Paper ID #35219

Paper: Using Asset-based Participatory Design Thinking to Develop Culturally-Relevant STEM Video Modules to Promote Intrinsic Motivation

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Work-in-Progress: Using Asset-based Participatory Design Thinking to Develop STEM Video Modules to Promote Intrinsic Motivation in Engineering

Abstract

This paper presents the current progress of a STEM-NET research project titled as "Using Asset-based Participatory Design Thinking to Develop Culturally-Relevant STEM Video Modules to Promote Intrinsic Motivation." With the primary goal of identifying effective video design strategies to enhance student learning in engineering courses, this collaborative research project applies an innovative instructional design method called Participatory Design Thinking (PDT) to address the needs of the target learners. The first step of PDT is Empathize where we study the perspectives of engineering students with diverse cultural and educational backgrounds towards video learning modules. This paper focuses on describing the findings at Empathize stage through interviews and student survey, as well as a recommended design checklist to create relevant and engaging video based on the findings. The design checklist is utilized to construct a storyboard template that can be used to formulate video design in both formal and informal learning settings.

1. Introduction

Videos are shown to serve as a valuable supplement for traditional in-classroom instruction [1]. Well-designed instructional videos provide students with the necessary tools to succeed, especially at their own pace. One of the benefits of instructional videos is that it allows for learner control. Students can pause, play, and interact with a timeline. Other interactions include hotspots that allows users to accentuate specific content and quizzes to create more in-depth learning and retention. While research has found that student perceptions of instructor-generated videos were generally positive [2], utilization of video learning modules has resulted in limited success in engineering courses where the contents are highly theoretical. At California State University Los Angeles (Cal State LA) where more than 60% of students come from low-income families and are the first generation in their families to go to college, many engineering faculty reported that although students were initially excited about the videos, their engagement diminished over time and using instructional video did not necessary translate to improved academic performance.

In Spring 2020, shortly after the instruction was moved online due to COVID 19 Pandemic, the College of Engineering, Computer Science, and Technology at Cal State LA received a STEM-NET research grant to explore effective strategies to make instruction video more relevant and engaging to engineering students. Through a close collaboration between engineering faculty and education researchers, an innovative instructional design method called participatory design thinking (PDT) [3] is utilized to develop video learning modules that better address the needs of the target learners, in particular students from underserved communities. A unique feature of participatory design thinking is its direct involvement of all stakeholders including the students in the design process as a means to understand prevalent underlying issues in achieving learning outcomes. Through the project efforts, we expect to better understand how students with diverse cultural and educational backgrounds respond to various features of video learning modules, and identify effective video design strategies that will foster a learner-centered experience recognizing both individual strengths and the cultural assets of the communities that our students belong to.

This paper presents the progress of the research project during the past year. The participatory design thinking process is an iterative process with five stages, namely *empathize*, *define*, *ideate*, *prototype*, and *test*. So far stages one through three have been completed. During "Empathize" stage, we performed a thorough assessment of the needs and characteristics of the learners through interviews and student surveys. The paper will share the data collected and the analysis results, and describe a design checklist derived from the needs assessment. Based on the checklist, a storyboard template was created and two prototype video learning modules are being developed: (1) supplemental video learning modules used in a Mechanical Engineering core course, and (2) exploratory video learning module used in the MakerSpace, an informal learning environment.

The paper is organized as follows. Section 2 presents the theoretical framework of participatory design thinking and explains how it is applied in the video design process. Section 3 provides an overview of data collection and analysis focusing onstudent and faculty perspectives towards instructional video.. The recommended design checklist and the prototype video under development are described in Sections 4 and 5 respectively. Section 6 concludes the paper.

2. Theoretical Frameworks

To design effective video content, we use an asset-based participatory design thinking process. According to Henriksen [3], the Stanford design thinking model has five phases or steps of design thinking that are worked through towards a resolution of an issue, as shown in Figure 1. The principle of participatory design thinking is to involve the end users (which are the students in this case) in every stage of the design process. In our project, four students with diverse cultural and ethnic backgrounds (including two male students, one Hispanic and one Asian American, and two female students, one Hispanic and one White) have been identified to serve as "co-designers." The participatory design thinking provides a mutual learning process in which faculty and student co-designers better understand each other's perspectives and students are empowered to make substantial design decisions.

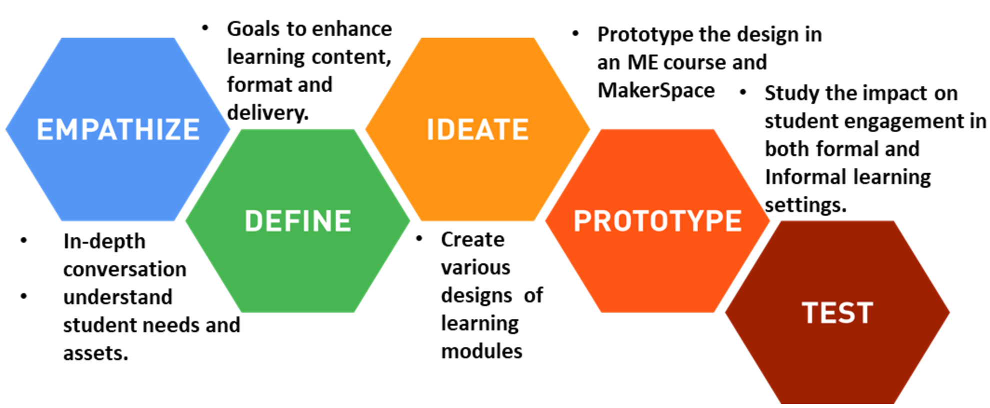

Figure 1. Asset-based Participatory Design Thinking to Build Video Learning Modules

We started from the "Empathize" stage in Fall 2020 semester to perform a thorough assessment of the needs and characteristics of the learners. The results of the needs assessment in the Empathize stage have been translated into the design goals during the "Define" stage. Currently, in the "Ideate" stage, faculty and student co-designers have been exploring various ideas to build key pedagogical elements including the content, delivery method, sequence, and interaction. In addition, the video co-designers have been very intentional in leveraging the unique assets of our students in the design process. Innovative and creative ideas from different perspectives have been generated and incorporated into the design of the video prototypes for formal and informal learning.

3. Data Collection and Analysis

The first stage in the design process in asset-based PDT is Empathize, where we study the perspectives of engineering students with diverse cultural and educational backgrounds towards video learning modules. In Fall 2020, six interview sessions were conducted with two engineering faculty and four student co-designers that are part of the STEM Video design team. In addition, using a five-point Likert scale, a student survey with open-ended questions was conducted in two Mechanical Engineering courses to solicit students' qualitative feedback on instructional video. A total of 25 students responded to the survey. Among the survey participants, 60% are Latinx or Hispanic and 72% are first-generation college students.

Both the student interviews and the student survey were conducted to investigate underlying design and learning issues with current supplemental and instructor-created videos. The qualitative data collected from student interviews and the open-ended questions in student survey provided valuable information to analyze the students' past experiences with instructional video, their expectation towards an effective video that enhanced their learning, as well as reasons that they liked or disliked an instructional video. Faculty interviews focused on how video was used in their instructional settings and changes needed to make the video a better tool to facilitate learning.

The interview transcripts and the student responses to open-ended survey questions were analyzed and coded, which involved coding the data based on categories from relevant frameworks and design principles, as well as codes that emerged from the data, assigning labels to codes, grouping codes into themes, and linking interrelated themes [9]. More specifically, to shed light on how to better design the video content, delivery method, sequence, and interaction, we examined the data based on the following frameworks and principles: Cognitive Apprenticeship framework [4, 5], Keller's ARCS (attention, relevance, confidence, satisfaction) motivational design principles [6], Mayer's Principles of Multimedia design [7], and Gagne's Nine Events of Instruction [8]. In addition, we adopted the community-based participatory research perspective [10], emphasizing a co-learning and empowering process, and building on strengths and resources of underrepresented students within our university community. The collected data were reviewed carefully to identify how students' cultural background and past experiences influenced their views and expectations towards "a good learning video". The student interview data indicated that it is important to consider "emotional side of learning" and "provide a safe space" for students to learn. In addition, the interview data also reflected the asset that our student brought into the classroom, particularly their "resilience" and "growth mindset". Sample student quotes include:

- "…like a safer space for students because STEM is really scary. And I don't think professors always really recognize like those things like in the classroom, like all the challenges. Like all the psychology that's coming in."
- "To kind of like correlate the emotional side of like learning. The relationship side of like bonding with students."
- "Maybe use a little bit more growth mindset language in there, particularly when there's like a challenging concept."
- "…to hear those things like you know it's okay to make a mistake. This is hard, but this is why you are learning. This is why you are here. I think normalizing that is encouraging."
- "I learned a lot of like resilience and strategies...that's huge, because I'm sitting there like oh my god I know growth mindset… that's more of a psychological advantage, more than anything."

Overall, the data analysis help to connect the learners' perspectives with the design focus of STEM video, which was critical in the formulation of the recommended Video Design Checklist.

4. Video Design Checklist

Based on the data analysis and needs assessment, a comprehensive design checklist for effective video in STEM courses was created to inform the design of the video content and style (Table 1) as well as strategies to engage and motivate students (Table 2). The design checklist highlights the importance of cultural relevance and evidence-based design principles as below:

- The diverse student population of 15% Asian, 4% Black, 63% Hispanic, and 7% White [11] at Cal State LA brings a wealth of cultural capitals such as aspirational, linguistic, resistant, and social capitals that form a good support system for underrepresented students. Instructional design of the STEM video project should strengthen the safe and supportive learning environment by integrating affective learning such as fostering self-confidence and a higher level of emotional engagement. This can be achieved by employing Keller's ARCS (attention, relevance, confidence, satisfaction) motivational design principles [6].
- Good instructional videos should apply evidence-based design principles that help educators create pedagogically sound educational video content. Derived from our interview and survey data, relevant principles include Mayer's Principles of Multimedia design [7] and Gagne's Nine Events of Instruction [8].
- STEM videos should focus on (a) expert modeling, a cognitive apprenticeship process [4, 5] of making the thinking process visible, and (b) helping students make connections between theory and practice.

Table 1. STEM Video Design Checklist for Content and Style Development

Content and Organization
Structure of the content is easy to comprehend ✓ Help learners build mental models ✓ Model thinking processes ✓ Use cues that highlight the organization of content to help with retention and transfer
Move students progressively toward a stronger understanding ✓ Use Guiding Questions ✓ Build on students' prior knowledge

Content is presented in manageable segments. ✓ Chunk content if video is long and add timeline for structure and organization ✓ Video sequences pause at logical segments with play controls (user can control/click on a specific section)
Use organizational graphics to show the structure of the message or relationships ✓ Use diagrams to illustrate procedures ✓ Find balance between diagrams and procedures—reduce cognitive load
Content covers essential information. Video does not contain irrelevant information ✓ Eliminate extraneous detail: video presents the core content with the minimal amount of words and graphics needed to help the learner understand the main points ✓ Reduce operational and cognitive costs of users
Graphics and Text
Graphics and text are used to present instructional content especially for novice learners ✓ Graphics are used when relevant; avoid distracting visuals. Pictures are not overused – where not needed ✓ Graphics are described by onscreen text ✓ When key terms are unfamiliar, they are supported by onscreen text ✓ Place directions on the same screen in which the steps are to be applied
Place text next to the graphic it describes. Text corresponds with visual content to enhance learning outcome and knowledge transfer ✓ Display corresponding words and pictures simultaneously that are relevant ✓ Use Word to type out content to avoid messy hand-writing for smoother transfer of knowledge
Audio
Use of audio narration to explain onscreen graphics/procedures. ✓ Narration and sound support text and illustrations ✓ Limit the amount of onscreen text and expand explanation with audio narration/voiceover.
Video does not contain extraneous sounds in the form of background music or sounds
Audio is clear, at the right volume and free of distractions
Screen Design
Screens are not cluttered ✓ Images are properly sized and easily understandable ✓ Text is legible (good font, size, color, line length)

Table 2. STEM Video Design Checklist to Engage Learners using ARCS Model

Attention
Design: Use visual cues to direct attention to relevant portions of the procedures ✓ Gain attention at the beginning (e.g., with guiding questions) ✓ Draw attention to difficult or challenging parts ✓ Use close up shots to focus specific information and gain attention ✓ Gain attention with contrast, color, audio or text styles (e.g., bold, size, color, indents, italics)
Pace: Rate of message presentation is neither too slow (wandering) or too fast (poor perception)
Variety: Use a variety of media and strategies to gain learner attention (e.g., add captions)
Active participation: Provide learner with user interface controls (replay button, timeline) or other means to interact with the video (quiz or survey)
Relevance

Link to previous learning: Help learners establish connections of the new information and what they already know
Communicate present and future usefulness ✓ Explain how the information presented will equip learners with new knowledge and skills that will help them with current projects/assignments/tests ✓ Explain how the information presented will help learners later in their lives or careers.
Modeling: Provide an example of successful application of the new knowledge or skills presented ✓ Demonstrates a new concept or approach to achieve learning objective ✓ Use a series of static images to illustrate how things work ✓ Use examples ✓ Inform learners of the practical use of the material by employing real world examples
Use language the learner can relate
Confidence
Facilitate self-growth to meet different levels of confidence ✓ Use a conversational style language and a friendly voice ✓ Treat knowledge lacks in a positive way; ✓ Provide a safe space by addressing affective learning (encourage and help them believe in themselves)
Communicate objectives: explain to learners what is expected of them and how they will be evaluated
Teach prerequisites: ✓ Teach prerequisites that are necessary for conceptual understanding (e.g., provide an introduction to go over basic terms, definitions, concepts.) ✓ Technical terms are defined/labeled before or during the video ✓ Key concepts are named/labeled/described in presenting the processes or procedures
Provide feedback: Knowledge check, quiz or survey
Give learners control: Add interactive features
Satisfaction
Praise or rewards: Present learners with some kind of reward/sense of accomplishment
Immediate application: Engage learners to apply their newly acquired knowledge and skills in real problem-solving activities

5. Prototype Video Development

Based on the checklist, a storyboard template was developed accordingly to guide the design of STEM videos. Currently, two prototype video learning modules are being developed. One for ME 3030 Fluid Mechanics, a junior level course with high DFW (D, F, and Withdrawal) rates as it is conceptually difficult and heavy on mathematics. The other is an exploratory video to be used in the MakerSpace, an informal learning environment. In this section, we use the ME 3030 video as an example to illustrate how to apply the STEM Video Design Checklist to design and develop the prototype video.

First of all, it was decided that the goal of our prototype video is to clarify the ‘muddiest point’ in the course. To achieve this goal, the faculty and student co-designers reviewed the course learning outcomes and topics as well as the interrelatedness of concepts covered. Then, we identified the ‘muddiest’ concept in which subsequent concepts in the course are built upon, which is the law of conservation of mass (COM), as well as the key prerequisite concepts including control volume, control surface, and steady/unsteady flows. During the design process, we also explored existing online videos on fluid mechanics and engineering in general for ideas that our students can relate to. After numerous brainstorming sessions and feedback from other co-designers, graduate researchers, and faculty, a storyboard was developed by following the STEM Video Design Checklist. The storyboard is structured as follows:

1. Tell a role-playing game-like story about climate change in local community, in which students need to take part to protect the community.
2. Clearly state the goals of the video.
3. Identify and define concepts to be reviewed: control volume, control surface, steady flow, and unsteady flow.
4. Expand on the story about climate change in local community and explain why COM is important in this story.
5. Introduce COM and apply COM in the climate change story.
6. Ask students to reflect and think of another engineering application in which COM is useful.
7. Review the concepts of control volume and control surface by going through scenarios in the climate change story.
8. Ask students to answer two review questions involving control surface and control volume.
9. Review the concepts of steady flow and unsteady flow by going through scenarios in the climate change story.
10. Ask students to answer a question involving steady flow and unsteady flow.
11. Discuss COM by integrating with the concepts reviewed while going through previous scenarios. Use friendly voice and language to cultivate confidence.
12. Present a challenging final knowledge check problem. Students will need to submit a scenario in which COM can be applied. The scenario does not need to be related to fluid mechanics.
13. Congratulate students with a certificate of completion for taking the first step to protect the community.

The prototype video for MakerSpace follows a similar process. It is worthwhile to mention that both videos also follow the Video Design Checklist for the display format including graphics and text, as well as usage of sound and visual effects to keep students interested and engaged.
The prototype video will be developed using Adobe Captivate which provide rich features to support interaction. Figure 2 shows a snapshot of the preliminary MakerSpace video with interactive feature called “hotspot”. Video with interactive features like this allows for active participation and helps to retain the learners’ attention.

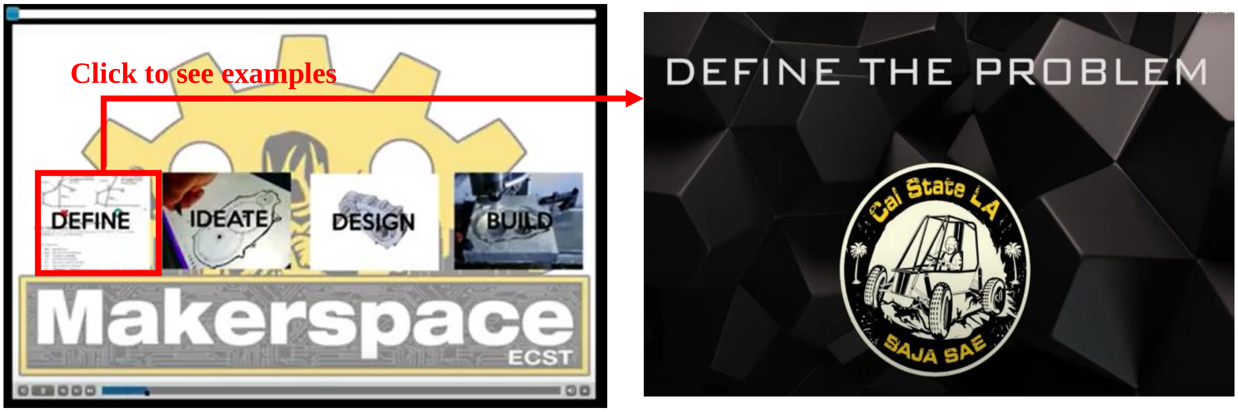

Figure 2. MakerSpace video with "hotspot" interaction to connect steps in design process with explanation and examples.

Conclusions and Future Work

It is projected that video/online learning modules will be more widely used in higher education post-Pandemic. The presented research shared valuable findings on student and faculty perspectives regarding what leads to effective design of an instructional video in engineering courses. The recommended STEM Video Design Checklist showed useful strategies to make video more relevant and engaging to students. Currently, two prototype videos are being developed and we anticipate to introduce them to students later in Spring semester. Moving forward, we will study how students respond to the newly developed video and refine the Design Checklist accordingly. We anticipate that the refined video design strategies will be used to develop video modules in other engineering courses to benefit more students in the future.

Acknowledgment

This work is sponsored by CSU STEM-NET program.

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