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Integrated framework for developing instructional videos for foundational computing courses

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Completed Research Paper

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Abstract

Instructional videos are widely used in higher education due to their effectiveness and flexibility of personalized learning features. Computing courses usually focuses on programming, user interface design, server connectivity, data storage, and architecture, among others. The design of instructional videos varies in not only the course content but also the style of content creation. We propose an integrated framework, Computing Videos Design Framework (CVDF), for designing and developing instructional videos for computing courses. CVDF combines the cognitive skills from Bloom's taxonomy, video design principles, and course learning outcomes for designing different types of instructional videos. We apply the framework to the Web Application Development II course and share findings and insights from the student surveys. The framework described in this paper together with the examples provides one pathway for computing faculty to design and develop effective instructional videos, and additionally, we share the video URL links where examples are discussed.

Keywords: Integrated Framework, Computing Courses, Bloom's taxonomy, Learning outcomes, Video design principles

Introduction

Teaching computing courses offered by computer science or information systems curricula comes with its own unique set of challenges. The nature of most computing courses requires deep hands-on "practices" of concepts, and this has been the norm across many science and engineering courses around the world (Argyle, 1994). For learners to truly master the concepts and principles of computing, it is critical that they put the concepts and principles into solution development. Thus, in our university, computing courses are designed to mix both concepts and hands-on lab exercises during lesson time.

In a typical course in our university, a lesson is constrained by a time limit of three hours. In alignment with the emerging trend of e-learning (Zhang et al., 2004; Wang, 2003; Johnson et al., 2014), our university's School of Information Systems has adopted a new form of learning delivery that leverages video-based learning. Multimedia and communication technologies in recent years have led to a rising trend of e-learning (Giannakos, 2013). One great advantage of video-based learning is the ability to "jump" to a particular video segment (Salomon et al., 1991) and be able to play the segment repeatedly, which can be challenging during usual lesson times. Furthermore, videos can overcome the real-world constraint of physical boundaries. In recent months during the COVID-19 pandemic, videos have been used in parallel with other learning tools such as Slack (for collaborative real-time synchronous chat platform) and Zoom video conferencing tool. Many modern Learning Management Systems (LMSs) supports seamless integration with third-party platforms. Videos can be hosted either in-house within the LMS itself or by linking to third-party platforms such as YouTube. This combination of various learning tools provides an integrated online learning environment for students.

Instructional videos for programming courses have been very successful in helping students achieve computer programming competencies (Manley & Urness, 2014; Lockwood & Esselstein, 2013). Prior studies have shown that students benefit from lessons adopting video instruction (Manley & Urness, 2014), and they prefer video-based lectures combined with classroom lectures (Lockwood & Esselstein, 2013). Most of these prior studies investigate the impact of videos and majorly focus on programming courses. In many computing courses, videos are usually designed with concepts and step-by-step coding and testing instructions towards solution development. Instructors often face challenges in the video designing process as existing video design frameworks are mostly catered for general instructional videos (Moussiades et al., 2019). Theories and instructional design models for video-based learning mostly concern with the quality of video and sound (Mullin et al., 2001) and the guidelines for title and image appearance (Dufour et al., 2005; Patterson, 2007). Additionally, effective video-based learning must take into consideration the cognitive characteristics of learners (Macgregor, 1999).

Competency models such as Bloom's taxonomy (Bloom, 1956) or SOLO taxonomy (Biggs & Collis, 1982) are commonly used for CS course content and assessment design (Macgregor, 1999; Thompson et al., 2008; Fuller et al., 2007). In this paper, we propose a framework, the Computing Videos Design Framework (CVDF) that integrates the education frameworks and video design principles together with the learning outcomes of the course to develop the instructional videos for computing courses. We apply the CVDF to the design and development of the Web Application Development II course. Amongst many computing courses, the web application development courses typically include both programming and user interface design. Due to the highly visual and interactive nature of web applications, video-based learning is deemed the most suitable method of learning as videos can best represent a continuous stream of user actions and events as rendered in web browsers. We study the impact of the instructional videos on students' learning outcomes. We conduct a survey on both the video effectiveness and the learning outcomes of students.

The rest of the paper is arranged as follows. Firstly, we present the background of Bloom's taxonomy for computing courses and video principles. Next, we describe the Computing Videos Design Framework (CVDF) in detail. Next, we present a case study of applying the CVDF to the Web Application Development II course. We then present the survey results and findings from our case study. Lastly, we present our conclusions.

Background

In this section, we first present the background of Bloom's taxonomy for computing courses followed by the video principles for instructional videos.

Bloom's Taxonomy for Computing Programs

Bloom's taxonomy of the cognitive domain has six cognitive levels with a considerable impact on the teaching and learning process (Selby, 2015).

Bloom's Cognitive Levels

We describe each level and provide the corresponding example relevant to computing courses.

1. Understanding – At this level, the student can explain ideas, concepts, or construct meaning from written material or graphics. Examples include describing the code or what is the output of code etc.
2. Remembering – In this level, the student can recall facts, basic concepts, or retrieval of material. Examples include listing the different types of variables or identifying a function etc.

3. Applying – At this level, the student can use information in new situations such as models, diagrams, or presentations. Examples include given user requirements create the login functions or random number generator etc.
4. Analyzing – In this level, the student can draw connections among ideas, concepts, or determining how each part interrelates to an overall structure or purpose. Examples include analyzing the code with errors or what to do to fix the broken code.
5. Evaluating – At this level, the student can justify a stand or decision; to make judgments based on criteria and standards through checking and critiquing. Examples include choosing the logic using if statement versus switch statement or building the vertical vs horizontal menu etc.
6. Creating – At this level, the student can produce new or original work, develop, design, work, and assemble. Examples include building a loan web application or a learning management system.

Bloom's Taxonomy for Computing Courses

Analyzing Bloom's taxonomy on computing courses aids us in studying variations in the courses in terms of the emphasis on cognitive skills. It is performed by analyzing the verbs in the course learning outcomes (Goel & Sharda, 2004) and scoring the cognitive levels. Table 1 shows the emphasis on Bloom's cognitive levels on the foundational computing courses in our school. We selected only four courses for this study to argue that the learning outcomes (LOs) of the course are also critical in designing the videos for the given course.

Table 1. Sample computing courses and the corresponding Bloom's Cognitive levels

Course (Year) \ Cognitive Level	Understanding	Remembering	Applying	Analysing	Evaluating	Creating
Data Management (Year 1)	**50%**	10%	10%	10%	10%	10%
Programming (Year 1)	**27%**	**32%**	18%	5%	5%	14%
Web Application Development I (Year 1)	**30%**	5%	10%	10%	5%	**40%**
Web Application Development II (Year 2)	15%	4%	**19%**	8%	**19%**	**35%**

From Table 1, we observe that the LOs for each course have a different emphasis on the cognitive levels, and this observation plays an important role in video design. For example, if the emphasis is on understanding, the faculty should create the corresponding videos by applying the principles that enable the "understanding" cognitive level. Table 1 shows that a second-year course has a significant emphasis on evaluating and creating whereas the first-year courses mostly emphasize understating and remembering. In the next sub-section, we describe the video design principles used to achieve various goals in students' learning.

Video Design Principles

It is important for the faculty to consider three elements for video design: cognitive load, non-cognitive elements that impact engagement, and features that promote active learning. A prior study suggests 25 video principles for designing effective instructional videos (Fyfield et al., 2019). We choose the most relevant principles for computing instructional video design for our framework. We further categorize them under cognitivism, engagement, and active learning sections (Brame, 2015; Moussiades et al., 2019; Koumi, 2015). Table 2 shows the video design principles useful for developing instructional videos for computing courses to enable active learning, improve student engagement and minimize cognitive load.

Table 2. Computing instructional video design principles

Cognitivism design principles	
Coherence	Instructional material that is directly related to the key learning goal of the video should be included.
Attention Guiding Principle	Important information should be deliberately pointed out or selectively revealed during a presentation by using arrows, highlighting, flashing etc.
Worked Example Effect	Videos should include full worked examples of the skill or concept. They should not force learners to generate answers through problem-solving.
Encouraging Mental Model Making	Videos should explicitly encourage learners to create mental models by prompting pausing of the video, contemplation statements, encouraging creative notetaking, and linking to previous learning
Segmentation	The interface should be designed to pause after important information, prompting the learner to click 'continue' or the segmentation should be specifically highlighted.
Misconception Effect	Conceptual videos should dispel common misconceptions at the start. Simple statements like "you might have thought…" can help achieve this effect.
Engagement design principles	
Audio Quality	Audio should be clear, with no distracting hissing or interference
Personalisation (Conversational Voice)	Narrations should use first/second person conversational speech. Replacing "the" with "you or your" is effective.
Seductive Detail (music)	Background music for challenges and dry and complex topics.
Pre-training principle	Key elements required to understand a concept should be taught to novice learners prior to watching the video, either by a tutor or in a preliminary video.
Optimal Video Length	Videos should be less than ten minutes and longer videos should be edited or split.
Active learning design principles	
Learner Control Effect	Video interface should be designed so that pause, play, speed up, and slow down buttons are controlled by and clearly visible to the learner.
Integrated Practice Activities	Videos should contain practice activities, either during pauses in the presentation or following the video.

Cognitivism principles are based on human sensory memory and have a positive impact on the cognitive activity that enables them to achieve desired learning goals. One of the most important aspects of creating educational videos is to include elements that help promote student engagement which can be achieved by the engagement design principles. Active learning principles help students get the most out of an educational video, as it provides tools for them to process information and to monitor their understanding.

Similar to the course material creation for computing courses, in our framework, we apply Bloom's taxonomy for video designs as the educational taxonomy provides a structure for the video material. Since the emphasis on the Bloom's cognitive levels varies across the courses, the content of the video varies to align with the LOs of the courses. For example, recall from Table 1 that the programming course videos focus more on understanding whereas the videos for web application development focus on creating (e.g. interactive webpages). In conclusion, the instructor should design video content based on course LOs, cognitive levels, and the corresponding video design principles. We present our video design framework, CVDF, in the next section by integrating Bloom's model, video design principles and the course learning outcomes.

CVDF - Integrated Framework for Designing Videos for Computing Courses

Instructional videos can successfully aid in teaching practical skills, and they can be analyzed using the multiple categories and levels of Bloom's taxonomy (Cooper & Higgins, 2015). Applying Bloom's taxonomy to the design of instructional videos has been implemented in arts courses (Wicks, n.d.). Motivated by Wicks (n.d.), we integrate Bloom's taxonomy with video principles. Essentially, designing and delivering the course depends on the learning outcomes and instructional methods for class delivery (Bourner, 1997). Similar to face-to-face class delivery, the instructional videos serve as a platform for class content delivery, and the LOs are part of the video design. Given the role of all three components in a course, we propose the integrated framework of video design for computing courses (Figure 1).

Figure 1. Computing videos design framework (CVDF)

Figure 1 shows that Bloom's taxonomy is the core of the framework that integrates the video design principles with LOs of any course in computing curricula. We first build the mapping between Bloom's taxonomy and video design principles. Next, we apply these mapped rules to the course. Table 3 depicts the mapped rules - video design principles essential for each cognitive level.

Table 3. Mapped rules for Bloom's taxonomy and video design principles

Bloom's cognitive level	Video design principles
Understanding	Coherence, attention guiding principle, segmentation, learner control effect, engagement design principles
Remembering	Coherence, encouraging mental model making, learner control effect, engagement design principles
Analyzing	Encouraging mental model making, worked example effect, misconception effect, learner control effect
Applying	Encouraging mental model making, misconception effect, learner control effect, integrated practice activities
Evaluating	Encouraging mental model making, learner control effect, misconception effect, integrated practice activities
Creating	Learner control effect, misconception effect, integrated practice activities

Table 3 shows that the learner control effect principle is part of all cognitive levels as this principle enables personalized learning and flexibility. Similarly, engagement design principles are critical for lower-order cognitive levels as the students are at the beginning stage of their computing education. One may argue that these principles can be applied to all videos. However, in our framework, we only map the most important video principles for each cognitive level that the faculty should primarily focus on during video design and development.

To apply the CVDF for a given computing course, the course designer should integrate the above mapped rules with the course learning outcomes to develop the instructional videos. In the next section, we present the case study of Web Application Development II (WAD II) where we apply the framework to design and develop the instructional videos. We selected WAD II as a case study because it is the most challenging second year course with an emphasis on the high order cognitive levels. At the same time, the content taught in the course is complex than in other programming courses.

CVDF Applied to Web Application Development II Course – Case Study

Web Application Development - Background

In our school, after students complete their introductory programming course in Year 1 Term 1 using Python, they are to complete two web application development courses – in Year 1 Term 2 and in Year 2 Term 1. The first Web Application Development course (WAD I) is designed to equip students with the knowledge and skill to develop well-styled database-driven web applications.

The second Web Application Development course (WAD II) is designed to equip students with knowledge and skills to develop well-styled and responsive web applications that provide rich user experiences. Table 4 shows an overview of the WAD II course content.

Table 4. WAD II course design depicting the key topics

Course components	Sub-components	Description
Web framework and Software setup	Web architecture	The structure of the website to achieve business goals.
	Set up development environment	Install Google Chrome Web Browser, IDE, and HTML/CSS/JavaScript extensions for effective development and testing
Web design	Analyze a Web page design	Master the concepts of HTML structure and Bootstrap's container and responsive breakpoint concepts
	Translate it into HTML and CSS requirements	Execute several small-scale end-to-end web development challenges.
Web development	Programming capability for front-end web development	Master the concepts of CSS, Bootstrap, JavaScript, AJAX, API, and JSON concepts. Be able to utilize all of these to build end-to-end web development applications. Deploy finished applications to a remote server.
	Server-side development	Continuing with IS113's PHP-based back-end web application and enhance it with CSS/Bootstrap/JavaScript-written front-end User Interface development.
Project (real world case)	Web application development	Given a real-world business problem, develop a full stack web application.

Instructional Video design for WAD II based on the Integrated Framework

LOs Mapped to Bloom's

Table 5 shows Bloom's and LOs mapping for the WAD II course. It shows that various cognitive skills are designed as goals of the course and emphasis is on the higher order skills. This observation indicates that we need to develop several videos for each LO and respective Bloom's category using the proposed framework.

Table 5. Bloom's and LOs mapping for WAD II

Learning Outcomes	Bloom's Cognitive level
1. Explain and build the concept of client-side and server-side programming	Understanding, Creating
2. Understand CSS and be able to create and debug responsive web pages using various styling properties	Understanding, Evaluating, Creating
3. Able to control/design web page layout, colors and fonts and control the layout of multiple web pages efficiently	Creating, Evaluating
4. Understand JavaScript and able to create interactive and animated webpages	Understanding, Creating
5. Able to manipulate HTML Document Object Model (DOM) and handle or react to events such as mouse hovering in/out, mouse click, content changes, etc.	Applying, Evaluating
6. Able to use JavaScript and AJAX to interact with API applications and process and summarize JSON data from external sources such as Social Media APIs, Geolocation API, and Government APIs (e.g. LTA, IRAS, Singapore Police Force)	Analyzing, Evaluating
7. Able to use a CSS framework (Bootstrap) to build responsive, interactive, and complex web applications in an efficient, scalable manner.	Applying, Creating
8. Able to use a JavaScript framework (Vue.js) to build complex web applications in an efficient, scalable manner.	Applying, Creating
9. Able to solve logic problems that can be encountered while creating full stack web applications, and create suitable solutions using CSS, JavaScript and PHP.	Applying, Creating
10. Able to use, combine several pieces of supporting software together to build applications, e.g., WAMP server, Visual Studio Code IDE and extensions,	Analyzing, Evaluating, Creating

PHPMyAdmin, Postman, Online JSON Viewer, GitHub, Ngrok, Google Chrome Developer Tools, command-line interface, etc.	

Video design for WAD II – Examples and Discussions

From previous sections, we observe that multiple videos are required for achieving the LOs. At the same time, each video is based on a certain topic, learning outcome, and the corresponding video principles. In this section, we describe the video design principles applied to the WAD II course videos. The video URLs are shared for each example, and we discuss the application of video principles in the context of Bloom's cognitive levels. In this section, we focus on cognitivism and active learning principles as they are the key to the WAD II course learning outcomes and also due to the space constraints.

Cognitivism Design Principles

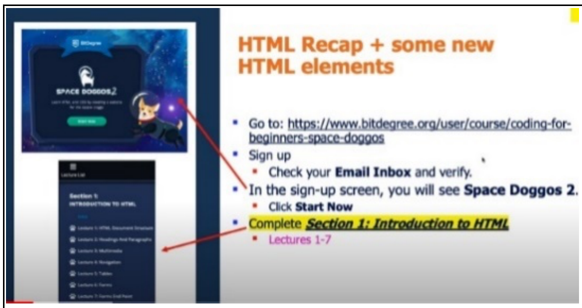
1. Coherence: Coherent content helps focus the learner on the content they need to learn and minimizes the cognitive load imposed on memory by irrelevant and possibly distracting content. For example, the topic of JavaScript has several sub-topics and requires several short videos. At the same time, each video focuses only on the given sub-topic. Recall that this principle contributes significantly to the cognitive level, understanding.

http://y2u.be/DFNtzKvTXZU

http://y2u.be/07k-T-WUcyA

Figure 2. Video examples of coherence

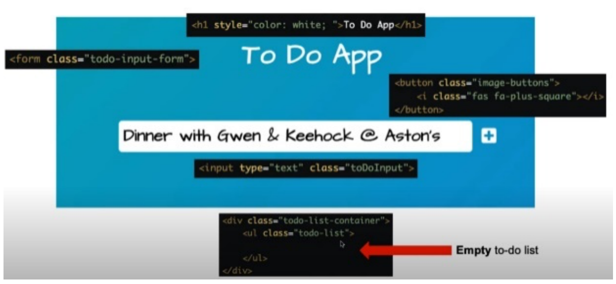
2. Attention Guiding Principle: Signaling components aids in drawing the attention of the students to the most important parts of the lesson. In a web application, the students have to learn the skills by focusing on various parts of the webpages, Therefore, the use of arrows, circles, highlighting or bolding text, and pausing or vocal emphasis in narration is critical. For example, in the given example, we use highlights and arrows to indicate the focus points on the webpage. Recall that this principle contributes significantly to the cognitive levels, understanding and remembering.



http://y2u.be/qU1Rl99YRK4

Figure 3. Video example of attention guiding principle

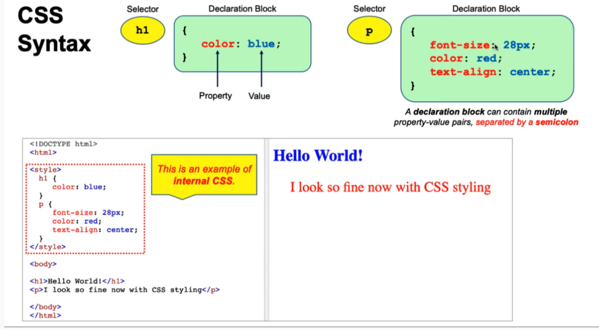
3. Encouraging Mental Model Making: Mental models help to reduce the complexity of the concepts and aid the students to reason and consider or choose the best option from multiple concepts. For example, given a webpage, the student should be able to learn how to analyze and evaluate CSS style sheets by creating a mental model of the different CSS style elements. Recall that this principle contributes significantly to two cognitive levels: analyzing and evaluating.



http://y2u.be/07k-T-WUcyA

Figure 4. Video example of encouraging mental model making

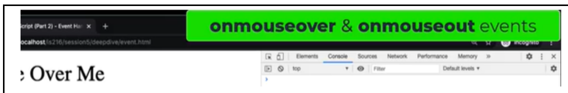
4. Worked Example Effect: A worked example is a step-by-step demonstration of how to solve a problem. The students who learn from the worked examples perform significantly better in the higher cognitive levels. For example, to create a webpage with style elements, each style component should be demonstrated by the instructor as the style effects on the webpage can vary drastically with every CSS style object used. Recall that this principle contributes significantly to cognitive level and analyzing.



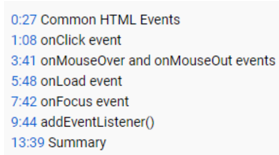
http://y2u.be/NtTLeF-szhw

Figure 5. Video example of worked example effect

5. Segmentation: Deeper learning occurs when content is broken into small chunks or by breaking down long text passages into multiple shorter ones. In terms of videos, the instructor should create user-paced segments instead of a continuous presentation. Such segments can be achieved by color controls or segment time indicators. For example, YouTube provides a feature called timestamp link which can be added to the video and the students can click on the link to jump to the specific segment of the video contributing significantly to the "understanding" cognitive level.



(a) Colors



(b) Timestamp

https://youtu.be/b6XT4K_NTfU

Figure 6. Video example of segmentation

6. Misconception Effect: Presenting misconceptions activate prior knowledge, allowing students the opportunity to reorganize and challenge differences between existing knowledge and correct concepts on the topic. For example, to describe how a modern web technology "AJAX" enables asynchronous HTTP request/response and more efficient webpage uploading compared to the traditional models, misconceptions are effective means in the WAD II course. Recall that the misconception principle contributes significantly to applying and evaluating skills.

https://youtu.be/DFNtzKvTXZU

Figure 7. Video example of misconception effect

Active Learning Design Principles

7. Learner Control Effect: Deep learning is possible when learners can control the rate at which they move forward through content. For example, technical courses are usually enrolled with the students having a wide range of capabilities. Therefore, high prior-knowledge learners may learn better when the lesson moves forward automatically, but they need a pause button that allows them to stop when they choose to do so. YouTube provides video control features by default.

https://youtu.be/DFNtzKvTXZU

Figure 8. Video example of learner control effect

8. Integrated Practice Activities: Practices maximize the students learning and also prepare them for higher-order cognitive skills. Instructors should create the practices after the key sub-topics in the WAD II course. In particular, the WAD II exercises should be explained in the videos to demonstrate what is expected from the students on a given webpage in terms of events as well. The activities can be smaller ones to reinforce the learning on a single concept or larger ones such as creating a complete webpage with the application of multiple concepts. These activities contribute to the higher-order cognitive skills such as applying and creating.

https://youtu.be/W9kpiEArBGk

Figure 9. Video example of integrated practice activities

Video Effectiveness Analysis - Findings and Discussions

Two sets of data were collected to better understand students' video-based learning experience. Firstly, we conducted a Likert-scale based survey designed to evaluate the effectiveness of video-based learning in the WAD II course. It focuses on two areas - Video Design and Learning Experience. Secondly, we collect qualitative feedback from students on a weekly basis towards improved video design for the subsequent weeks' video design.

Survey Analysis on WAD II Videos

The survey focuses on Video Design Principles and Learning of Course Concepts. Consisting of 17 multiple choice questions, students indicated their scale of agreement or disagreement with each question statement. We conducted the survey twice, at mid-term and at the end of the term. We received 109 responses in each survey.

Analysis of Video Design Principles

The first set of questions are designed around the video design principles specifically concerning the Cognitivism design principles and Active learning design principles as depicted in Table 6.

The summative results of the survey suggest that students respond positively to video-based learning. Through the contents presented (>99%), together with coding examples (>92%), students can control and personalize their learning at their own pace (>97%). Additionally, many students find that the course topics are organized clearly (>95%), and they can learn the concepts easily. Over 94% of the students indicated that the videos grabbed their attention on the key concepts, and over 95% of the students indicated that the videos organized the topics and sub-topics which helped them in their learning. We also observe that the misconception effect is rated low (>67%) at mid-term but has significantly increased by end of the term (88%). This is due to the improved quality of videos over time, taking students' feedback into consideration and more students find it beneficial to learn concepts from the videos as they become more complex. Additionally, pre-recorded videos allow students to replay anytime as many times as needed to help students clarify on misconceptions. Overall, many of the students responded well to video-based learning.

Table 6. Survey Results on Video Principles (SA- Strongly Agree)

Video Design Survey (Likert scale)						
			Mid Term		End Term	
Coherence	The content in the videos is coherent for the given topic. (**Cognitivism**)	SA	50.5%	97.3%	56.9%	**99.1%**
		Agree	46.8%		42.2%	
Attention guiding principle	The videos grab my attention on the key concepts. (**Cognitivism**)	SA	45%	90%	51.4%	**94.5%**
		Agree	45%		43.1%	
Worked example effect	I learn better with the examples demonstrated via the video. (**Cognitivism**)	SA	45.9%	87.2%	60.6%	**92.7%**
		Agree	41.3%		32.1%	
Misconception effect	I have misconceptions about some topics and am able to clear these misconceptions. (**Cognitivism**)	SA	28.4%	67.8%	44%	**88%**
		Agree	39.4%		44%	
Encouraging mental model making	I am able to link the different concepts with the help of video presentation. (**Cognitivism**)	SA	28.4%	81.6%	44%	**88%**
		Agree	53.2%		44%	
Segmentation	The videos clearly organize the topics and sub-topics. (**Cognitivism**)	SA	46.8%	94.5%	49.5%	**95.4%**
		Agree	47.7%		45.9%	
Learner control effect	I am able to control and personalize the learning needs and pace. (**Active learning**)	SA	45%	85%	59.6%	**97.2%**
		Agree	40.4%		37.6%	
Integrated practice activities	The activities in the video enable me to test my learning. (**Active learning**)	SA	33.9%	83.4%	44%	**89%**
		Agree	49.5%		45%	
	The instructions for the activities in the video are clear and easy to follow. (**Active learning**)	SA	39.4%	85.3%	49.5%	**96.3%**
		Agree	45.9%		46.8%	
Optimal video length	I am able to have a better attention span with micro-videos (**Engagement**)	SA	46.8%	78%	61.5%	**88.1%**
		Agree	31.2%		26.6%	

Analysis of Students' Learning Outcomes

The second set of questions make specific reference to various topics covered in the WAD II course, aligned with Bloom's cognitive levels as shown in Table 7. The survey results indicate that more than 97% of the students find video-based learning an effective way of understanding web application development concepts by end of the term. By the end of the term, over 97% of the students indicate that they can create web pages based on the concepts learned in the videos. The percentage of students who indicate that they can debug web layouts using appropriate tools has increased from 76% to 89% by end term. At mid-term, more than 80% of the students indicate that they can create new web pages, identify different web components, understand how different web components are inter-related, and design a web layout applying concepts learned in the course, and this figure has increased to 97% by the end of the term. We also observe that by the end of the term, 89% of the students are able to remember WAD II concepts taught in class, and this is a significant increase from 61.5% indicated at mid-term. Overall, many students have achieved the LOs of the WAD II course by the end of the term.

Table 7. Survey Results on Students' Learning Outcomes (SA- Strongly Agree)

Learning Outcomes Survey (Likert scale)						
			Mid Term		**End Term**	
Understanding	I am able to understand the concepts covered in IS216, which includes CSS, Bootstrap, JavaScript, DOM, AJAX, API, and JSON.	SA	22%	86.42%	46.8%	**97.3%**
		Agree	61.5%		50.5%	
Remembering	I am able to remember (list, describe, identify, and answer questions) the concepts taught in IS216, which includes CSS, Bootstrap, JavaScript, DOM, AJAX, API, and JSON.	SA	13.8%	61.5%	33%	**89%**
		Agree	47.7%		56%	
Evaluating	I am able to debug the web layout using concepts such as CSS, Bootstrap, JavaScript, DOM, AJAX, API, and JSON, using appropriate debugging tools such as Google Chrome Web Browser's Developer Tools.	SA	23.9%	76.2%	35.8%	**89%**
		Agree	52.3%		53.2%	
Creating	I am able to create a web page using the concepts taught in IS216, such as CSS, Bootstrap, JavaScript, DOM, AJAX, API, and JSON.	SA	25.7%	80.7%	41.3%	**97.3%**
		Agree	55%		56%	
Analyzing	I am able to determine how web components are interrelated in a web layout using concepts such as CSS, Bootstrap, JavaScript, DOM, AJAX, API, and JSON.	SA	20.2%	81.7%	41.4%	**95.5%**
		Agree	61.5%		54.1%	
Applying	I am able to edit the web layouts using the concepts such as CSS, Bootstrap, JavaScript, Dom models etc.,	SA	56.9%	80.8%	41.3%	**97.3%**
		Agree	23.9%		56%	
	I am able to design a web layout using the components taught in IS216, such as CSS, Bootstrap, JavaScript, DOM, AJAX, API, and JSON.	SA	22.9%	78.9%	40.4%	**94.5%**
		Agree	56%		54.1%	

Correlation Analysis

We use Pearson correlation coefficient scores between the ratings and student grade to analyze the impact of videos on grades (Figure 10).

Video design principles	***Cognitivism***	***Engagement***	***Active learning***
Cognitivism	1	0.64	0.79
Engagement	0.63	1	0.63
Active learning	0.79	0.63	1

(a) Pair-wise correlations (p-value =0.0*)

Video design principles	**Pearson r**	**p-value**
Cognitivism	0.124	0.09
Engagement	0.134	0.07
Active learning	0.089	0.17

(b) Grades and design principles

Figure 10: Correlations for video design principles

From Figure 10, we observe strong positive pair-wise correlations among design principles. In terms of grades, we do not have significant evidence indicating inconclusive results. In our analysis, we observed grades are normally distributed whereas the ratings are highly skewed. This observation explains the lack of correlations between the grades and ratings.

Qualitative Analysis of Student Feedback

Students provided several suggestions on the video design (Figure 11). Based on the above comments, the faculty made some changes to the new videos. For example, to address the students' feedback about font size used in code demonstration in Visual Studio Code, the teaching team used bigger font in all subsequent videos. Furthermore, on the one video spanning 40 minutes, students' feedback comments indicate that they much preferred bite-sized or shorter videos – which re-affirms our principle of "bite-sized" or videos of shorter lengths. While the videos serve a good purpose in showing how different components in a web page changes in a responsive and interactive way, students also prefer written document for challenges with all screenshots in a single document – to which the teaching team provided an additional full write-up as a Google document.

"(In YouTube videos) when you are coding in Visual Studio Code, is it possible to zoom in because I'm unable to zoom into the video on my mobile phone"

"(Regarding one YouTube video which is 40 minutes long) is it possible to keep it bite-sized or less than 20 minutes each? … a bit hard to follow or find a good place to stop."

"For the challenges, it would be easier to reference if we were given an image of the expected outcome. However, I still really liked the video!"

"Would like the challenges to be in a pdf/text document so that all the things that needs to be changed can be in one page"

Figure 11. Qualitative feedback from students

Design Framework Discussions

Teaching computing courses online can be very challenging as the concepts are very abstract and require examples and hands-on activities to provide a good learning experience for the students. CVDF framework aims to achieve higher student LOs through a minimized cognitive load, improved engagement, and active learning environment.

The results from the survey on cognitivism principles (coherence >99%, attention guiding principle >94%, worked example effect >92%) indicate the low cognitive load on the students. Moreover, if students were experiencing high extraneous cognitive load, they would have commented that the videos were difficult to understand, hard to follow, went too fast, or were confusing. No such comments were made in the quantitative comments. Our survey questions on engagement are only on video length and not on voice or other features of the video. The survey results on engagement principles (optimal video length >88%) indicate high engagement. Moreover, the students did not comment negatively on the other engagement features suggesting that students are engaged. The survey results on active learning (learner control effect >97%, an average of integrated practice activities >92%) indicate the effective active learning space for students through the instructional videos.

Recall that for WAD II, the emphasis of the cognitive levels is on 'applying', 'evaluating' and 'creating' (Table 1). Significant results were observed for all cognitive levels of WAD II knowledge areas. This result is consistent with CVDF design objectives that the instructional videos have a significant impact on their learning. It is important to emphasize that any conclusions about learning outcomes are limited because the data collected was based on self-assessment. In addition, it would be spurious to assume that the only influence on learning was the use of instructional videos. Students may have consulted the faculty, referred to textbooks and other web-based resources, and received help from friends to augment their knowledge of WAD II concepts. Direct evidence from survey and open-ended questions suggested that specific design features such as segmentation and coherence are effective while misconception is not effective in the videos. More, research should be conducted to find the link between student attitudes or background and learning outcomes.

This study is a first attempt to examine and evaluate a research-based framework for designing and creating instructional videos for computing courses. Several notable caveats are worth mentioning in our work. Firstly, formal pre-tests and post-tests on WAD II concepts would provide more persuasive data regarding the impact of videos on learning performance. As WAD II is a core course for all sophomores, there are many sections taught in a term. While the sections are taught by a few different faculty members, the core learning materials - such as slides and coding exercises - are shared across the sections. Given this, one possible pre-tests and post-tests design is where certain sections adopt video-based learning while others do not. Then, we can perform a comparison between the two groups to see if video-based learning leads to enhanced learning experience and higher success in terms of grades. Secondly, students' attitudes and perceptions can influence their learning (Candeias et al., 2011; Shamsuddin et al., 2018). If students' attitudes towards and perceptions of a new form of learning (such as video-based learning) are positive, their learning experience is likely to be enhanced. Students who strongly prefer only instructor-led lectures may respond negatively towards this form of learning, and thus, their learning experience will suffer. Combining findings from a deeper investigation into students' attitudes and perceptions would lead to a more comprehensive understanding of factors that influence students' learning. Thirdly, the present study was conducted during the COVID-19 pandemic period. As the pandemic was gradually brought under control, our school was able to resume face-to-face teaching to a certain extent – by adopting a synchronous hybrid classroom. In this setup, lessons are conducted both physically (on campus) and remotely (via conference call technologies such as Zoom) in a concurrent manner where students take turns to come to campus on a bi-weekly basis. Informal feedback from students revealed that not all students enjoyed a conducive learning environment at home. This difficulty is due to several factors including lack of stable Internet connection, lack of calm and quiet environment where students can follow the instructional videos attentively, and lack of peer support.

Conclusion

This paper presents an integrated framework, CVDF, for designing and developing videos for computing courses. Our framework integrates Bloom's taxonomy, video design principles and the learning outcomes of the course. In our case study, we applied this framework to our university's Web Application Development II – a core undergraduate programming course in an Information Systems curriculum. The quantitative survey feedback shows that most of the students (>94%) responded positively to video-based learning. The instructional videos successfully help our students learn and understand the concepts in the course. They can effectively debug their codes, create new web pages by applying the learned concepts, and analyze how different web components are used in a web layout. Students are confident that they can apply the concepts to design responsive and interactive web pages.

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