

Instructional Videos, Conceptual Understanding and Self-Efficacy in the Time of COVID

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Abstract

Advances in technology offer new opportunities for teaching. Many students engage with online videos that enable them to watch, and re-watch these support materials flexibly and at their own pace. In our large-enrolment introductory first-year physics unit, many students find the content very challenging. To support their learning, we have developed short videos of 4-7 minutes explaining concepts and providing demonstrations of the problem-solving process. Our study was originally designed to evaluate and compare the effect on conceptual understanding and self-efficacy of students engaging with two different types of videos: screencasts (e.g. Khan Academy style) and lightboard videos, where the teacher presents direct to the camera on a writable transparent board (the image is then inverted to be the right way round). Then COVID struck, and all our learning was moved online. Thus, in the second semester of the study, we only used screencasts, and focused our research on exploring the relationship between online engagement, self-efficacy and conceptual understanding of students. We found that students preferred lightboards, and that both semesters' average survey scores on self-efficacy and conceptual understanding were generally stable or increased only slightly. This is at odds with other studies of similar cohorts. However, the small number of paired responses in our study meant that a self-selection bias may have skewed results. Scores on the conceptual understanding were weakly correlated with assessment performance, suggesting the presence of other contributing variables. Initial self-efficacy scores did not predict subsequent engagement. Instead, missing multiple early assessments was identified as a stronger predictor of failing to pass the subject.

Background

Self-efficacy and conceptual understanding are important aspects of student learning in physics. In this paper we will be exploring the relationship between self-efficacy and conceptual understanding with students using different video resources, how these change over the semester, and how these measures relate to assessment performance and student attrition.

Self-efficacy

The concept of self-efficacy was first developed by Albert Bandura in the 1980s as a person's "judgments of how well [she or he] can execute courses of action" (Bandura, 1982, p. 122), or in other words how well the person believes they can perform a particular task. Self-efficacy has been related to academic achievement and persistence in formal STEM education (Lent et al., 1986), and in physics in particular (Sawtelle et al., 2012). There is a gender divide, with female STEM students on average having a lower self-efficacy than comparably performing male STEM students (Marshman et al., 2018).

In the Australian context, Lindstrøm and Sharma (2011) developed the Physics Self-Efficacy Questionnaire to investigate the self-efficacy of first-year physics students over two semesters at The University of Sydney. One finding was that males had a higher self-efficacy than females, though this gender difference wasn't borne out in exam performance. Indeed, the group that scored the highest average self-efficacy was male students who had no prior formal instruction in physics. Another finding was that self-efficacy scores did not distinguish between those students who continued in physics, versus those that withdrew. Finally, over the students' first semester of physics, there was a statistically significant drop in self-efficacy. However, this wasn't the case in their second semester of physics, where there were no statistically significant differences in self-efficacy from the start to the finish of the subject.

Conceptual understanding

Student conceptual understanding has been a focus of physics education research arguably since studies using the Force Concept Inventory demonstrated the persistence of misconceptions about fundamental physics (Hestenes et al., 1992). Much subsequent research has focused on developing concept inventories to assess student understanding in different domains (Richardson, 2004), or on developing and evaluating pedagogical strategies to overcome misconceptions (e.g. Mazur (1997)).

Another approach has been to consider more broadly how students consider physics concepts and the nature of physics in general. For example, Adams et al. (2006) developed the Colorado Learning Attitudes about Science Survey, of which the 'Conceptual Understanding' category of questions evaluates respondents' views about whether physics is an independent collection of unrelated algorithms for solving repetitive textbook problems, or a more expert-view of physics as an inter-related framework of fundamental concepts that can be applied to understand real-world physical phenomena. They found that traditional teaching practices generally lead to a shift away from expert-like views.

Furthermore, Mazur (2010) found that quantitative problem-solving prowess was not a reliable predictor of conceptual understanding, with several of his students scoring full marks on complex quantitative problems, but zero on corresponding qualitative conceptual questions. Conversely, Steinberg and Sabella (1997) found that scoring well on tests of conceptual understanding was a good predictor of quantitative problem-solving performance.

Videos in education

Videos and other multimedia have been used for decades in education, but only relatively recently have they become an object of study in physics education research (Muller, 2008). Muller (2008) found that student learning from videos depended critically on their design, with greater conceptual learning gains resulting from including misconceptions, associated with a greater mental effort.

Short video lessons have proven to be effective in engaging students (Brame, 2016) and over recent years, students have been given short videos of 4-5 minutes explaining concepts and problem-solving (Hall et al., 2017; Loch, 2012; Loch et al., 2012; Loch & McLoughlin, 2012; Morris & Chikwa, 2014). Although videos are not inherently effective, Brame (2016) argues that they can be effective in engaging students if they are relatively short, and incorporate elements to decrease cognitive load and to increase student engagement and promote active learning.

Literature shows social cues, hand gestures and personalised experience have a big impact in decreasing the cognitive load, thereby increasing students' conceptual understanding (Mayer, 2009; Mayer & Fiorella, 2014; Paas & Sweller, 2014; Sweller, 1989) and self-efficacy (Schunk, 1981). Learning from instructor modelling is effective because watching an expert solving a problem helps prevent learners from engaging in extraneous cognitive processing that is irrelevant to the instructional goal. Also, as humans have evolved to observe and imitate the behaviours of others, learners may be able to actively interpret the actions of a model without the risk of cognitive overload (Paas & Sweller, 2014). Screencasts and lightboards (Figure 1) are being used by many academics to increase the personalised experience. In screencasts (Khan-style videos) students can only see what the instructor writes on the screen of the tablet. In lightboard videos, the instructor writes on a glass board which is placed between the video camera and the presenter. In this recording, the instructor faces the audience while he/she writes on the lightboard. Lightboard videos can provide more personalised experiences as students can see the hand gestures, body movement, and eye movement of the presenter. In this study we will compare student engagement with these two different kinds of videos and will provide a rationale for their use.

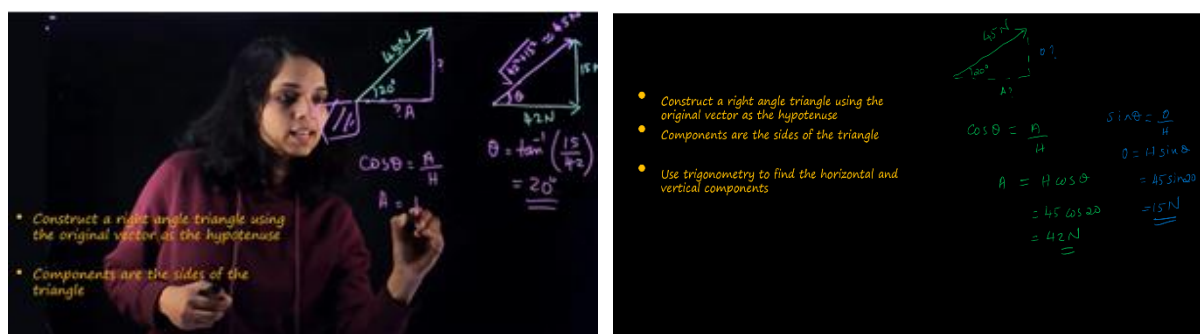


Figure 1: Screenshots of lightboard (left) and screencast videos (right)

Research aims

In this study, self-efficacy and conceptual understanding were measured at the beginning and end of the physics semester, over two iterations. In the first iteration, with a generalist introductory physics class (PHY10002), two types of videos were used with students: Screencasts and lightboards. In the second semester, a combination of screencasts and narrated PowerPoint presentations were used in a core physics subject for physics and engineering majors: *Electronics and Electromagnetism* (PHY10004). The study was designed to investigate the following research questions:

First iteration – PHY10002

1. Do students prefer watching one video form to the other, and does this preference have any relation to student self-efficacy or conceptual understanding?

Both iterations – PHY10002 & PHY10004

2. Do self-efficacy or conceptual understanding shift over the semester?
3. Does conceptual understanding on the survey correlate with performance on conceptual exam questions and other assessments?
4. Do initial measures of self-efficacy predict student attrition?

Context of the study

PHY10002 is a large-enrolment first-year introductory physics unit at Swinburne University of Technology, a technology-focused university in Melbourne, Australia. The unit is 12 weeks long and is mainly taken by novice students having little or no prior knowledge in physics. The formal and informal feedback for this subject reveals that many students consider physics to be one of the hardest units and they struggle to understand the concepts. Analysis of students' exam performance suggests that their academic performance and conceptual understanding in physics is low even after completing this unit. Our perception has been that students often seem stuck in understanding the concepts and require more time with the experienced teacher to help them understand the concepts.

Each week of semester there were three 1-hour lectures to cover the content, complemented by a 1-hour tutorial. This is perhaps insufficient to cover concepts at the slower pace required by many students. Furthermore, some students cannot even attend all the activities because of other commitments. To support students, video lessons were initially developed as supplementary resources. When all learning moved online due to the COVID-19 pandemic, videos became the central teaching and learning delivery mode. As mentioned earlier (cf. Figure 1), screencasts and lightboard videos are two different kinds of videos that have been produced. Lightboard videos can have a big impact on increasing the conceptual understanding and self-efficacy of students as they can provide more social cues and personalised experience (Mayer, 2009; Mayer & Fiorella, 2014; Paas & Sweller, 2014; Schunk, 1981).

In the first semester of this project, each video was made on two different platforms and students could watch the videos as per their preference. Each pair of videos had exactly the same content and differed only in the platform. These videos were posted in the ECHO360 platform of the Learning Management System (LMS). We then studied how students engage with these videos, and their impact on self-efficacy and conceptual understanding. This project thus will provide the rationale in using the screencast or lightboard videos (or any personalised videos) in blended or online learning and will suggest ways to improve conceptual understanding and self-efficacy of students.

Formal prior physics instruction seems to have some impact in determining the self-efficacy of students (Cervone & Palmer, 1990; Lindstrøm & Sharma, 2011). Also, there seems to be some correlation between academic achievement and self-efficacy. PHY10004 is another first year physics unit taken by engineering students. Most of these students had prior formal instruction in physics. Even with their prior physics knowledge, similar cohorts seem to have less conceptual understanding and have many persistent misconceptions (Greaves et al., 2018). In this study we will be looking at how self-efficacy and conceptual understanding changed in two different physics units (PHY10002 & PHY10004), and if formal instruction has an impact. This will enable comparisons with the work of Lindstrøm and Sharma (2011), who studied the self-efficacy of ostensibly similar cohorts of physics students.

Methods and Instruments

The study was conducted over two twelve-week long semesters in 2020 for different physics units. In Semester 1, for the PHY10002 unit, videos in both formats were posted on the Learning Management System (LMS). That is, for each topic, students had the choice of

watching videos on the same topic in either format. There were 13 videos covering topics such as motion in two dimensions, Newton's laws, work, energy, and power.

A pre-post study design was used. At the start of semester, the third author (who was not involved in teaching the unit) posted a short video on the LMS promoting the study and inviting students to take part. Students were invited to complete a brief anonymous survey with questions on their self-efficacy regarding learning physics and on their conceptual understanding of physics (see the text of the survey questions in the Appendix). Several reminder invitations were posted to the LMS.

At the end of semester, the process was repeated, but with the addition of several questions about their use of and preferences towards screencasts versus lightboards (see Appendix). In line with our ethics approval (Swinburne approval code SUHREC 20201537-3804), student responses were only shared with teaching staff after assessment results had been finalised for the semester.

During the third week of semester 1, the onset of the COVID-pandemic meant all learning moved to online delivery. We hypothesised that this change could affect self-efficacy and attrition. Therefore, in semester 2, for the PHY10004 unit, the survey design was altered to focus solely on self-efficacy and conceptual understanding, rather than examining the student engagement with videos. Additionally, we collected data to evaluate if the pre-test measures of students' self-efficacy predicted student attrition. In both units, self-efficacy was measured using the survey instrument (cf. the first five questions in the Appendix) used in the Lindstrøm and Sharma (2011) study, and conceptual understanding (cf. the latter eight questions in the Appendix) was investigated using the questions from Adams et al. (2006). Although these original instruments were created on a 5-point Likert scale, some data was accidentally collected on a 7-point Likert scale. These responses have been scaled using a linear transformation to a 5-point scale.

Results and Discussion

Survey data was collected over two semesters using a pre-post approach. Responses were tracked using codes to match pre- and post-responses from the same students, to better make judgements about shifts over the semester (see Table 1).

Table 1: Number of responses over both semesters

	Pre-test	Post-test	Matched	Total enrolments
Semester 1	42	21	11 (6.0%)	184
Semester 2	65	33	18 (4.9%)	371

RQ1: Do students prefer watching one video form to the other, and does this preference have any relation to student self-efficacy or conceptual understanding?

We investigated this research question in Semester 1 using two approaches. The first was to include a question in the post-test survey about their preference of either video type (i.e. screencasts versus lightboards), see Table 2. These data do not suggest a strong preference for

either platform. Furthermore, since only three of the 11 matched responses indicated a preference for one platform over the other, we are unable to distinguish if either platform was more effective in developing conceptual understanding or self-efficacy.

Table 2: Survey responses about preferred video mode

	Lightboards	Screencasts	Both equally	Didn't watch either
# of responses	3	5	8	1

However, we were able to indirectly investigate preferences by examining viewing statistics for the different types of video, by collecting learning analytics data from the ECHO360 of the LMS. In Figure 2, the percentage of each video that has been viewed, across all students in the subject (for example, if 40% of students watched 50% of a video, this would show up in the chart as an average of $0.4 * 0.5 = 20\%$ viewed), has been plotted for all videos. The graph shows a clear preference towards lightboards. In Semester 2, when under the pressures of the COVID-19 pandemic, we switched all learning to be online, the videos were a mix of screencasts and narrated PowerPoint presentations.

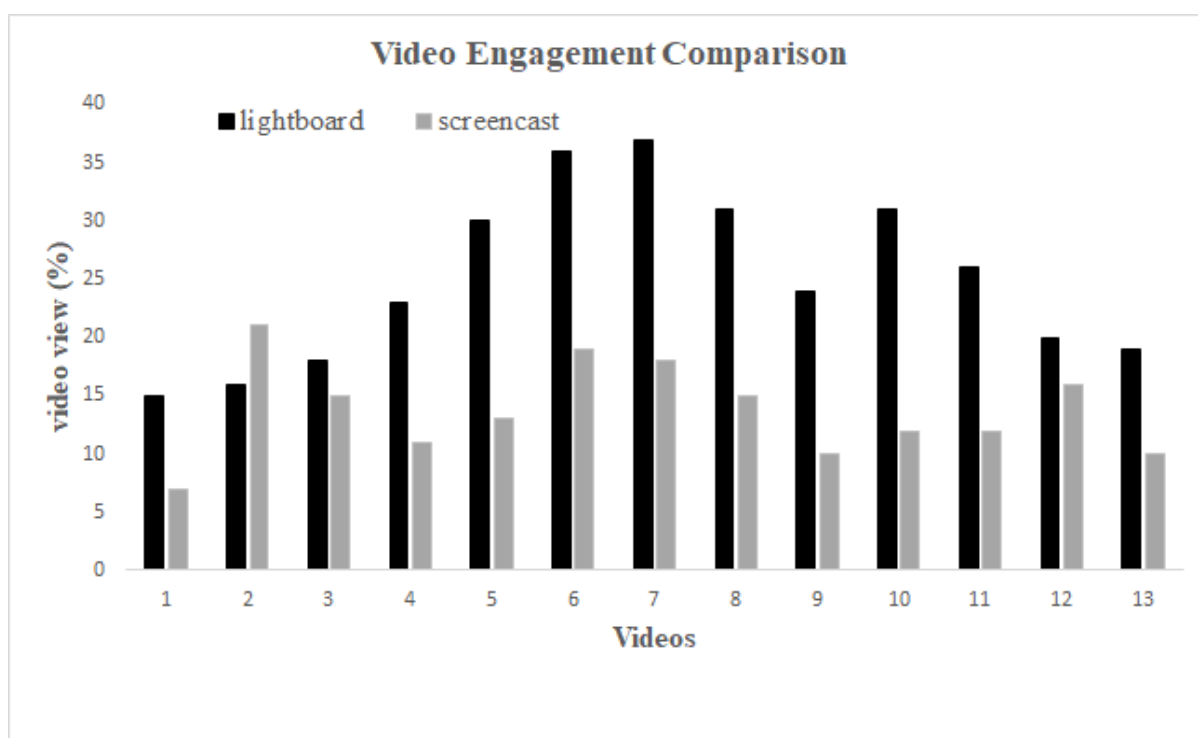


Figure 2: Comparative engagement for lightboard videos versus screencasts

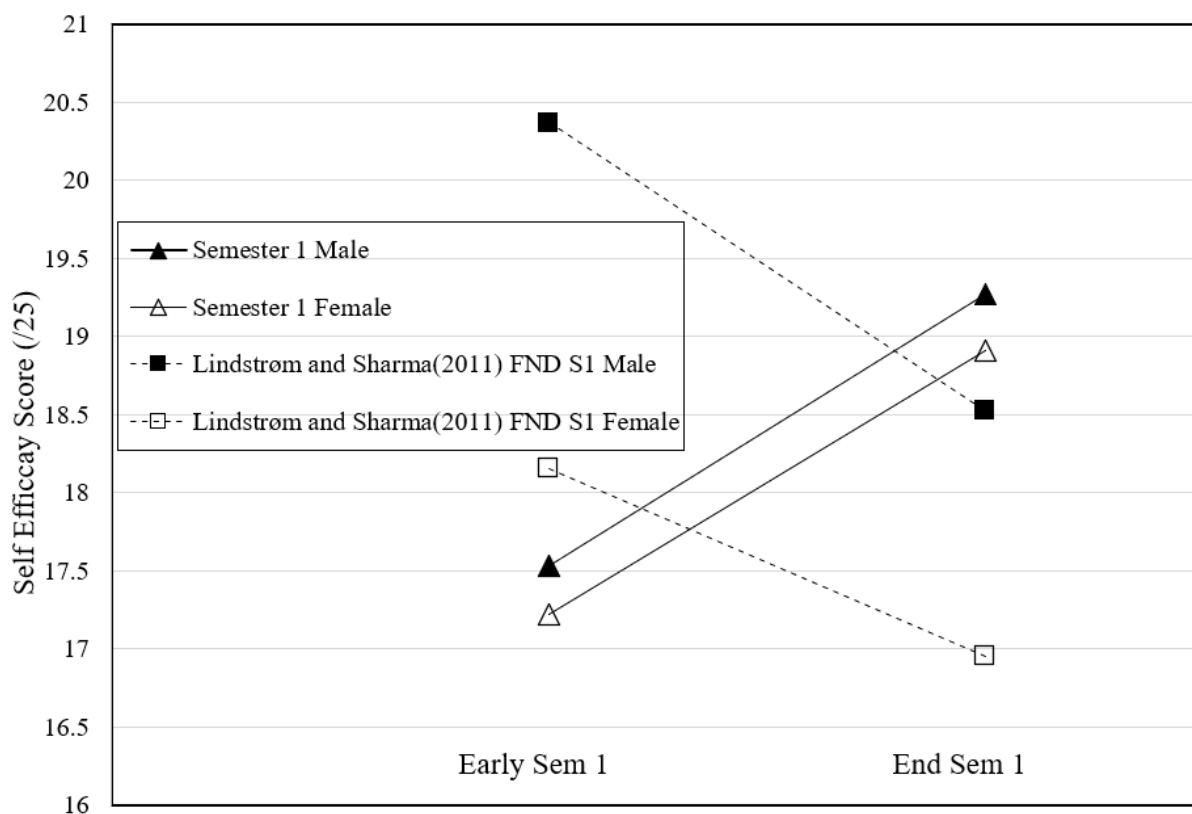
RQ2: Do self-efficacy or conceptual understanding shift over the semester?

By matching responses from pre- and post-test surveys, in both semesters 1 and 2, we were able to calculate shifts in self-efficacy and conceptual understanding (at least as operationalised as scores on the two sets of questions we used). Note in Table 3, that as the scores on the Likert scale questions are simply summed to generate the scores, the range of scores on Self-efficacy is 5-25, while the range of scores on Conceptual understanding is 8-40.

Table 3: Matched pre-/post-test scores on self-efficacy and conceptual understanding

	Semester 1 (N=11)		Semester 2 (N=18)	
	Pre(SD)	Post(SD)	Pre(SD)	Post(SD)
Self-efficacy (/25)	17.4 (3.6)	18.7 (2.4)	19.6 (3.4)	20.1 (3.3)
Conceptual understanding (/40)	22.0 (6.4)	25.15 (4.2)	28.1 (4.2)	27.6 (4.6)

A couple of observations are worth making. First, with regard to self-efficacy, the observations here are somewhat at odds with the findings from Lindstrøm and Sharma (2011). In Semester 1, scores for self-efficacy increased. The introductory physics unit from which this data was collected is perhaps most like the Foundation Physics unit described by Lindstrøm and Sharma (2011). In Figure 3, our findings, further broken down by gender, have been plotted with Lindstrøm and Sharma's data.

**Figure 3: Comparing pre-/post self-efficacy scores for introductory-level students**

We found an opposite trend to Lindstrøm and Sharma (2011), who found that there were significant drops in self-efficacy over the semester. This was surprising as we had suspected the shift to online instruction during the semester might lead to a greater reduction in self-efficacy than Lindstrøm and Sharma had observed in a purely face-to-face context. However, given the low rate of matched responses (~6%), this could be a self-selection effect where it is

only the most motivated students that responded to both surveys. Nevertheless, this pattern of small increases in self-efficacy was also observed in Semester 2 (Figure 4). This is more consistent with the findings of Lindstrøm and Sharma (2011), who found that in the 2nd semester of physics study, more advanced students reported a higher self-efficacy, and small average gains were observed over the semester. These small but positive increases in measured self-efficacy mean we have no evidence that the shift to online instruction under COVID-19 negatively impacted students' self-efficacy with regard to learning physics.

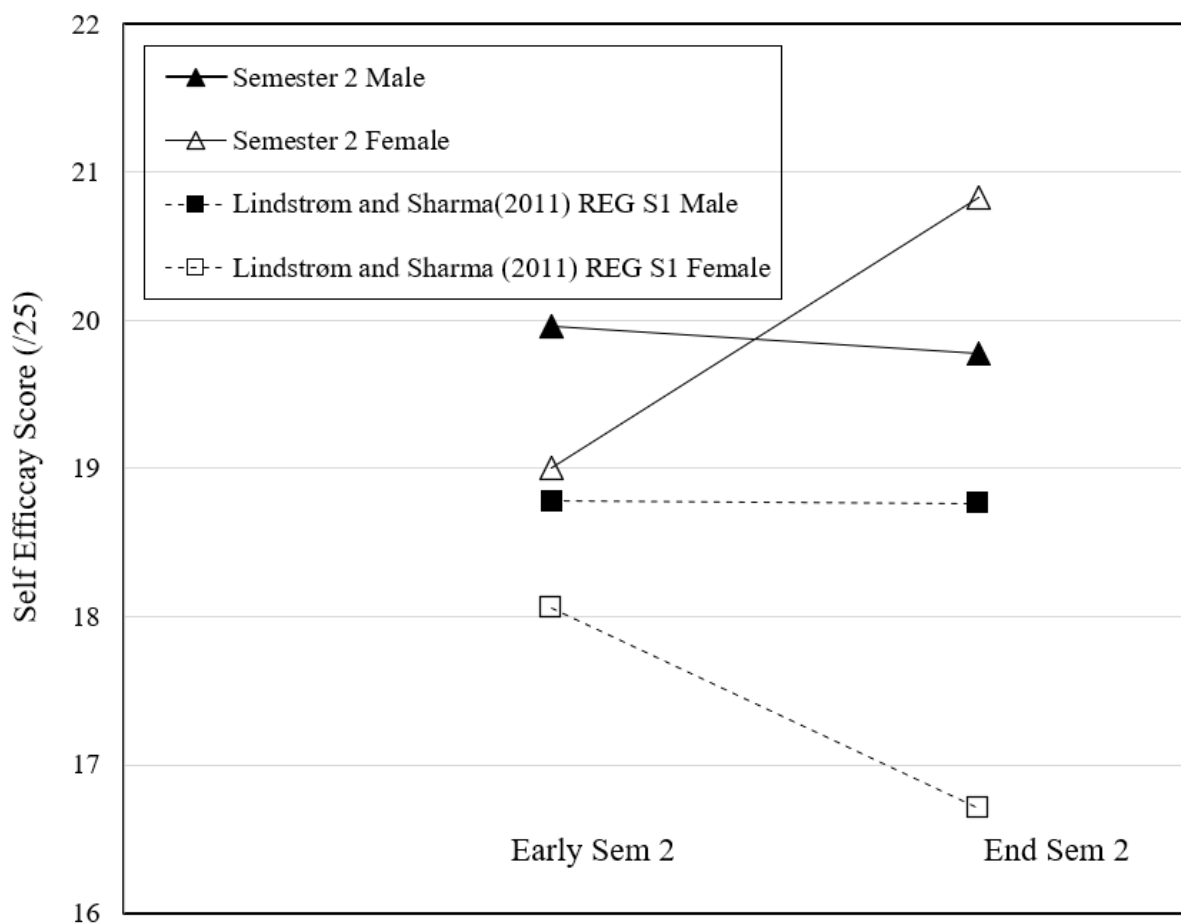


Figure 4: Comparing pre-/post self-efficacy scores for more advanced students

With regard to conceptual understanding, the largest shift was observed in Semester 1, with an average normalised gain $g = 0.18$. Note that “average normalised gain” is calculated as

$$g = \text{observed gain} / \text{maximum possible gain}.$$

This measure was popularised by Hake in his seminal paper (1998). This is a partial validation of the teaching approaches, as shifts *away* from a deep, expert-like approach to learning (i.e. a lower score on this measure of conceptual understanding) have been observed with traditional teaching practices (Kember & Gow, 1994).

RQ3: Does conceptual understanding on the survey correlate with performance on conceptual exam questions and other assessments?

Arguably, one test of the validity of the conceptual understanding of physics measure is the extent to which it predicts performance on subsequent assessments. The summative examination at the end of semester comprises a mix of conceptual and quantitative problem-solving questions.

In Figure 5 and

Figure 6, exam performance, for both the subset of conceptual questions and the overall score on the whole exam, has been plotted against scores on the conceptual understanding of physics survey, for PHY10002 and PHY10004 respectively.

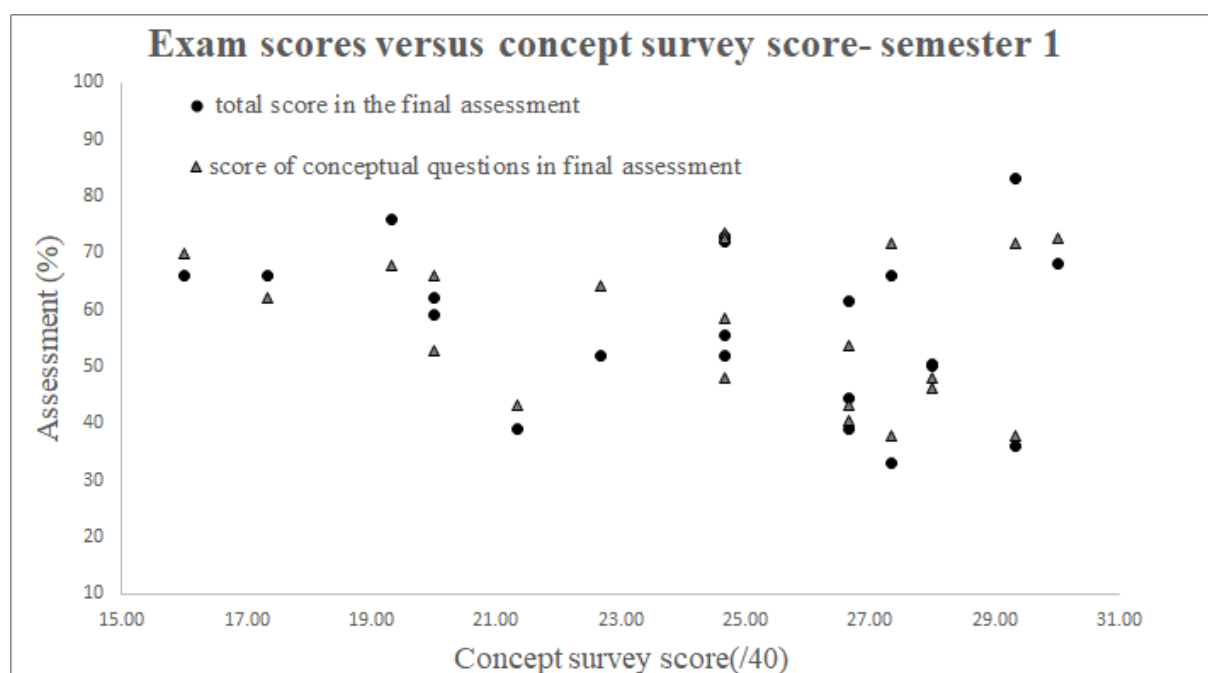


Figure 5: Do concept survey scores predict assessment performance in PHY10002?

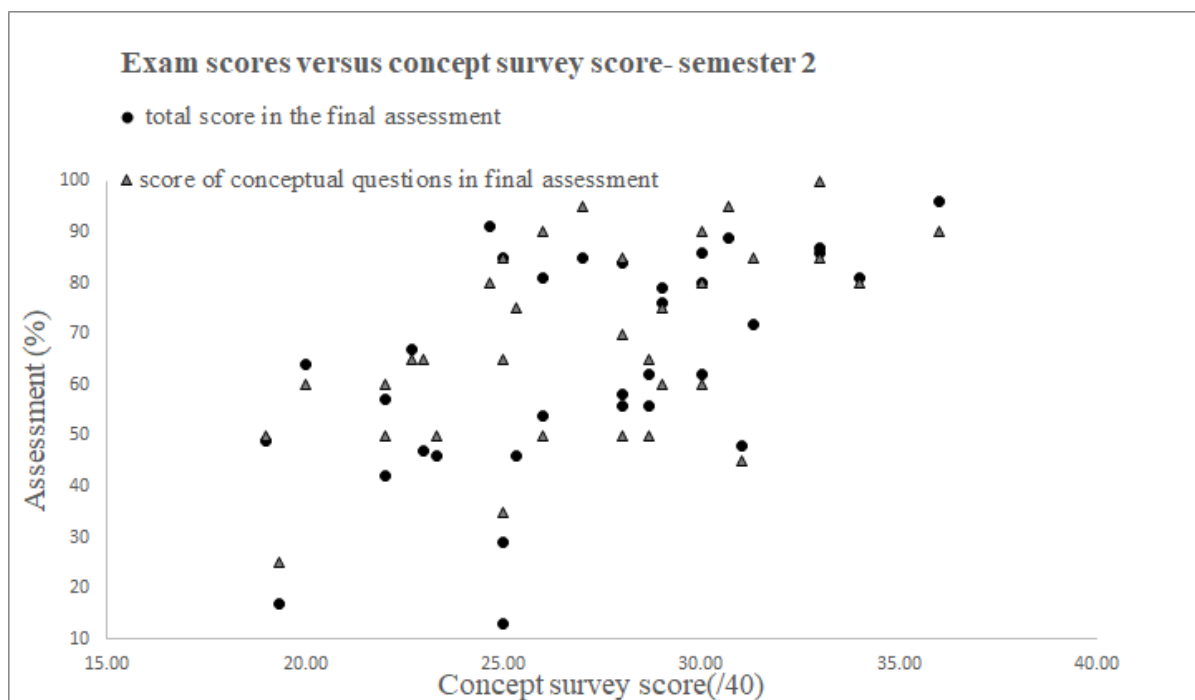


Figure 6: Do concept survey scores predict assessment performance in PHY10004?

With the PHY10002 cohort, there seems to be little relationship between the scores on the conceptual survey questions, and exam performance. However, it should be noted that few of these scores are above the mid-point of the survey range of 24. Conversely, with the PHY10004 cohort there is a weak positive relationship. These observations are borne out by correlational analysis (Table 4).

Table 4: Correlation analysis of conceptual post-test scores with assessment performance

Correlations with post-test conceptual understanding survey	With conceptual exam questions	With whole-exam performance
Semester 1 (PHY10002) (N=21)	$r=-0.27$ $r^2=0.071$	$r=-0.23$ $r^2 = 0.052$
Semester 2 (PHY10004) (N=33)	$r=0.56$ $r^2 = 0.31$	$r=0.59$ $r^2 = 0.35$
Combined	$r=0.38$ $r^2=0.14$	$r=0.39$ $r^2=0.15$

For PHY10004, these small but positive correlations suggest that conceptual understanding of physics does indeed predict assessment performance, but that there are other contributing variables. These could include motivation, work ethic, grit, or others, and is a potential topic of future research.

RQ4: Do initial measures of self-efficacy predict student attrition?

Retention and attrition are important considerations in university education. Being able to identify at-risk students early allows for the possibility of targeted mechanisms to better support students to achieve their learning goals. Our final topic of investigation was therefore focused on identifying predictors of student attrition. We first considered measures of self-efficacy, and in Table 1, have compared self-efficacy pre-test scores against subsequent engagement in the unit as operationalised by participation in assessment (noting that both subjects in question involve a large number of small assessment tasks such as quizzes and lab reports).

Table 5: Self-efficacy as a predictor of engagement

Engagement	Self-efficacy pre-test average
Engaged students (those who sit the exam and miss less than 10 of the assessments [N=44])	18.7
Disengaged students (those who complete the pre-test, but miss 10 or more of the assessments or don't sit the final exam [N=21])	18.0

These data suggest that the self-efficacy pre-test score is not a strong indicator of subsequent engagement. Instead, we sought other predictors and questioned whether completion rates of the large number of small assessments might reveal relevant patterns. Between tutorial worksheets, lab reports, and homework assignments, there are 14 low-stakes assessments in the first 4 weeks of semester. In Figure 7 and Figure 8, we have broken down students' final grade in each of the two subjects, by the number of missed assessments in these first four weeks. These graphs show that roughly three-quarters of students who miss more than two of these early assessments go on to fail the subject. The implication for future practice is that missing two assessments could be a useful trigger for an intervention to offer support to students, as missing more most often leads to poor outcomes.

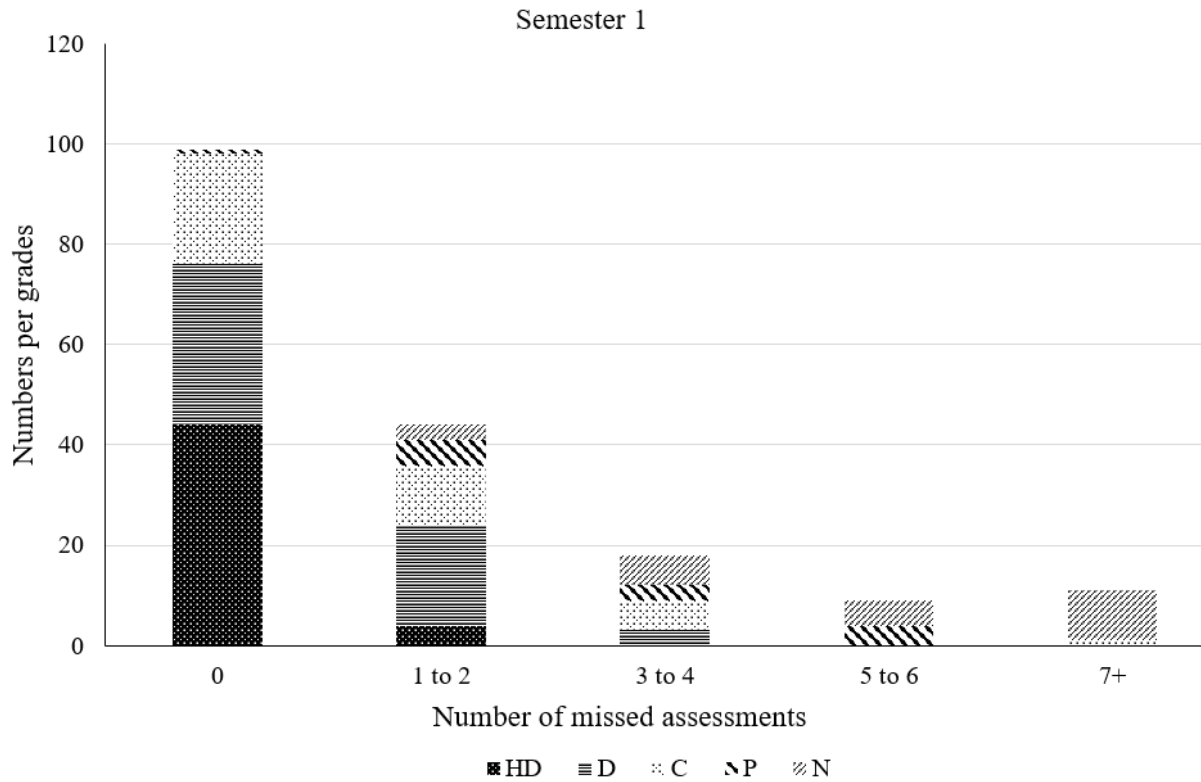


Figure 7: Final grades by number of missed assessments in first 4 weeks - PHY10002

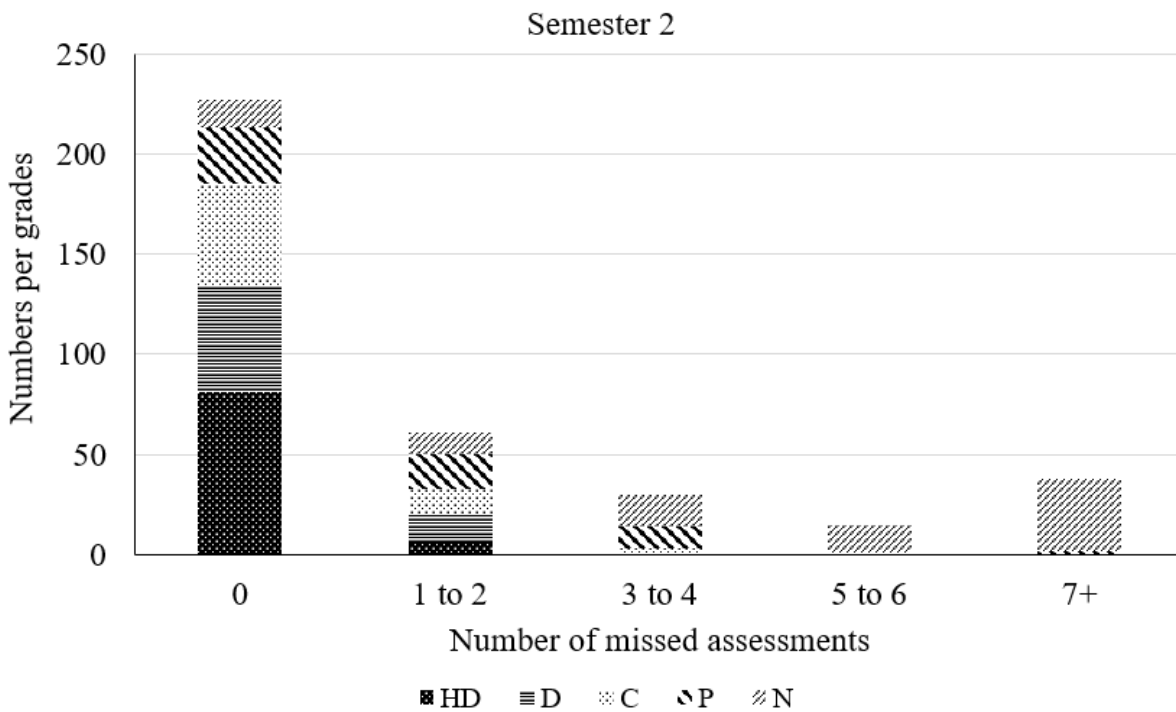


Figure 8: Final grades by number of missed assessments in first 4 weeks – PHY10004

Conclusion

In this study, we investigated four research questions:

1. Do students prefer watching one video form to the other, and does this preference have any relation to student self-efficacy or conceptual understanding?
2. Do self-efficacy or conceptual understanding shift over the semester?
3. Does conceptual understanding on the survey correlate with performance on conceptual exam questions and other assessments?
4. Do initial measures of self-efficacy predict student attrition?

RQ1: In the survey responses, there was no evidence of a strong video preference, and therefore we were unable to relate video preferences to self-efficacy or conceptual understanding. However, viewing statistics from the Learning Management System showed a clear preference towards lightboards.

RQ2: With students of PHY10002, we observed small increases in average self-efficacy, at odds with the findings of Lindstrøm and Sharma (2011), who observed the opposite. Scores for PHY10004 students were comparatively stable over the semester. However, with both subjects, the number of students who responded to both the pre- and post-test surveys, thus allowing us to track changes over the semester, was less than 6%, and therefore unlikely to be representative of the whole cohort.

RQ3: We found only a weak relationship between conceptual understanding and assessment performance. One surprise was that for PHY10002 students, almost half of whom scored below the mid-point of the survey score range, the correlation was insignificant ($r^2 \sim 0.06$). Conversely, for PHY10004 students who almost all scored above the mid-point of the survey score range, the correlation was much stronger ($r^2 \sim 0.33$). In any case, conceptual understanding, as measured by the survey, only predicts *some* of the variation in assessment performance. It is interesting to consider what the other contributing factors may be.

RQ4: We found that initial measures of self-efficacy in physics, as measured by our survey instrument, were not a reliable predictor of subsequent engagement in the subject. Instead, we found that early disengagement with assessment (i.e. missing more than two of the first few weeks' worth of low-stakes tutorial and lab assessments) was a much better predictor.

Areas of future research include collecting larger data sets to allow for more meaningful statistical analysis, evaluating different interventions to reduce attrition, and investigating other contributing variables to student performance beyond self-efficacy and conceptual understanding.

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Appendix

Text of survey instrument

Self efficacy:

1. In my most recent, relevant experience of studying Physics, I generally manage to solve difficult physics problems if I try hard enough.
2. With my relevant experience in Physics, I know I can stick to my aims and accomplish my goals in physics.
3. With my recent experience in Physics, I know I can remain calm in my physics exam because I know I have the knowledge to solve the problems.
4. I know I can pass the physics exam if I put in enough work during the semester.
5. The motto 'If other people can, I can too' applies to me when it comes to physics.

Conceptual Understanding and Connections:

6. After I study a topic in physics and feel that I understand it, I have difficulty solving problems on the same topic.
7. A significant problem in learning physics is being able to memorize all the information I need to know.
8. Knowledge in physics consists of many disconnected topics.
9. I do not expect physics equations to help my understanding of the ideas; they are just for doing calculations.
10. If I don't remember a particular equation needed to solve a problem on an exam, there's nothing much I can do (legally!) to come up with it.
11. Spending a lot of time understanding where formulas come from is a waste of time.
12. If I want to apply a method used for solving one physics problem to another problem, the problems must involve very similar situations.
13. If I get stuck on a physics problem, there is no chance I'll figure it out on my own.

Semester 2 survey had an extra question "Which Physics course have you completed most recently?" to capture their previous physics knowledge. This question was not asked in the Semester 1 survey as most students in that unit had not completed formal instruction in physics.