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Review

Developing Supplemental Instructional Videos for Construction Management Education

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Abstract: Technological advancements and lower production costs since the mid-1990s have dramatically improved opportunities for instructors to tailor self-made instructional videos for their students. However, video production technology has outpaced the development of educational theory, causing instructional videos to consistently fall short of their pedagogical potential. Responding to these shortcomings, scholars from various backgrounds have started publishing guidelines to help practitioners as they develop instructional videos for their respective fields. Using a rapid literature review, this article contributes to this ongoing effort by synthesizing theory-based, best-practice guidelines for a specific subcategory of educational videos called supplemental instructional videos (SIVs). SIVs are different from other types of instructional videos in that they are used to support and magnify other learning methods, mediums, and materials rather than substitute for them. Bringing the best-practice guidelines synthesized in this paper immediately into application, they were used to inform the production of SIVs for an undergraduate course that was held in the Building Construction Department of a major public university in the United States during the Spring 2020 semester. The methods used in the production of the SIV guidelines were systematically documented during the course for future researchers and practitioners to learn and build from.

Keywords: building construction; construction management; supplemental instructional videos; higher education

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1. Introduction

In the 1980s and 1990s, construction management (CM) departments attempted to incorporate instructional videos into their classroom with minimal success [1,2]. Video production technology was limited, making the video production process difficult and expensive, even for professional contractors [1,2]. For example, one estimate in 1994 placed the cost of professionally produced CM instructional videos between $800 and $1000 per minute [1]. Today, owing to the technological boom at the turn of the millennium, high-quality videos can be designed and developed internally and at minimal cost with many user-friendly options in recording equipment, editing software (e.g., TechSmith Camtasia 2018 v 9.1.5, Adobe Presenter, iMovie), and video hosting platforms (e.g., YouTube, ScreenCast, Vimeo) [3]. As a result, videos are commonly used in higher education today. Unfortunately, the creation and use of instructional videos are happening despite teachers having "little or no knowledge of the design techniques that actually improve learning" ([4] p. 19). Many instructional videos produced today amount to little more than recorded lectures, and students often complain that these video lectures are confusing, boring, irrelevant, lengthy, and have unacceptably low production quality [5,6]. Noting this problem, researchers across fields have begun to investigate the advantages and disadvantages of using instructional videos in higher education and to describe best practices in their design and development that make them most effective [4]. Using a rapid literature review, this paper presents an interdisciplinary synthesis of best practices in supplemental instructional video (SIV) design and production. The best practices were used to produce a series of SIVs that were used as teaching aids for an undergraduate CM course.

2. Cognitive Theory of Multimedia Learning

Teaching with video enhances learning [7]. Noting this, researchers have focused on explaining what makes video different from traditional, didactic, reading-and-lecture-based teaching methods. One prevailing theory is the cognitive theory of multimedia learning (CTML). CTML states that people learn better from both words and images because they are transmitted through two separate cerebral channels for processing verbal and visual material [8]. Thus, video is more effective because it allows learners to focus more cognitive energy on decoding and internalizing information rather than unlocking it from less effective single-channel mediums, such as readings [8].

CTML also explains how video helps learners overcome a learning obstacle known as cognitive overload [9], a discouraging situation that many students have experienced. Cognitive overload happens when the cognitive demands of a learning task exceed the learner's ability to receive, process, and store new information [8,10]. One common example of this is when students are studying for their final exams and feel that they cannot transfer any more information from their textbooks into their brains. CTML (in consonance with its forerunning cognitive science theories—i.e., Paivio's [11] dual-coding theory, Baddeley's [12] theory of working memory, and Wittrock's [13] generative-learning theory) proposes that by using multimedia or video to open up additional channels for learning, the information can more easily pass through the working memory to be stored in the long-term memory, which has limited processing capacity and is apt to overload [14].

3. The Benefits of Using Instructional Videos

Research over the past two decades has documented the institutional benefits of using instructional videos, such as reducing cost [15,16], sparing instructional time [15,17], and increasing accessibility [15]. Video also has specific learning benefits unique to the medium. In 2013, Sever, Oguz-Unver, and Yurumezoglu published a review of previous studies on this topic [18]. From their research, they uncovered two key benefits. First, video prompts both concentration and motivation in students throughout their learning experience. This happens through the connections that video helps the students make with the subject matter. According to Kearsley and Shneiderman's *Engagement Theory: A Framework for Technology-based Teaching and Learning*, technology, namely video, has the unique capability of connecting students with each other, to new ideas, and to meaningful tasks [19]. It asserts that student engagement is a product of three components: relating (exchanging ideas), creating (envisioning the application of those ideas), and donating ("making a useful contribution while learning" in an "authentic learning context [which] increases student motivation and satisfaction") ([19] p. 20).

The second benefit listed by Sever et al. [18] is that instructional videos can help students understand and internalize complicated or abstract concepts. Elizabeth Choe, whose work focuses on instructional video design, emphasized this point. Choe writes that videos are capable of "transcend[ing] space and time to make concepts clearer or more interesting" ([20] p. 4). They can make visible inaccessible events and processes and are able to "provide visual metaphors that make abstract concepts tangible" ([20] p. 9). Hence, through the amplified realism [21] that video provides, students have the ability to view impossible-to-see, real-life phenomena in action. To provide an example of this in a CM context, video can demonstrate the microscopic, imperceptibly slow, start-to-finish, chemical process of hydration that bonds cement to stone aggregate to yield concrete—a feat impossible with other traditional, single-channel mediums.

Other advantages of using instructional videos from the literature include improving student attention, improving achievement, improving attitude [4], preventing cognitive overload [22], improving the ease of learning [23], and accommodating the preferences of a younger, college-age audience [16]. With instructional videos, students are able to watch and re-watch course material at their convenience, in their environment, on their devices, at their own pace [24], and even take any corresponding assessments in tandem [25].

The literature warns that instructional videos may be associated with some learning limitations. Using instructional videos may negatively impact accessibility for older or economically disadvantaged populations [4]. They may also have the adverse consequence of distracting from primary learning sources and even "add to the passivity of students and may ultimately encourage less engagement" ([26] p. 17). Even with recent advancements in video production technologies, producing quality instructional videos can be a time-consuming process for busy teachers [14], an obstacle that should not be overlooked.

4. Supplemental Instructional Videos

According to Kay [27], four subcategories of instructional videos are commonly used in higher education. These are lecture-based, enhanced, worked examples, and supplemental. Lecture-based videos are recorded lectures. They are teachers filming themselves teaching. Enhanced videos are an embellishment of another medium. They are frequently used to upgrade or enrich a lecture with the goal of inspiring excitement about a topic. Worked examples are video explanations of procedural problems. They are frequently used to help with math and other calculation-based instruction. Supplemental instructional videos (SIVs), in contrast with enhanced videos, are informational rather than motivational, reinforcing the main messages of the instruction by providing emphasis, focus, or clarity. They are often used to support another teaching medium, such as readings. Hence, rather than videos merely substituting for an in-person lecture (i.e., lecture-based instruction) or embellishing existing learning materials (i.e., enhanced videos), SIVs complement other forms of instruction, including in-person teaching, readings, and group work, to deliver a full learning experience.

While the lecture-based category is the most common form of instructional video used in higher education, supplemental is recommended due to its ability to provide "significantly more educational value" ([26] p. 317). Speaking specifically of SIVs, McGarr [26] claimed that as well as providing revision and summary material, supplementary material can also be in the form of additional material, which may broaden or deepen the student's understanding. This type of use typically results in higher cognitive learning outcomes since the provision of supplementary material can provide students with alternative perspectives on content previously delivered or enable further and deeper exploration of topics ([26] p. 317). Despite the ability of SIVs to facilitate higher learning, very little research has been directed specifically at this subcategory of instructional video. Most literature on the subject, by far, is still focused on lecture-based videos in which teachers film themselves delivering content.

5. Interdisciplinary Synthesis of Best Practices for SIVs

The success of any instructional video relies on using the proper production theories and techniques. It is imperative, therefore, that correct and contemporary guidelines are used to inform their design and development [28]. Using the rapid literature review method—a method used to produce focused and actionable research—Table 1 is a contribution to this effort, merging best practices across a variety of applied disciplines, including biology [7,29], engineering [25], education [4,6,8,10,14,27], STEM fields [20], library science [30], construction management [31,32], computer science [33,34], medicine [35,36], and business and marketing [37], among others [20].

Table 1. Best practices to optimize student learning with supplemental instructional videos.

Guideline	Rationale	Supporting Sources
Short	Videos should be made only as short as necessary to convey the message. Because sources vary somewhat in defining what this means, it makes sense to recommend an upper limit. Ideally, most instructional videos should not exceed 15 min. (Some recommend that the length should not exceed 1.5 min per grade level of the learning audience. Others claim that between 1–4 min is ideal. Much of the current literature seems to agree that between 5 and 10 min is the target duration of an instructional video, stating, specifically, that 6 min is the ideal length.)	[4,6,7,14,15,20,25,32–34,37–39]
Scripted	A carefully written script is essential for a clear message. Impromptu monolog can be detrimental to the delivery, quality, and effectiveness of the instruction.	[37,40]
Segmented	Instead of introducing multiple topics in a single video, one video should be used to cover a single topic.	[4,7,14,20,22]
High-quality	Video, audio, graphics, and animations should be neat, smooth, sufficiently loud, and visually and auditorily clear so students are not distracted or confused by jarring media.	[4,8,10,14,20,25,32,33,35]
Self-made	As often as possible, instructional videos should be created or commissioned by the teacher. Custom-made videos do better to connect students with both their teacher and lesson material, in addition to augmenting the relevance of the content.	[4,16,25,31,33,38,41,42]
Engaging	Instructional videos should include abundant visual and auditory stimuli such as hand gestures, vocal inflection, facial expressions, sound effects, complex backgrounds, changing colors and contrasts, and motion graphics. It can also be effective to appropriately elicit emotion by, for example, using humor.	[4,7,14,20,22,25,27,29,32,33,40,42]
Clear	All audio and visual content should be deliberate and have a clear purpose. Only necessary sounds and visuals should be used (e.g., avoid meaningless background music). The content of the instructional video should be expressed in the most efficient and easy-to-understand way possible. Remove any visual clutter. Use effective combinations of narration, written text, and imagery (e.g., written, on-screen text should typically not be coupled with visuals. Narration and visuals are a better combination).	[4,8,10,14,25,31–34]
Personalized	Narration should use personalized, polite, conversational language and avoid third-person references (e.g., say “you” and “I” instead of “him”, “her”, or “the students”). Topics should not use too much difficult terminology or jargon.	[4,6,7,30,33,38]
Active	Instructional videos should incorporate guiding and interactive questions or other interactive digital elements that are coordinated with other assignments.	[7,25,30,34]
Connecting	Instructional videos should address the learning topic directly in a way that is relevant to the student.	[14,20,30,32,34,35]
Paced	Instructional videos should have an effective and reasonable pace that is fast enough to retain the students’ attention but slow enough so students are not overloaded and lost.	[6,8,12,27,32,34,42]

While many articles have contributed to the literature review in Table 1, those written by Choe [20], Brame [7], Kulgemeyer [14], and Jensen et al. [29] were the core works that informed the construction of the Table. Each of these articles was based on theory and written for application, detailing how teachers can use the proposed techniques to benefit their students. Choe [20] and Brame [7] affirm that video is not inherently superior to other learning mediums. These articles emphasize conscious video creation—staying flexible with the guidelines and focusing on the objectives of the video. They warn that any attempt to rigidly standardize the design process for all videos for all audiences will undoubtedly diminish the effectiveness of the final products. Kulgemeyer [14] and Jensen et al. [29] both provide theoretical explanations of why certain production techniques seem to work better than others. They also provide detailed insights on how to incorporate instructional videos into curriculums.

By no means is the literature review in Table 1 intended to be an exhaustive collection of all scholarship that has ever commented on the subject of instructional video design; rather, it is a curated collection of recent guidelines focused on supporting teachers, instructional designers, and researchers as they use accessible technology to tailor SIV content for their specific audiences. Because the set of guidelines presented in Table 1 was generated from a wide variety of disciplines, the principles and techniques presented are broadly applicable, as demonstrated by their shared points of overlap.

6. Case Study: Incorporating SIVs in a Construction Management Course

In the spring semester of 2020, the guidelines outlined in Table 1 were incorporated into the development of a series of supplemental instructional videos (SIVs) for an undergraduate construction management (CM) course called Residential Construction Technologies, which was offered at a large, public university in the United States. All 46 students who were invited to participate in this research course were made aware of the study and gave their consent to participate in writing. Prior to signing up, students in the class were given a short presentation and handout describing the research activities and objectives. All research activities were approved by and conducted in accordance with the [university redacted] Institutional Review Board (Protocol 19-853). Seventy-eight percent (n = 36) of the 46 students in the course were male. Twenty-two percent (n = 10) were female. Eighty-nine percent (n = 41) were majoring in Building Construction. Seventeen of the students were in their third year of college, 12 were in their fourth year, 10 were in their second year, 2 were in their fifth year, and 1 was in his first. The remaining students did not have a clearly defined year in school.

The course focused on teaching students to critically evaluate and compare competing construction technologies. For each of the 12 weeks in the semester, the 46 students participating in the course were asked to complete readings about a specific, industry-standard construction technology. The standard construction technologies were termed the conventional technologies. Conventional technologies covered a wide range of construction topics, including foundations, wall framing, floor framing, roof framing, the mechanical system, the electrical system, the plumbing system, windows, roofing, insulation, exterior wall finishes, and finished flooring. After learning about conventional technologies, students were assigned readings covering more advanced alternatives called conventional-plus technologies.

To provide an example of this course outline, in week seven, the conventional technology was a standard, 50-gallon storage tank water heater, a widely used model found in millions of homes across the United States [43]. Students were provided reading material describing this water heater model in detail. Then, they were assigned readings covering the conventional-plus technology, a condensing storage water heater, which is purportedly superior to the traditional model in a number of ways but primarily in energy efficiency [44]. Consistent with the guidelines to keep the videos as short as necessary, a four-minute SIV was produced by the instructor and provided to the students to accompany the condensing storage water heater readings.

7. SIV Preproduction

Preproduction of the SIVs in Residential Construction Technologies involved preparing standard tools and procedures to help the development process remain as consistent as possible across all 12 SIVs created for the course. The video editing software chosen to develop the SIVs was TechSmith Camtasia 2018, a widely recognized, user-friendly, and relatively low-cost option that provides many professional-grade capabilities. A standard introduction and outroduction (i.e., intro/outro) were constructed and saved in a TechSmith Project file template to be used for all videos. The introduction used engaging "bump" music and an attractive animated sequence introducing the course and SIV topic (e.g., condensing storage water heaters). The outroduction mimicked the introduction, only it was shorter. Music was procured from the YouTube Audio Library, a vast collection of free music made available specifically to support video production. All music used for the template was taken from the attribution-free portion of the music library. Consistent with theory, music and sound effects were applied, so all sounds had a specific purpose. No background music was included in any of the SIVs. According to CTML, if words and imagery synergize to enhance learning, meaningless background music and sounds would only detract from the narration.

No professional studio or equipment was used to create the SIVs. Camtasia, Microsoft Office, the internet, and a laptop computer were the extent of the software and equipment required to produce all SIVs for the course. None of the SIVs required the use of external video recording equipment, videography, or photography. Hence, no cameras, lighting equipment, external microphones, or audio recording equipment were necessary. Nearly all images, graphics, animations, music, and sound effects came from free, license-free, and attribution-free sources (i.e., Pixabay.com, Google, YouTube Audio Library, FreeSounds.org). The few attribution-required content that were used received attribution inside of the video and were used in compliance with the four-factor test for fair use under the Copyright Act of 1976 [45]. Instructor narration was recorded using the laptop microphone in a quiet room. Screen recording was facilitated by Camtasia and Microsoft PowerPoint.

The final step of the preproduction process was authoring a script for the narration. After the first draft of a script was written, it was reviewed and revised multiple times because the narration is the typically best opportunity to connect students to new ideas and motivate them, as promoted by Kearsley and Shneiderman's Engagement Theory. Fortunately, because the SIVs were designed to supplement the at-home readings rather than the classroom lecture, developing the script for each SIV was simple and straightforward. The main points of the readings were highlighted, notes were taken, and any confusing points or unresolved questions left by the text were researched and answered. The main summary points were then written into a script using basic, personalized language that could be recorded during the production process.

8. SIV Production

For this animated SIV series, which did not include traditional filming with cameras, the production process centered on gathering and combining discrete digital elements for both the audio track (e.g., recorded narration, music, and sound effects) and visual tracks (e.g., fair-use stock video, photographs, captions, and animations).

Recording and editing the narration was the first step for each SIV. After the narration was recorded in Microsoft PowerPoint, the raw audio file was listened to and edited in Camtasia to remove any misspoken words, unwanted sounds (e.g., coughs, bumping the table), and outtakes. Additional audio effects were added to the narration track to increase the volume, level the sound, and, if necessary, reduce any persistent background noise (i.e., room noise).

With the narration complete, the visual tracks were developed to support the narration. License-free stock videos, images, and graphics were used liberally from a variety of sources (e.g., Pixabay, Google, Archive.org). Also, Camtasia's embedded library of animated icons and objects was used to support the development of the visual tracks. Screen recordings were also used in certain instances.

After the visual elements were constructed, preset animations and behaviors in Camtasia (e.g., fly-in images, bouncing words, rotating photos) were applied to improve visual engagement. Sound effects (e.g., pops, swooshes, and dings) were used sparingly to emphasize some of the visuals. Occasionally, transition effects (e.g., fading and fading to black) were used between scenes, but not often. Other visual effects, such as blurring, fading, highlighting, and zooming in and out were appropriately applied to the visual elements throughout the SIVs as well. The SIV was then watched and re-watched to ensure that it remained appealing and professional.

Following the semi-experimental production of the first few SIVs in the research course, an effort was made to document the time required to produce the remaining SIVs. Table 2 outlines the time expended during each step in the production sequence of the final seven SIVs in the course. This Table does not include the time spent on researching the assigned readings, building the Camtasia project file template, production team discussions or revisions, or launching the video on Canvas LMS. For production events in which the time expense was difficult to calculate precisely (e.g., writing and editing the script would sometimes require additional research halfway through the task, spreading the activity over multiple days), they were estimated to the closest minute, 5 min, or, in some cases, 15 min.

Table 2. Recorded time for various production stages of seven SIVs created for the course.

	Write and Edit Script	Audio Recording and Editing	Production of Visual Layers	Render	Review, Edit, Revise	Re-Render	Total Production Time	Length of Final Video
Video 1	90	45	120	7	15	7	284	2.73
Video 2	120	45	60	8	15	10	258	4.05
Video 3	60	30	90	4	15	4	203	2.13
Video 4	60	30	90	6	15	5	206	2.03
Video 5	90	45	90	10	5	0	240	3.13
Video 6	90	25	90	10	5	0	220	2.46
Video 7	90	30	90	9	5	0	224	2.59
Total	600	250	630	54	75	26	1635	19.12
Average	85.71	35.71	90.00	7.71	10.71	3.71	233.57	2.73

All times in minutes.

9. Results and Discussion

This research study has two main achievements. First, Table 1 provides an informed catalog of the best video production practices for supplemental instructional videos (SIVs). Practitioners should use it when designing and developing their own SIVs. While it is recommended to follow Table 1 as closely as possible, it is sometimes wise for an instructor to depart from specific guidance. This is because when it comes to design and production, "there's no one-size-fits-all technical approach to video", and excessively rigid compliance with the guidelines can be detrimental to the overall learning experience ([20] p. 3). Thus, some instructors may decide that "interactive questions or other interactive digital elements that are coordinated with other assignments" are not necessary for their specific class goals and may choose not to use them. Alternatively, some instructors may not find it necessary to author a carefully worded script on subject matter for which they have ample teaching experience. For these instructors, reading from a script might even detract from the quality of the SIV, making it sound overly rehearsed or "read". For instructors who are not interested in producing their own SIVs or in cases in which SIVs already exist for specific subject matter, Table 1 can be used as a rubric to search for and evaluate these outside videos for classroom use. With the certainty that the use of video in the classroom will increase with time, more instructors will find this alternative to be useful.

The second achievement, and possibly the most important, is the confirmation that the theoretical guidance provided in Table 1 is feasible. With only minimal resources and technology, this research study demonstrated that a college instructor can tailor SIVs in compliance with the latest theory for a specific audience. This is not to say that certain challenges do not remain. For example, as documented in Table 2, one of the greatest is the time requirement. On average, each minute of the final video required approximately 1 h and 15 min of production time, a ratio of 1 to 85. A six-minute video could take an instructor nearly a whole workday to produce. This ratio for SIVs appears to fall somewhere between the ratio for high-quality, animated instructional video content, which is reportedly 1 min to 480 min [46], and lower-quality, lecture-based, or tutorial videos [47], which is closer to 1 to 18.

One way to alleviate the time burden of SIV production is to enlist the help of students. Kulgemeyer [14] advocates for students to create their own instructional videos, underscoring the benefits of the activity for both the students and their teachers. Given this, professors should consider using their students as teaching assistants (TAs) to help them produce their SIVs. Under the direction of professors and guided by best practices such as those found in Table 1, TAs could be the primary technicians who develop the videos. In a draft process, professors can review the initial video rendering, request revisions, and eventually give their approval of the final product. This format is ideal because it concurrently familiarizes TAs with the course subject matter while sparing the professor's time from the technical tediousness of creating videos themselves. Other benefits of this structure include:

- Training for TAs in video-editing software and delivering course subject matter [47];
- Building the TAs' knowledge and improving their resumes and portfolios with meaningful contributions [14];
- Making educational materials more accessible and distributable by segmenting and modularizing them digitally [7];
- Building a digital content warehouse of SIVs that can be easily recycled by professors and departments for use in future courses [47].

Not all instructors have assistance. This can make producing videos more challenging but not impossible. Köster [47] encourages instructors who have no technical assistance to be flexible in their methods and temper their expectations of the final product so they can learn from their experiences and build on previous work with greater quality and efficiency. In this study, the 12 SIVs that were used in Residential Construction Technologies were produced by a single instructor without any TAs or other supporting technical assistance, and it was performed over a period of about two months.

10. Limitations

The literature used to synthesize the guidelines of this paper in Table 1 is new enough to remain technologically and educationally relevant but has also been in publication long enough to be widely circulated and cited by other scholars. In the fast-moving and constantly shifting pedagogical and technological environments, existing sets of best-practice guidelines must be routinely checked for relevance and updated. For instance, in the short time since this case study was conducted, a number of other papers have been published on video design (e.g., [48–52]). This new literature may have implications for the design and development of future SIVs.

The theory used to synthesize the SIV guidelines in Table 1 came from a wide array of academic domains with the intention of making them broadly applicable. Practitioners and instructional designers should take this into account as they design SIVs for their specific disciplines. For example, the guideline to use personalized language in an SIV for construction management (CM) will probably be different from the personalized language used in English Literature. Even within the field of CM, an SIV for cost estimating should emphasize certain guidelines differently from those for an SIV on project safety.

For the case study presented above, the instructor who produced the SIVs had years of experience in every stage of the instructional video production process (e.g., planning and authoring messages, writing and narrating scripts, and working with video editing software). Hence, those with little or no history of producing instructional videos will likely have different experiences from the ones documented in this paper as they make their first attempts to create their own videos. To this end, newcomers should take encouragement that not long ago, Microsoft PowerPoint undoubtedly seemed overwhelmingly complex in comparison with transparencies and overhead projectors. In the coming years, video production will almost certainly be even more intuitive than it is now, and those previously excluded from adopting the medium because of computer interface challenges will likely feel more comfortable after time and practice.

11. Conclusions and Future Research

Over the past few decades, easily accessible, low-cost video editing software has provided professors with new opportunities to produce high-quality instructional videos. However, producing college-level instructional videos requires more than exceptional technology. Instructors need guidance from informed sources. This research contributes to this effort by using the rapid literature review method to provide a set of best design practices for supplemental instructional videos (SIVs)—a specific subcategory of instructional videos used to complement other teaching materials and methods. The best practices were then applied in a real construction management classroom by producing a series of SIVs to support assigned readings. The tools and procedures used to create the SIVs were carefully documented for teachers and instructional designers to follow.

Future work in this area includes more primary research for expanding and improving the best-practice theories of SIVs, especially considering the rapid pace at which the field is advancing. With each update to the theory, empirical studies should be conducted to objectively measure the effectiveness of SIVs that were designed under the latest guidelines. Educators need scientific evidence that the teaching tools and methods that they are using improve learning. Students should also be given an opportunity to report their learning experiences and preferences regarding SIVs. They should be surveyed to learn about their opinions of the new teaching method. Finally, while this paper focuses on SIVs, more research is needed on the other mentioned subcategories of instructional videos (lecture-based, enhanced, and worked examples) to identify points of commonality and departure.

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