chance.

Prior to the lab: All video group students watched the video, read the lab preparation handout developed by the professor, and then watched the same video again. All comparison group students read the same lab preparation handout developed by the professor. This same process occurred for the second lab.

Before conducting the lab: All students completed the Time 1 assessment in the lab, under the supervision of their professor or teaching assistant. For the video group, the purpose of the Time 1 assessment was to identify whether the video *added* to student knowledge about the lab they would soon perform (beyond what the lab handout offered).

Immediately following the lab: All students completed the Time 2 survey-assessment in the lab, under the supervision of their professor or teaching assistant. For the video group, the purpose was to: 1) identify whether the videos contributed to student experiences of the lab (e.g., their sense of confidence); *and* 2) determine whether the earlier video use continued to give the video group the edge over the comparison students, now that all students had conducted the lab.

Analytic Procedures

For DeSales University and Clemson University: All assessments were scored to identify the percentage of correct items and to generate descriptive statistics. Then we employed Analysis of Variance (ANOVA) models to determine whether the video and comparison groups had equivalent baseline levels of confidence and general knowledge. Lastly we created Analysis of Covariance (ANCOVA)² models to examine whether video group students scored higher in their Time 1 assessment and/or Time 2 assessment than students in the comparison group. We included baseline general knowledge scores and confidence ratings in the model, to make sure that any differences in final outcomes were *not* because they came into the study feeling more confident or having more general knowledge.

For Clemson University only: A class environment can also affect students' performance—they may have an instructor or classmates that influence how they feel or how much they learn. This was more likely to happen at Clemson University, given that there were 14 sections and four teaching assistants that worked directly with students on labs. Therefore, we also created a two-level hierarchical model³. At level 1 of the model, we included individual student variables (e.g., baseline general knowledge and confidence). Then at

²ANOVA is a statistical method used to test differences between two or more means, made by analyzing how those means vary. ANCOVA is used to test the main and interaction effects of categorical variables on a continuous dependent variable, controlling for the effects of other continuous variables, which co-vary with the dependent. To be sure these models were appropriate for these data sets, we tested the normality and homogeneity of variance assumptions.

³Hierarchical linear modeling is a complex form of regression that measures the influence of key factors within commonly occurring levels. For instance, the level of student data might be nested in the level of teacher data or classroom data, as a teachers/classes commonly influence student learning.

Level 2, we nested students within their sections. This allowed us to account for any statistical influence of teaching assistants or classmates, as well as use of video.

Study Results: DeSales University

1) Did the video group and comparison group students begin with the same levels of confidence and knowledge?

YES. Our baseline analyses showed that there were *no statistical differences* in baseline knowledge items or in confidence ratings. Therefore we feel confident that the groups were quite similar in these areas prior to participating in the study.

2) Results of the Plasmid Purification lab:

Overall results for this lab are depicted in Figure 1. Detailed description about differences between the video group and the comparison group follow.

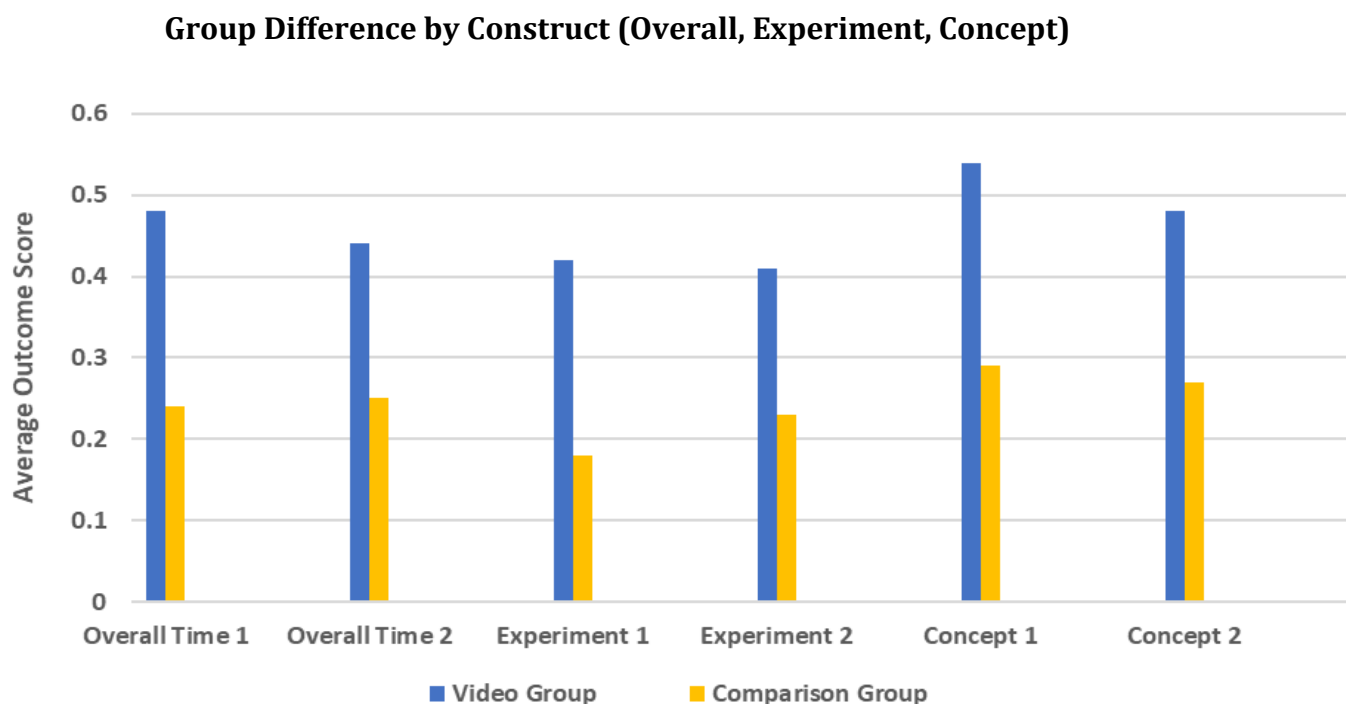


Figure 1: Plasmid Purification

Did students in the video group perform better at Time 1 overall?

YES. As seen in Table 1, we had a complete set of data from 87 students at Time 1 (44 in the video group and 43 in the comparison group) for the Plasmid Purification lab, with a higher raw score from the video group.

	Overall Time 1		
	Number of participants	Mean outcome score	Standard Deviation
Video Group	44	0.48	0.22
Comparison Group	43	0.24	0.15

Table 1

Our analyses show that:

- The average outcome score (the raw average percentage of correct items) for the video group was .48 and the average outcome score for the comparison group was .24.
- The video group scored **significantly higher ($t=5.55$, $p<.001$)** than the comparison group on Plasmid Purification knowledge items, controlling for baseline general knowledge and confidence. *Such a result suggests that the difference was not due to chance, and that the probability that the video had no effect on the scores was very low.*
- Watching the video made a big difference—when we tested its impact alone, it contributed to at least 26% (Partial R square=0.26) of the video group's higher outcome.
- However, one might expect that other factors, in combination with the video, could account for higher scores (e.g. the number of AP science courses taken in high school, one's socioeconomic status, or being hungry and tired when taking the assessment). Therefore, we collected data about two likely factors—student confidence and general knowledge of basic biology concepts. Controlling for these, we found that the video still accounted for at least 23% of the video group's higher outcome.

Did students in the video group perform better at Time 2 overall?

YES. As seen in Table 2, we had a complete set of data from 87 students at Time 2 (45 in the video group and 42 in the comparison group), with a higher raw score from the video group.

	Overall Time 2		
	Number of participants	Mean outcome score	Standard Deviation
Video Group	45	0.44	0.22
Comparison Group	42	0.25	0.17

Table 2

Based on our analyses, we know that:

- The average outcome score for the video group was .44 and the average outcome score for the comparison group was .25.
- The video group scored **significantly higher ($t=3.89$, $p<.001$)** than the comparison group on Plasmid Purification knowledge items, controlling for baseline general

knowledge and confidence. Such a result suggests that the difference was not due to chance, and that the probability that the video had no effect on the scores was very low.

- As we might expect there was less of a difference between the groups after they both worked on the Plasmid Purification lab in the same way. Still, watching the video made a difference— when we tested its impact alone, it contributed to at least 14% (Partial R square=0.14) of the video group’s higher outcome.
- Controlling for baseline confidence and knowledge, we found that the video accounted for at least 18% of the video group’s higher outcome.

Did students in the video group perform better on experimental process assessment items at Time 1 and Time 2?

	Experiment 1			Experiment 2		
	Number of participants	Mean outcome score	Standard Deviation	Number of participants	Mean outcome score	Standard Deviation
Video Group	44	0.42	0.27	45	0.41	0.32
Comparison Group	43	0.18	0.20	42	0.23	0.24

Table 3

- **YES.** As seen in Table 3, video group students scored **significantly higher (t=4.23, p<.001)** on the Plasmid Purification experimental process items than students in the comparison group, controlling for students' baseline general knowledge and confidence. Watching the video contributed to at least 17% (Partial R square=0.17) of the video group’s higher outcome related to experimentation. Controlling for baseline confidence and knowledge, we found that the video contributed 22% to the outcome.
- Students in the video group scored **significantly higher (t=2.56, p<.01)** at Time 2 as well, controlling for baseline general knowledge and confidence. The comparison group made some gains, but watching the video still contributed to at least 6% (Partial R square=0.06) of the video group’s higher outcome related to experimentation. Controlling for baseline confidence and knowledge, we found that the video contributed at least 16% to the outcome.

Did students in the video group perform better on conceptual assessment items at Time 1 and Time 2?

	Concept 1			Concept 2		
	Number of participants	Mean outcome score	Standard Deviation	Number of participants	Mean outcome score	Standard Deviation
Video Group	44	0.54	0.33	45	0.48	0.31
Comparison Group	43	0.29	0.25	42	0.27	0.26

Table 4

- **YES.** As seen in Table 4, video group students scored **significantly higher ($t=3.65$, $p<.001$)** on the Plasmid Purification conceptual items than students in the comparison group, controlling for students' baseline general knowledge and confidence. Watching the video accounted for at least 12% (Partial R square=0.12) of the video group's higher outcome related to conceptual knowledge. Controlling for baseline confidence and knowledge, we found that the video contributed at least 24% to the outcome.
- Students in the video group scored **significantly higher ($t=3.09$, $p<.001$)** at Time 2 as well, controlling for baseline general knowledge and confidence. Yet scores dropped slightly for both groups. Watching the video still contributed to at least 9% (Partial R square=0.09) of the video group's higher outcome related to conceptual knowledge. Controlling for baseline confidence and knowledge, we found that the video contributed at least 20% to the outcome.

3) SDS PAGE lab: Group Difference by Construct (Overall, Experiment, Concept)

Overall results for this lab are depicted in Figure 2. Detailed description about differences between the video group and the comparison group follow.

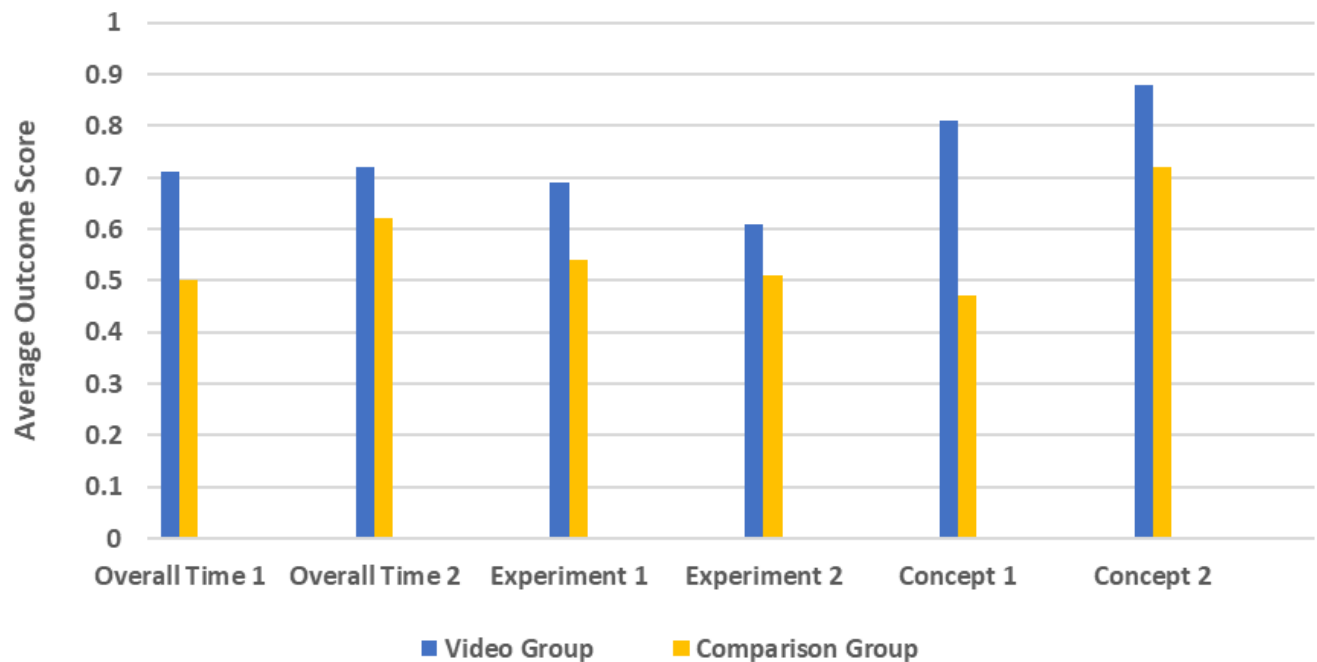


Figure 2: SDS PAGE

Did students in the video group perform better at Time 1 overall?

YES. As seen in Table 5, we had a complete set of data from 90 students at Time 1 (45 in the video group and 45 in the comparison group), with a higher raw score from the video group.

	Overall Time 1		
	Number of participants	Mean outcome score	Standard Deviation
Video Group	45	0.71	0.17
Comparison Group	45	0.50	0.20

Table 5

Based on our analyses, we know that:

- The average outcome score for the video group was .71 and the average outcome score for the comparison group was .50.
- The video group scored **significantly higher ($t=5.75$, $p<.001$)** than the comparison group on SDS PAGE knowledge items, controlling for baseline general knowledge and confidence. Such a result suggests that the difference was not due to chance, and that the probability that the video had no effect on the scores was very low.

- Watching the video made a difference—when we tested its impact alone, it contributed to at least 27% (Partial R square=0.27) of the video group’s higher outcome.
- Controlling for baseline knowledge and confidence, we found that the video accounted for at least 22% of the video group’s higher outcome.

Did students in the video group perform better at Time 2 overall?

YES. As seen in Table 6, we had a complete set of data from 91 students at Time 2 (46 in the video group and 45 in the comparison group), with higher raw scores from the video group.

	Overall Time 2		
	Number of participants	Mean outcome score	Standard Deviation
Video Group	46	0.72	0.15
Comparison Group	45	0.62	0.19

Table 6

Based on our analyses, we know that:

- The average outcome score for the video group was .72 and the average outcome score for the comparison group was .62.
- The video group scored **significantly higher ($t=3.14$, $p<.01$)** than the comparison group on SDS PAGE knowledge items, controlling for baseline general knowledge and confidence. Such a result suggests that the difference was not due to chance, and that the probability that the video had no effect on the scores was very low.
- As we might expect there was less of a difference between the groups after they both worked on the SDS PAGE lab. Still, watching the video made a difference— when we tested its impact alone, it contributed to at least 9% (Partial R square=0.09) of the video group’s higher outcome.
- Controlling for baseline confidence and knowledge, we found that the video accounted for at least 12% of the video group’s higher outcome.

Did students in the video group perform better on experimental process assessment items at Time 1 and Time 2?

	Experiment 1			Experiment 2		
	Number of participants	Mean outcome score	Standard Deviation	Number of participants	Mean outcome score	Standard Deviation
Video Group	45	0.69	0.22	46	0.61	0.19
Comparison Group	45	0.54	0.22	45	0.51	0.20

Table 7

- **YES.** As seen in Table 7 video group students scored **significantly higher ($t=3.24$, $p<.01$)** on the SDS PAGE experimental process items than students in the comparison group at Time 1, controlling for students' baseline general knowledge and confidence. Watching the video contributed to at least 10% (Partial R square=0.10) of the video group's higher outcome related to experimentation. Controlling for baseline confidence and knowledge, we found that the video contributed at least 15% to the outcome.
- Students in the video group scored **significantly higher ($t=2.39$, $p<.05$)** at Time 2 as well, controlling for baseline general knowledge and confidence. The average outcome score dipped a little for both groups. Still, watching the video contributed to at least 5% (Partial R square=0.05) of the video group's higher outcome related to experimentation. Controlling for baseline confidence and knowledge, we found that the video contributed at least 10% to the outcome.

Did students in the video group perform better on conceptual assessment items at Time 1 and Time 2?

	Concept 1			Concept 2		
	Number of participants	Mean outcome score	Standard Deviation	Number of participants	Mean outcome score	Standard Deviation
Video Group	45	0.81	0.27	46	0.88	0.24
Comparison Group	45	0.47	0.38	45	0.72	0.29

Table 8

- **YES.** As seen in Table 8 video group students scored **significantly higher ($t=5.55$, $p<.001$)** on the SDS PAGE conceptual items than students in the comparison group at Time 1, controlling for students' baseline general knowledge and confidence. Watching the video contributed to at least 25% (Partial R square=0.25) of the video group's higher outcome related to conceptual knowledge. Controlling for baseline confidence and knowledge, we found that video contributed at least 38% to the outcome.
- Students in the video group scored **significantly higher ($t=3.40$, $p<.001$)** at Time 2 as well, controlling for baseline general knowledge and confidence. The comparison group made larger gains, but watching the video still contributed to at least 11% (Partial R square=0.11) of the video group's higher outcome related to conceptual knowledge. Controlling for baseline confidence and knowledge, we found that the video contributed at least 19% to the outcome.

Study Results: Clemson University

1) Did the video group and comparison group students begin with the same levels of confidence and knowledge?

YES. Our baseline analyses showed that there were *no statistical differences* in baseline knowledge items or in confidence ratings. Therefore, we feel confident that the groups were quite similar in these areas prior to participating in the study.

2) Spectrophotometry lab: Group Difference by Construct (Overall, Experiment, Concept).

Overall results for this lab are depicted in Figure 3. Detailed description about differences between the video group and the comparison group follow.

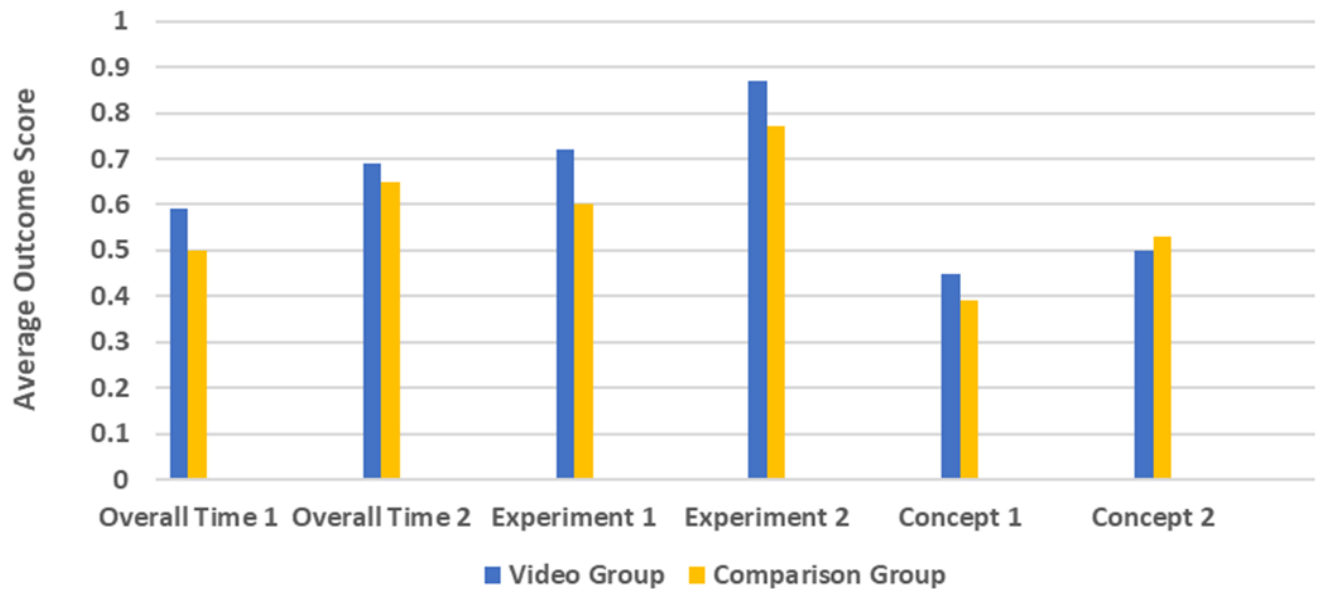


Figure 3: Spectrophotometry

Did students in the video group perform better at Time 1 overall?

YES. As seen in Table 9 we had a complete set of data from 254 students at Time 1, with 131 in the video group and 123 in the comparison group), with a higher raw score from the video group.

	Overall Time 1		
	Number of participants	Mean outcome score	Standard Deviation
Video Group	131	0.59	0.19
Comparison Group	123	0.50	0.21

Table 9

Based on our analyses, we know that:

- The average outcome score for the video group was .59 and the average outcome score for the comparison group was .50.
- The video group scored **significantly higher ($t=3.62$, $p<.01$)** than the comparison group on Spectrophotometry knowledge items, controlling for baseline general knowledge and confidence, and also taking into account the course section of each student. Such a result suggests that the difference was not due to chance, and that the probability that the video had no effect on the scores was very low.
- Watching the video made a difference—when we tested its impact alone, it contributed to at least 5% (Partial R square=0.05) of the video group's higher outcome.
- Controlling for baseline knowledge and confidence, we found that the video accounted for at least 9% of the video group's higher outcome.

Did students in the video group perform better at Time 2 overall?

NO. As seen in Table 10 we had a complete set of data from 220 students at Time 2 (110 in the video group and 110 in the comparison group), with a slightly higher raw score from the video group.

	Overall Time 2		
	Number of participants	Mean outcome score	Standard Deviation
Video Group	110	0.69	0.21
Comparison Group	110	0.65	0.22

Table 10

Based on our analyses, we know that:

- The average outcome score for the video group was .69 and the average outcome score for the comparison group was .65.
- The video group score was not significantly higher (**$t=1.71$, $p<.11$**), than the comparison group on Spectrophotometry knowledge items overall, controlling for baseline general knowledge and confidence and accounting for course section. However, the p value was approaching significance, causing us to wonder about the variability in the data set. *In particular, we wondered whether students had greater difficulty with items for one of the constructs. If that were the case, an overall effect might be washed out.*

Did students in the video group perform better on experimental process assessment items at Time 1 and Time 2?

	Experiment 1			Experiment 2		
	Number of participants	Mean outcome score	Standard Deviation	Number of participants	Mean outcome score	Standard Deviation
Video Group	131	0.72	0.26	110	0.87	0.22
Comparison Group	123	0.60	0.29	110	0.77	0.28

Table 11

- **YES.** As seen in Table 11 video group students scored **significantly higher ($t=3.27$, $p<.001$)** on the Spectrophotometry experimental process items than students in the comparison group at Time 1, controlling for students' baseline general knowledge and confidence. Watching the video contributed to at least 4% (Partial R square=0.04) of the video group's higher outcome related to experimentation. Controlling for baseline confidence and knowledge, we found that the video contributed at least 12% to the outcome.
- Students in the video group scored **significantly higher ($t=3.14$, $p<.01$)** at Time 2 as well, controlling for baseline general knowledge and confidence. The comparison group made gains as well, but watching the video still contributed to at least 4% (Partial R square=0.04) of the video group's higher outcome related to experimentation. Controlling for baseline confidence and knowledge, we found that the video contributed at least 11% to the outcome.

Did students in the video group perform better on conceptual assessment items at Time 1 and Time 2?

	Concept 1			Concept 2		
	Number of participants	Mean outcome score	Standard Deviation	Number of participants	Mean outcome score	Standard Deviation
Video Group	131	0.45	0.24	110	0.50	0.30
Comparison Group	123	0.39	0.24	110	0.53	0.30

Table 12

- **YES and NO.** As seen in Table 12 at Time 1, video group students scored **significantly higher ($t=2.07$, $p<.05$)** on the Spectrophotometry conceptual items than students in the comparison group, controlling for students' baseline general knowledge and confidence. However the difference was small, and watching the video only contributed to at least 2% (Partial R square=0.02) of the video group's higher outcome related to conceptual

knowledge. Controlling for baseline confidence and knowledge, we found that the video contributed at least 7% to the outcome.

- At Time 2, video group student scores were lower than the comparison group on conceptual items ($p < 0.9$).

Thus, we see why the overall effect of the video at Time 2 was not evident in the earlier analyses. Lower outcome scores on the concept items dampened the overall effect, with the videos having a stronger influence on experimental processes than on conceptual understanding for this lab.

3) Microscopy lab:

Did students in the video group perform better at Time 1 or Time 2 overall?

NO. We had a complete set of data from 276 students at Time 1 (140 in the video group and 136 in the comparison group) and 218 students at Time 2 for the Microscopy lab. Our analyses show that:

- There were no significant differences at either time point, controlling for baseline general knowledge and confidence.

Why might there be no differences for the microscopy lab?

Further investigation of the data revealed:

- Small differences in average item scores between the video and comparison groups; and
- The vast majority of *all* students were correct, giving little room for growth. This is illustrated in Table 13 below, where we see approximately 75% or more students in both groups had a correct response on 4 of 6 items at Time 1, and a correct response on 5 of 6 items at Time 2.

Microcopy Assessment: Percentage of students with the correct answer for each item			
		Video Group	Comparison Group
Time 1	Q1	0.88	0.86
	Q2	0.90	0.84
	Q3	0.82	0.78
	Q4	0.60	0.59
	Q5	0.98	0.98
	Q6	0.70	0.63
Time 2	Q1	0.74	0.83
	Q2	0.95	0.94
	Q3	0.87	0.86
	Q4	0.86	0.80
	Q5	1.00	0.99
	Q6	0.85	0.68

Table 13

Although these were non-science majors, we suspect that most had familiarity with microscopes from high school courses, and therefore they knew the answer or could make an educated guess when completing the assessments.

Results: Student Perceptions of Video Use

In addition to performance, we studied whether students felt the videos had an impact on their learning experience. Following lab completion, students in the video group reported to what extent JoVE videos enabled them to *feel more confident* while doing the lab and to *understand how to conduct the lab*. In addition, students rated to what extent the video provided *helpful information about lab concepts*.

On a six-point Likert scale, where choices ranged from *not at all* to *greatly*, students reported their perceptions about the videos.

Perceptions of DeSales University students after using the Plasma Purification video for the DNA and Enzymes lab: Forty eight percent (48%) of the students reported that the video offered moderate to great levels of support, thus bolstering their confidence, and 50% of the students felt the video enhanced their ability to conduct the DNA and Enzymes lab. Sixty three percent (63%) of the students reported that the video helped them to gain key conceptual information. Rating categories for each item are presented in the Figures 4a, 4b, and 4c below.

■ not at all ■ a little ■ a fair amount ■ a moderate amount ■ a great amount

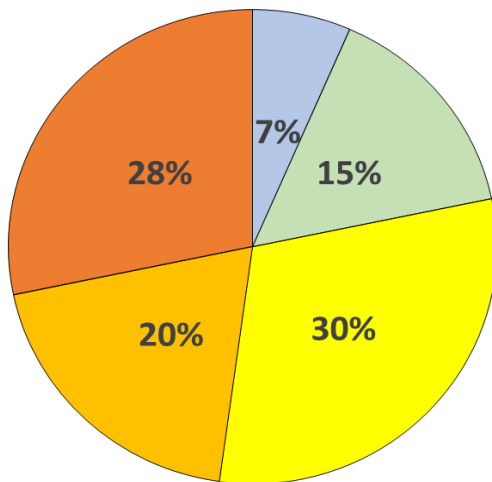


Figure 4a: Confidence

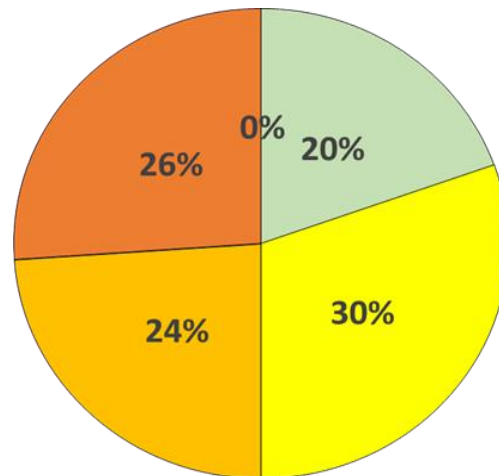


Figure 4b: Understanding of the lab

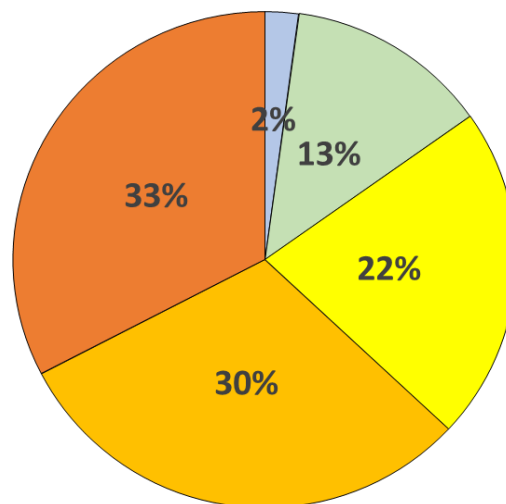


Figure 4c: Concepts

Figure 4: Perceptions of students after using the Plasmid Purification video

Perceptions of DeSales University students after using SDS PAGE video for the GFP Protein Denaturation lab: Sixty seven percent (67%) of the students reported that the video offered moderate to great levels of support, thus bolstering their confidence, and nearly 70% of the students felt the video enhanced their ability to conduct the GFP Protein Denaturation lab. Seventy two (72%) of the students reported that the video helped them to gain key conceptual information. Rating categories for each item are presented in the Figures 5a, 5b, and 5c below.

■ not at all ■ a little ■ a fair amount ■ a moderate amount ■ a great amount

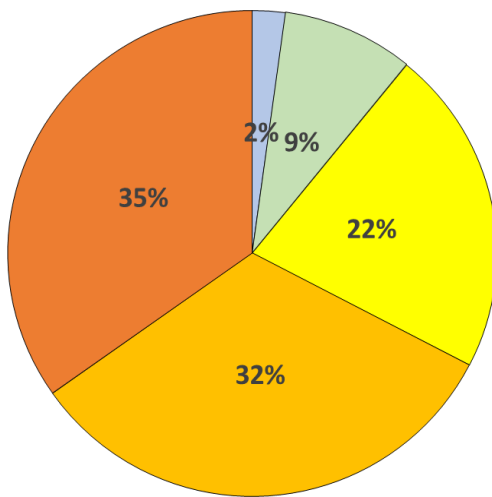


Figure 5a: Confidence

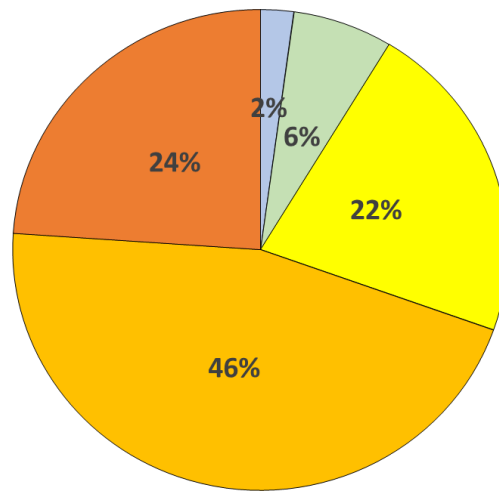


Figure 5b: Understanding of the lab

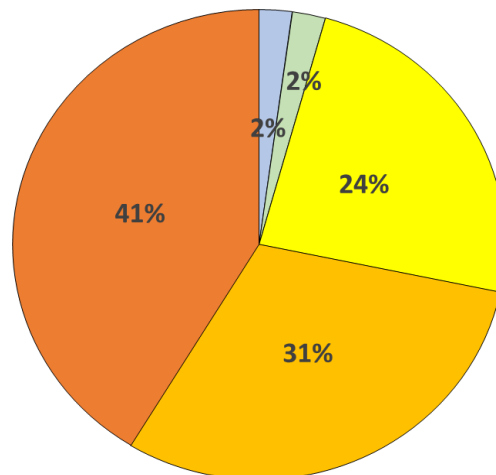


Figure 5c: Concepts

Figure 5: Perceptions of students after using the SDS PAGE video

Perceptions of Clemson Students after using the Introduction to the Spectrophotometer video for the Quantitative Biology lab: Forty one percent (**41%**) of the students reported that the video offered moderate to great levels of support, thus, bolstering their confidence, and nearly **35%** of the students felt the video enhanced their ability to conduct the Quantitative Biology lab. Thirty nine percent (**39%**) of the students reported that the videos helped them to gain key conceptual information. Rating categories for each item are presented in the Figures 7a, 7b, and 7c below.

■ not at all ■ a little ■ a fair amount ■ a moderate amount ■ a great amount

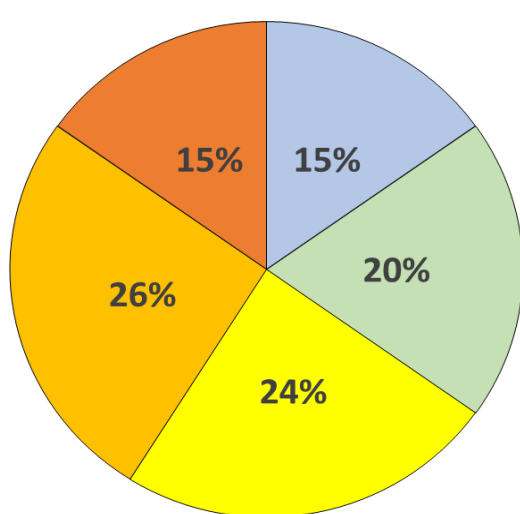


Figure 6a: Confidence

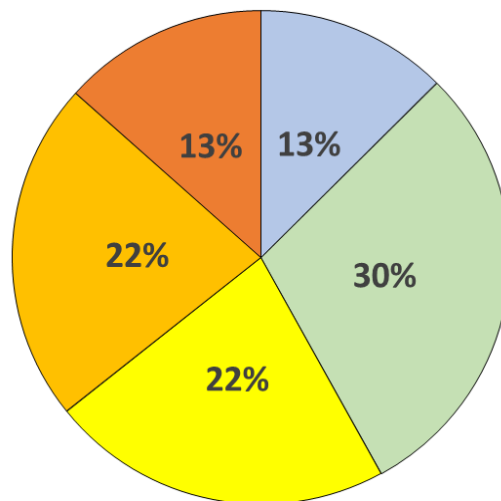


Figure 6b: Understanding of the lab

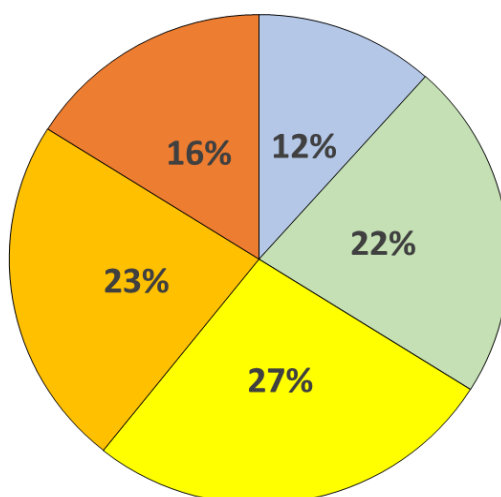


Figure 6c: Concepts

Figure 7: Perceptions of students after using the Spectrophotometer video

Perceptions of Clemson Students after using Introduction to the Light Microscope video for the Microscopy lab: Forty eight percent (48%) of the students reported that the video offered moderate to great levels of support in bolstering their confidence and 50% of the students felt the video enhanced their ability to conduct the Microscopy lab. Sixty three percent (63%) of the students reported that the video helped them to gain key conceptual information. Rating categories for each item are presented in the Figures 6a, 6b, and 6c below.

■ not at all ■ a little ■ a fair amount ■ a moderate amount ■ a great amount

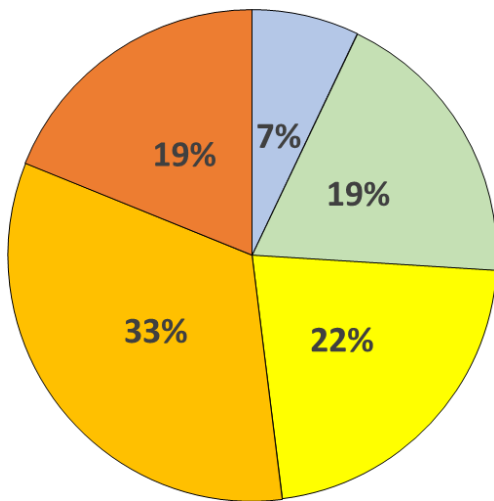


Figure 7a: Confidence

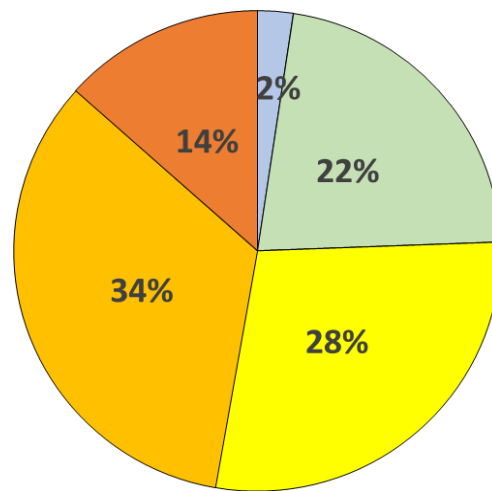


Figure 7b: Understanding the lab

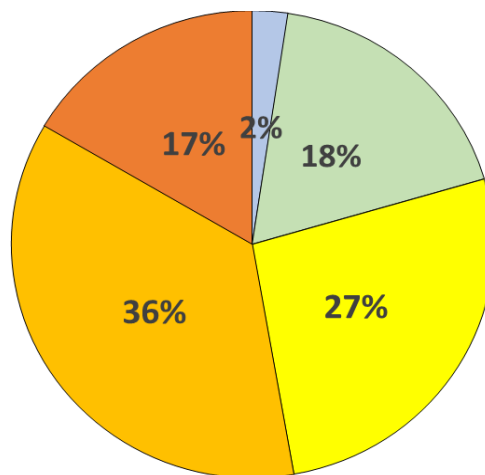


Figure 7c: Concepts

Figure 7: Perceptions of students after using the Light Microscope video

Summary of findings

DeSales University: In this study, we observed that watching video demonstrating scientific concepts and experiments before laboratory class has a significant impact on students' learning outcomes. On the Plasmid Purification lab, the outcome scores of students who watched videos were as much as two-fold higher in the pre- and post-lab assessments, as compared to the comparison group. In the SDS PAGE lab, students who watched videos scored as much as 42% higher than the comparison group in pre- and post-lab assessments. Our analyses show high statistical significance ($p < 0.001$) for these results.

The better performance of the video group in the post-lab assessment indicates long-lasting improvements and retention of the knowledge due to the video. Moreover, the results demonstrate that the video improved student learning of both the laboratory techniques and scientific concepts.

The students also reported positively on their perception of the videos. For the SDS PAGE video 89% students reported increased confidence, 91% reported better understanding of the laboratory and 96% reported better comprehension of the scientific concepts involved. For the Plasmid Purification video 78% students reported increased confidence, 80% reported better understanding of the laboratory and 85% reported better comprehension of the concepts involved.

Students reported higher confidence and understanding of concepts and experiment for the SDS PAGE video in comparison to the Plasmid Purification video. As a possible explanation, the lab instructor mentioned that the content covered in the Plasmid Purification video only mapped to one-third of the lab activities versus the content in SDS PAGE video mapped to most of the lab activities. This alone could have contributed towards students reporting lesser confidence about concept and the experimental steps in the Plasmid Purification lab, as the video only mapped to a portion of their lab and not the full lab.

Clemson University: Here we observed that watching video before lab led to improved performance for the Spectrophotometry lab but not for the Microscopy lab. In the experimental construct questions, the outcome scores of Spectrophotometry video group students were 20% and 12% higher ($p < 0.001$) in both pre- and post-lab assessments, respectively.

For the Spectrophotometry video 65% students reported increased confidence, 58% reported better understanding of the laboratory and 66% reported better comprehension of the concepts involved.

Analysis of pre- to post-assessment outcomes for the Microscopy lab indicates no significant differences due to video. Upon inspection of the data, we identified one likely cause—the students in both groups began with high levels of knowledge about the microscope. Thus, there was little room for improving their performance via the items on the assessment. Interview data, gathered from course teaching assistants and the professor

indicated that because microscopy is a basic topic often covered in high school, video and comparison group students entered the course with the same level of knowledge.

Although no significant differences were reported about improved performances in the Microscopy lab, students reported positive perception of the videos. 74% students reported increased confidence, 76% reported better understanding of the lab and 80% reported better comprehension of the concepts involved. Interviews with instructors revealed that they felt students in the video group appeared more confident during the Microscopy lab and handled microscopes better compared to past years' and comparison group students.

The results of this study show that watching JoVE videos pre-class significantly improves students' performance and learning experiences in undergraduate science laboratory classes. Because the study at DeSales University reported higher performance and perception of learning experience for video group students, it can be concluded that JoVE videos are especially effective for undergraduate science majors. As concepts and techniques get more complicated, learning from a visual platform like JoVE can contribute towards better performance and improved learning experience for college-level STEM students. These conclusions support integration of video-based learning tools in undergraduate science programs.

Disclosure: The costs of this study were reimbursed by JoVE.