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Developing Web-Assisted Learning Modules in Vector Dynamics

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Abstract

Online learning tools were developed by the authors at California State Polytechnic University, Pomona in an effort to improve student outcomes in a Vector Dynamics course. These tools include (1) a series of narrated video tutorials that show students step-by-step how to solve typical dynamics problems and (2) simulations of typical dynamics scenarios. The video tutorials were created using Camtasia Studio and the simulations were created using Working Model 2D. The impact of the learning tools on student outcomes were evaluated by comparing student performance in a web-assisted version of Vector Dynamics that included the learning tools to student performance in a regular version of the course that lacked the learning tools. Although results were inconclusive, the web-assisted section demonstrated minor improvement during the second half of the course. Additionally, students in the web-assisted section who did not view all the video tutorials performed worse than students who viewed all the video tutorials at least once.

1. Introduction

Vector Dynamics is one of the most challenging lower-division courses for engineering students since it requires a strong mathematical background, a basic understanding of industrial applications, and effective problem-solving skills. At California State Polytechnic University, Pomona (Cal Poly Pomona), Vector Dynamics is a bottleneck course due to a high number of failures and repeats, hindering many students from advancing in their engineering curricula and resulting in a high attrition rate.

Based on past teaching experience, students often have difficulty visualizing the abstract concepts discussed in Vector Dynamics. Students also struggle with relating those abstract concepts to familiar situations, leading to failure in understanding the underlying physical principles taught in the subject. Compounding these issues is the ambitious syllabus for Vector Dynamics at Cal Poly Pomona, covering topics such as kinematics of particles, kinetics of particles, kinematics of rigid bodies, and kinetics of rigid bodies within a 10-week academic term. The rapid pace of the course means there often is not enough time to go through a sufficient number of examples in the classroom. The project discussed in this paper was intended to help remedy these problems, ultimately increasing the retention rate of engineering students through improvements in their academic performance in Vector Dynamics.

The authors created video tutorials and virtual simulations to help students visualize dynamics concepts, as well as relate the theory and math to engineering problems.

1) The video tutorials were created for topics that students traditionally have the most difficulty mastering using the screen and voice capture software Camtasia Studio. In the tutorials, students are guided step-by-step through example problems and theory. The tutorials were designed to be short (< 10 min) in order to hold student's attention better,[1,2] as well as modular to allow students to focus on one concept at a time.

2) The virtual demonstrations illustrating dynamics concepts were simulated using the software package Working Model 2D. This software allows the instructor to set up typical dynamics scenarios and then observe how the position, velocity, and acceleration of objects change in time.

Both the videos and simulations were implemented in a "web-assisted" section of Vector Dynamics. Eight video tutorials demonstrating example problems of key topics in Vector Dynamics were delivered to students through the online learning management system, Blackboard. Students were able to watch the tutorials as many times as needed to fully understand a concept. Simulations of projectile motion and rolling without slipping were demonstrated in the classroom. It was hoped that the simulations would allow students to visualize these concepts better and retain students' attention longer since Bunce et al. (2010) have shown that non-lecture pedagogies are correlated with higher rates of attention.[3] The impact of the learning tools on student performance is evaluated by comparing student test scores in the web-assisted version of Vector Dynamics to student test scores in a regular version of the course that lacked the learning tools. The impact of viewing the video tutorials on student performance in the web-assisted class also is examined.

2.1 Development of video tutorials

Eight video tutorials were created by the authors for this study. The authors selected typical Vector Dynamics problems that show key topics in Vector Dynamics applied to different scenarios (Table 1).

Table 1: List of video tutorials used in this study

Video	Topic	Scenario	Length
V1	kinematics of particles	Projectile motion	8:50
V2	kinematics of particles	Relative motion of airplanes	2:29
V3	kinetics of particles	Mass sliding on moving ramp	3:35
V4	kinetics of particles	Mass suspended by string	5:08
V5	kinematics of rigid bodies	Linkage	9:40
V6	kinematics of rigid bodies	Connected sliders moving in guides	8:46
V7	kinetics of rigid bodies	Wheel rolling without slipping	6:47
V8	kinetics of rigid bodies	One-point constrained motion	5:51

Each video tutorial was created using a combination of PowerPoint and Camtasia Studio. Prior to recording, the authors created an animated PowerPoint presentation that reveals equations and images in a sequential manner as the narrator discusses the problem. The authors decided to use animated PowerPoint slides to deliver visual content for the following reasons:

- Equations and images created in PowerPoint are clearer than if a narrator drew them by hand. Additionally, it takes less time to reveal equations and images created in PowerPoint than to draw them by hand, reducing the length of the video tutorial.
- The narrator does not need to be concerned with drawing equations and images during the recording, allowing the narrator to focus on both discussing and explaining the content in the tutorial.

- Revealing content sequentially on a slide, instead of all at once, allows the viewer to focus on the equation or image currently being discussed and reduces the possibility of being distracted by content that will be discussed at a later time.

A script for the narrator was created along with the animated PowerPoint presentation to ensure the narration matches the content on the screen. The script also prevents the narrator from straying off topic, further reducing the length of the video tutorial. Additionally, the script can be used to create captions to ensure the videos meet American with Disabilities Act (ADA) requirements.

The Camtasia Studio add-in within PowerPoint was used to record each video tutorial. During the recording, the narrator's face and body are not shown in the video, but the narrator was a faculty member that is well-known to many students so that a familiar voice may further enhance the students' motivation to learn.[2] The authors decided to use Camtasia Studio and omit video of the narrator for the following reasons:

- Camtasia Studio is a screen and voice capture software that allows the user to record in high-definition (HD) and gives the user many editing options after the recording is completed.
- Omitting video of the narrator allows the viewer to focus solely on the content and reduces production costs since a film crew and expensive filmmaking equipment are not needed. The only costs are the Camtasia Studio software and the faculty member's time.

Following recording, the videos were edited using Camtasia Studio. The videos were produced in HD quality and closed captions were added to meet ADA requirements. The captions also may benefit students for whom English is their second language; over half of the students in the Mechanical Engineering Department at Cal Poly Pomona are Hispanic or Asian/Pacific Islander. Figure 1 shows screenshots from tutorial V1.

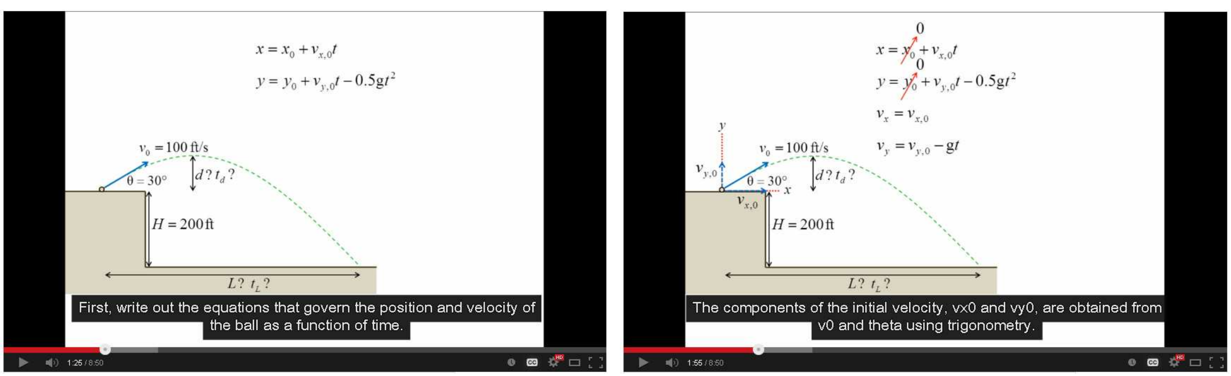

Figure 1: Two screenshots from a video tutorial showing how to solve a projectile motion problem (V1). The screenshots are taken 30 seconds apart, demonstrating how images and equations are revealed sequentially. The images were obtained from the department's YouTube channel with the closed captions feature turned on.[4]

2.2 Development of simulations

Two simulations were created to help students visualize typical Vector Dynamics scenarios (Table 2). Both simulations were created using the Working Model 2D software. The software allows the instructor to construct virtual 2D models and simulate the resulting dynamic motion. Velocity, acceleration, and force vectors of different points on the models can be displayed and the student can observe how these quantities change in time.

Table 2: List of simulations used in this study

Simulation	Topic	Scenario	Length
S1	Kinematics of particles	Projectile motion	0:30
S2	Kinetics of rigid bodies	Wheel rolling without slipping	0:55

Although Vector Dynamics students are taught how to calculate the trajectory, velocity, and acceleration of objects mathematically, they often are not given visual confirmation of their results through the use of simulations or live demonstrations. This can lead to confusion when non-intuitive results are obtained. For example, students are often surprised to find the velocity is zero at the bottom of a wheel that rolls without slipping and is a maximum at the top of the wheel. The S2 simulation (Figure 2) shows students how the velocity and acceleration vectors of points on the wheel vary with time as the wheel rolls along the ground.

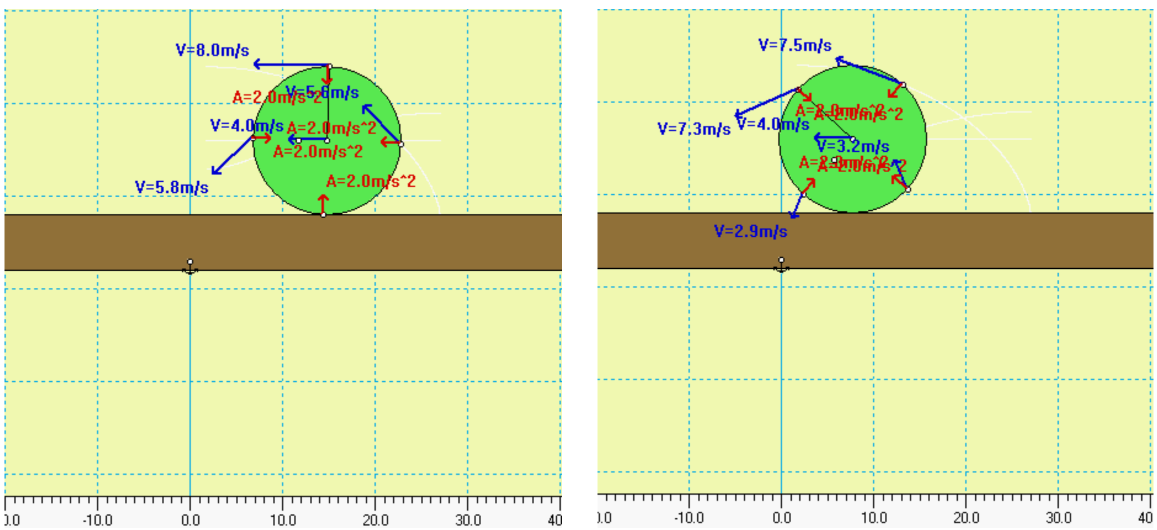

Figure 2: Two screenshots from a Working Model 2D simulation of a wheel rolling without slipping (S2). The screenshots are taken 15 seconds apart, demonstrating how the wheel moves in time. Velocity vectors (in blue) and acceleration vectors (in red) of five points on the wheel are shown. Faint white lines reveal the path of the five points during the simulation.

3. Implementation of learning tools in the classroom

The impact of the video tutorials and simulations alone on student learning were evaluated by comparing student performance in a "web-assisted" section of Vector Dynamics (Section A) that included the learning tools, to student performance in a "regular" section of the course that lacked the learning tools (Section B). The two sections met back-to-back on the same days. In order to eliminate the influence of teaching and grading styles, the same team member taught one section of the web-assisted course and one section of the regular course in the same 10-week academic term (Winter Quarter 2013). As seen in Table 3, both the web-assisted and regular sections of Vector Dynamics had similar number of students (27 versus 29). However, the percentage of students repeating the course was higher in the web-assisted class (59%) compared to the regular class (48%), which may have impacted the results discussed below.

Table 3: Number of first-time students and repeat students in the web-assisted and regular sections of the Vector Dynamics course

	Number of first-time students	Number of repeat students
Section A, web-assisted	11 (41%)	16 (59%)
Section B, regular	15 (52%)	14 (48%)

During the academic term, four quizzes, a midterm examination, and a final examination were given to both sections on the same days (Table 4). A pair of video tutorials were made available following each exam, starting with Quiz 1. The two tutorials discussed concepts that were directly relevant to the next exam. For example, V1 and V2 discussed concepts that appeared on Quiz 2, which took place two weeks later. Once a video was made available to students, it remained accessible for the remainder of the academic term.

The number of views for each video was tracked by uploading the video tutorials to a local server and permitting access only to students in Section A. Links to the videos were provided to the Section A students through the university's learning management system, BlackBoard. In order to watch a video, students were required to log in with their university's userid. BlackBoard recorded the student userid and video number each time a student watched a video.

Both simulations were shown and discussed in class during Week 8 to Section A only. It was the authors' initial intent to show S1 during Week 2, but software issues prevented this from occurring. Students did not have access to the simulations outside of the classroom environment.

Table 4: Weekly schedule of exams, video tutorials, and simulations for the web-assisted and regular Vector Dynamics sections

	Week Number										
	1	2	3	4	5	6	7	8	9	10	11
Exams (both sections)[a]		Q1		Q2		Mid		Q3		Q4	Final
Video tutorials (Section A only)[b]		V1 V2		V3 V4			V5 V6		V7 V8		
Simulations (Section A only)								S1 S2			

[a] Both sections met back-to-back and the same questions were given to both sections.
[b] V1 and V2 discuss concepts relevant to Quiz 2, the Midterm, and Final; V3 and V4 discuss concepts relevant to the Midterm and Final; V5 and V6 discuss concepts relevant to Quiz 3 and the Final; V7 and V8 discuss concepts relevant to Quiz 4 and the Final.

Student performance on the six exams is shown in Table 5. Quiz 1 is used as a control since no video tutorials or simulations were made available to students prior to that quiz. Students in the regular section (Section B) outperformed the web-assisted section (Section A) on Quiz 1, possibly indicating that on average Section B students were more academically capable than Section A students prior to the start of the term. Indeed, in four of the six exams (Quiz 1, Midterm, Quiz 4, and Final) the regular section had a higher mean score than the web-assisted section. One possible reason for this discrepancy is that there are a higher percentage of students repeating the course in Section A than in Section B (Table 3).

The web-assisted section appeared to demonstrate minor improvement during the second half of the course. Two of the three worst performances of Section A relative to Section B occurred during the first half of the course (Quiz 1 and Midterm). Additionally, Section A students performed most poorly relative to Section B students on the Midterm, with a mean score ratio of 0.79, but this ratio increased to 0.92 by the Final. However, these results need to be viewed with caution since an application of the Student's t-test indicates that there is a statistically significant difference between the performance of the two sections for only two of the six exams (Midterm and Quiz 4) at the 95% confidence level.

Although the student performance data is inconclusive, it is interesting to note that most students in the web-assisted section watched all of the video tutorials at least once. Figure 3 shows that the number of students who did not watch a video tutorial ranged from two (V1-V4) to seven (V7 and V8), with the number of students not watching the videos increasing as the academic term wore on. Perhaps not surprisingly, the seven students who did not watch all eight video tutorials received grades ranging from C- to F at the end of the term. Two students who did not watch any of the videos received a C- and D. This suggests that a student's level of participation in supplemental activities can be used as a predictor for their future performance on exams, similar to findings from previous studies.[5,6] Although not used in this study, BlackBoard has a Retention Center feature that can alert instructors to students who are participating infrequently. Use of this feature could identify students who are at-risk while there is still time to intervene.

Table 5: Comparison of student performance on exams in both sections

Exam	Section A Mean (SD), %	Section B Mean (SD), %	Mean score ratio mean A/mean B
Quiz 1	56.7 (30.4)	62.6 (23.4)	0.91*
Quiz 2	68.7 (21.8)	67.2 (22.1)	1.02*
Midterm	45.6 (20.9)	57.9 (20.5)	0.79
Quiz 3	53.5 (29.3)	49.5 (28.6)	1.08*
Quiz 4	61.2 (24.6)	74.4 (20.5)	0.82
Final	39.4 (17.6)	43.0 (14.8)	0.92*

* Student's t-test analysis indicates that there is no statistically significant difference between the scores of the two sections at the 95% confidence level for Quizzes 1-3 and the Final Exam.

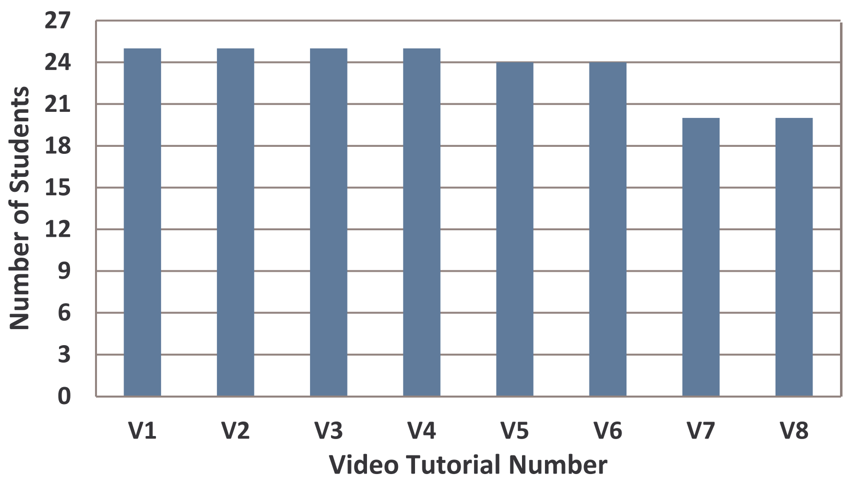

Figure 3: Number of students in Section A who watched a particular video tutorial at least once. There were 27 students in Section A.

4. Summary and Discussion

Learning tools were developed to enhance a Vector Dynamics course at Cal Poly Pomona. These tools include (1) eight video tutorials that explain step-by-step how to solve typical Vector Dynamics problems and (2) two simulations that allow students to visualize the motion of objects. The learning tools were implemented in a web-assisted Vector Dynamics course and student performance in that course is compared to student performance in a regular, non-enhanced Vector Dynamics course. Although the impact of the learning tools alone on student performance in exams is inconclusive, students in the web-assisted section who did not watch all the video tutorials at least once received lower overall grades in the course than those who did watch all the video tutorials at least once.

It is possible that the video tutorials could be used in a more effective manner to increase student performance. Further work should be conducted on the best way to use the videos to enhance existing Vector Dynamics courses. In the meantime, the videos have been uploaded to the authors' department's YouTube channel to so that instructors across the world can access to the content.[4]

5. Acknowledgments

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