Planning, Implementation, and Dissemination of Educational Videos: Guidelines and Recommendations for Instructors

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Yann Brouillette is a chemistry instructor at Dawson College. He developed a complementary course for non-science students entitled Comic Book Chemistry, using examples from the superheroes universe to introduce knowledge-seekers to the science of chemistry. With the financial support of SALTISE in 2013, 2015 and 2016, Yann has created three series of educational videos focusing on experimental procedures, modeling them on effects described in graphic novels and pop culture movies. Yann is also behind the YouTube channel Chem Curious (https://www.youtube.com/user/ChemCurious/playlists) and the website www.comicbookchemistry.com

Caroline Cormier and Véronique Turcotte are chemistry instructors. They received financial support from SALTISE in 2015 and 2016 which allowed them to create more than 25 videos on general chemistry and chemistry of solutions. In addition, Caroline collaborated with Bruno Voisard (Cégep André-Laurendeau) on the production of 70 educational videos on organic chemistry, which can be found on their popular YouTube channel http://www.youtube.com/c/CarolineCormierChimieCégep. Currently, this channel has nearly 3,000 subscribers worldwide.

2 Introduction

During the 2015-2016 academic year, the SALTISE (*Supporting Active Learning & Technological Innovation in Studies of Education*) executive committee offered financial support in the form of multiple mini-grants to instructors in order to promote evidence-based active learning approaches. To support collaborative work between disciplines and institutions, mini-grant recipients producing educational science videos were paired. In addition to the individual initiatives, a collective product related to teaching with active

learning pedagogy and technology was developed. The main goal of this product is to serve as general guidelines for how instructional videos should be put together so as to actively engage students, both in and outside of class. Recognizing that this type of production requires what is considered as Technological Pedagogical Content Knowledge (TPCK)[1], the authors worked collaboratively in order to ensure that the video productions also met the standards for quality pedagogical resources.

Whether these videos are designed to be used before, during, or after class time, useful insights on how to exploit them effectively will be given. Whether these videos are made available on an open platform, only to students, or not available at all, multiple presentation options will be suggested. Whether it is your first time creating a video, or you have made a series, these tips and guiding principles will benefit new and amateur video makers. Overall, this document was put together to help instructors prepare educational videos, keeping in mind important discipline considerations and avoiding making the same mistakes the authors made in their past experience with video making. Instructional videos have become an important part of education, and preparing them efficiently to successfully get the message across should never be neglected.

In the first part of this article, the cognitive and pedagogical considerations for the design and implementation of educational videos will be presented. In order to produce instructional videos that enhance the learning experience, the authors propose recommendations for the creation of such educational tool. Special emphasis is placed on the choice of content, planning, filming, video length and style, desired interaction with the learners, technological considerations (choice of software and hardware), and finally ways to spark the students' interest for this new approach to learning.

3 Effective Educational Videos: Standards and Guidelines

The flipped learning (FL) model of instruction is gaining attention and popularity among post-secondary professors in various disciplines, particularly in the sciences.[2] In this model, lecture-style instruction is delivered outside of class time in the form of online videos. Class time is used to engage students in activities that foster active learning in collaborative manner[3]. This model of instruction allows for a shift from instructor-centered teaching to student-centered learning environment. [4]

In the ever growing fields of FL, MOOCs, online learning, and blended learning, video is becoming one of the most prevalent methods of conveying learning objects to students of all ages.[5] Instructors who assign online videos as part of their teaching methodology (FL, MOOCs, etc.) use a variety of sources including Khan Academy, YouTube, TED Talks, ED-TED, as well as recording their own lectures.

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[1] Koehler MJ and Mishra P, 2009. What is technological pedagogical content knowledge? *Contemporary Issues in Technology and Teacher Education*, 9(1), 60-70.

[2] Bishop, J.L. and Verleger, M.A., 2013, June. The flipped classroom: A survey of the research. In *ASEE National Conference Proceedings, Atlanta, GA*.

[3] Johnson, L.W. et Renner, J. D. (2012). Effect of the flipped classroom model on a secondary computer applications course: student and teacher perceptions, question and student achievement. (doctoral thesis, University of Louisville) Available at: https://theflippedclassroom.files.wordpress.com/2012/04/johnson-renner-2012.pdf.

[4] Stone, B.B., 2012. Flip your classroom to increase active learning and student engagement. In *Proceedings from 28th Annual Conference on Distance Teaching & Learning, Madison, Wisconsin, USA*.

[5] Kay, R.H., 2012. Exploring the use of video podcasts in education: A comprehensive review of the literature. *Computers in Human Behavior*, *28*(3), pp.820-831.

Several meta-analyses have shown that technology can enhance learning[6], and multiple studies have shown that video, specifically, can be a highly effective educational tool[7] [8] [9].

In order for video to serve as a productive part of a learning experience, however, it is important for the instructor to consider three elements for video design and implementation: cognitive load, student engagement, and promotion of active learning (Fig. 1). Together, these considerations provide a solid base for the development and use of video as an effective educational tool.

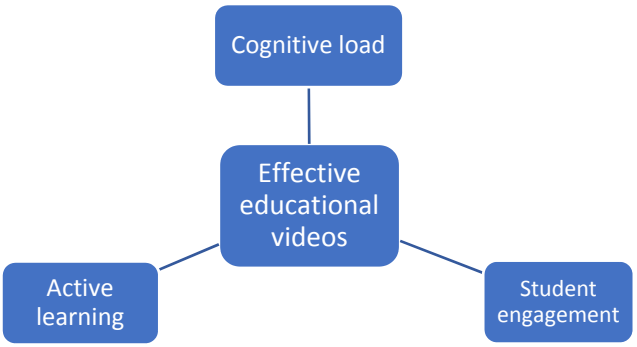

Figure 1. Elements of effective educational video. *Adapted from Brame (2015)*[10].

3.1 Cognitive Load

One of the primary considerations when constructing educational videos is cognitive load. Cognitive Load Theory or Cognitive Leaning Theory suggests that memory has several components (Fig. 2): sensory memory, working memory, and long-term memory. [11]

1. **Sensory memory** is transient, collecting information from the environment.
2. Information from sensory memory may be selected for temporary storage and processing in **working memory** (short-term memory), which has very limited capacity. Because working memory is very limited, the learner must be selective about what information from sensory memory to pay attention to during the learning process, an observation that has important implications for creating educational materials.
3. Processing of short-term memory is a prerequisite for encoding information into **long-term memory**, which has virtually unlimited capacity.

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[6] Schmid RF, Bernard RM, Borokhovski E, et al, 2014. The effects of technology use in postsecondary education: a meta-analysis of classroom applications. *Computer and Education*,72, 271-291.
[7] Allen WA and Smith AR, 2012. Effect of video podcasting on psychomotor and cognitive performance, attitudes and study behavior of student physical therapists. *Innovations in Education and Teaching International*, 49, 401-414.
[8] Hsin WJ and Cigas J, 2013. Short videos improve student learning in online education. *Journal of Computing Science in Colleges*, 28,253-259.
[9] Kay RH, 2012. Exploring the use of video podcasts in education: a comprehensive review of the literature. *Computers in Human Behavior*, 28, 820-831.
[10] Brame CJ, 2015. Effective educational videos. Available at http://cft.vanderbilt.edu/guides-sub-pages/effective-educationalvideos/. Accessed January 22, 2016.
[11] Sweller J, 1994. Cognitive load theory, learning difficulty, and instructional design. *Learning and Instruction*, 4, 295-312.

These definitions have implications for the design of educational materials and experiences. Because working memory has a limited capacity, and information must be processed by working memory to be encoded in long-term memory, it is important to prompt working memory to accept, process, and send to long-term memory only the most crucial information.[12]

Working memory has two channels for information acquisition and processing: a visual channel and an auditory channel.[13] Although each channel has limited capacity, the use of the two channels can facilitate the integration of new information into existing cognitive structures. By using both channels, working memory's capacity is maximized.

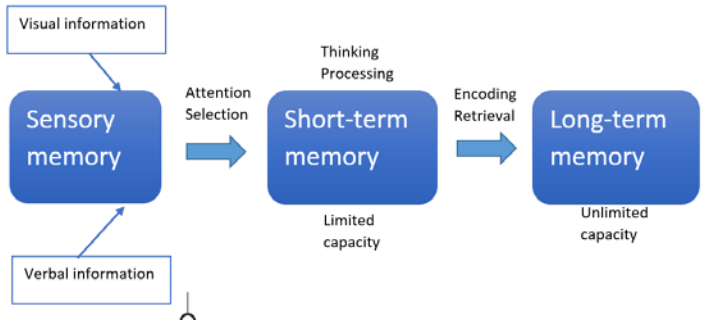

Figure 2. Cognitive load model. *Adapted from Brame (2015)*[14].

Based on the Cognitive Learning Theory, four effective practices are suggested for producing effective educational videos: signalling, segmenting, weeding, and matching modality (Table 1).

[12] Ibrahim M, Antonenko PD, Greenwood CM, Wheeler D, 2012. Effect of segmenting, signalling, and weeding on learning from educational video. *Learning, Media and Technology*, 37, 220-235.
[13] Mayer RE and Moreno R, 2003. Nine ways to reduce cognitive load in multimedia learning. *Educational Psychologist*, 38, 43-52.
[14] Brame CJ, 2015. Effective educational videos. Available at http://cft.vanderbilt.edu/guides-sub-pages/effective-educationalvideos/. Accessed January 22, 2016.

Table 1. Practices for the production of effective educational videos.

Process	Description	Example
Signalling (cueing)	Use of on-screen text or symbols to highlight important information.[15]	Appearance of key words or symbols that draws attention to a region of a screen. Zooming in on a region of a screen to draw focused attention to a particular piece of information.
Segmenting	Chunking of information to allow learners to engage with small pieces of new information as well as to give them control over the flow of new information. Shown to be important for student engagement with videos[16] [17] and learning from video.[18] [19]	Making shorter videos (6-10 minutes) Including pauses within a video to provide students with a question and prompting them to click forward after completion.
Weeding	Elimination of information that does not contribute to the learning objectives and that may overload the learners' memory. This has been shown to improve retention and transfer of new information from video.[20]	Music, complex backgrounds, or extra features or content can reduce learning.
Matching modality	Process of using both the audio channel and the visual channel to convey new information, fitting the particular type of information to the most appropriate channel. Using both channels to convey appropriate and complementary information has been shown to increase students' retention and ability to transfer information[21] and to increase student engagement with videos.[22]	Showing an animation of a process on screen while narrating it. Using Khan Academy-style tutorials that provides symbolic sketches to illustrate the verbal explanation.

[15] deKoning B, Tabbers H, Rikers R, Paas F, 2009. Towards a framework for attention cueing in instructional animations: guidelines for research and design. *Educational Psychology Review*, 21, 113-140.
[16] Guo PJ, Kim J, Robin R, 2014. How video production affects student engagement: an empirical study of MOOC videos. *ACM Conference on Learning at Scale (L@2014)*. Available at http://groups.csail.mit.edu/uid/other-pubs/las2014-pguo-engagement.pdf.
[17] Zhang D, Zhou L, Briggs RO, Nunamaker JF Jr., 2006. Instructional video in e-learning: assessing the impact of interactive video on learning effectiveness. *Information & Management*, 43, 15-27.
[18] Ibrahim M, Antonenko PD, Greenwood CM, Wheeler D, 2012. Effect of segmenting, signalling, and weeding on learning from educational video. *Learning, Media and Technology*, 37, 220-235.
[19] Zhang D, Zhou L, Briggs RO, Nunamaker JF Jr., 2006. Instructional video in e-learning: assessing the impact of interactive video on learning effectiveness. *Information & Management*, 43, 15-27.
[20] Ibrahim M, Antonenko PD, Greenwood CM, Wheeler D, 2012. Effect of segmenting, signalling, and weeding on learning from educational video. *Learning, Media and Technology*, 37, 220-235.
[21] Mayer RE and Moreno R, 2003. Nine ways to reduce cognitive load in multimedia learning. *Educational Psychologist*, 38, 43-52.
[22] Guo PJ, Kim J, Robin R, 2014. How video production affects student engagement: an empirical study of MOOC videos. *ACM Conference on Learning at Scale (L@2014)*. Available at http://groups.csail.mit.edu/uid/other-pubs/las2014-pguo-engagement.pdf.

3.2 Student Engagement

One of the most important aspects of creating educational videos is to include elements that help promote student engagement.

The following recommendations help increase the level of student engagement with the video content.

1. Keep the duration of the video short. In a recent study, it was suggested that the maximum median engagement time for a video of any length was six minutes. Making videos longer than 6-9 minutes is therefore likely to be wasted effort.[23] However, this can be circumvented by including pauses within a video to provide students with a question and prompting them to click forward after completion.
2. Use a conversational style. The use of conversational rather than formal language during multimedia instruction has been shown to have a large effect on students' learning, perhaps because a conversational style encourages students to develop sense of social partnership with the narrator that leads to greater engagement and effort.[24]
3. Speak relatively quickly and with enthusiasm. In Guo and colleagues' study (2014), student engagement was found to be dependent on the narrator's speaking rate, with student interest and engagement increasing as speaking rate increased. An educator may be tempted to speak slowly to help ensure that students grasp important ideas. Including in-video questions and speed control (fast-forward) can give students control over this feature. [25]
4. Present video information that feels like it is for your students in your class. It is important to create videos for the type of environment in which they will be used. Research suggests that student engagement can be significantly reduced when video content is borrowed from resources and is not made with particular consideration to your class style.[26]
5. Match modality. When teaching about invisible phenomena, it is helpful to provide illustrations. Providing visual elements that add to the lesson promote student understanding and engagement with the lesson.[27]

It is also noted by educational research that the contents seen in videos by students in a FL environment must be truly course contents, and not enrichment material. This allows students to better accept this new teaching method and therefore become more engaged[28].

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[23] Guo PJ, Kim J, Robin R, 2014. How video production affects student engagement: an empirical study of MOOC videos. *ACM Conference on Learning at Scale (L@2014)*. Available at http://groups.csail.mit.edu/uid/other-pubs/las2014-pguo-engagement.pdf.

[24] Mayer RE, 2008. Applying the science of learning: evidence-based principles for the design of multimedia instruction. *Cognition and Instruction*, 19, 177-213.

[25] Guo PJ, Kim J, Robin R, 2014. How video production affects student engagement: an empirical study of MOOC videos. *ACM Conference on Learning at Scale (L@2014)*. Available at http://groups.csail.mit.edu/uid/other-pubs/las2014-pguo-engagement.pdf.

[26] Guo PJ, Kim J, Robin R, 2014. How video production affects student engagement: an empirical study of MOOC videos. *ACM Conference on Learning at Scale (L@2014)*. Available at http://groups.csail.mit.edu/uid/other-pubs/las2014-pguo-engagement.pdf.

[27] Guo PJ, Kim J, Robin R, 2014. How video production affects student engagement: an empirical study of MOOC videos. *ACM Conference on Learning at Scale (L@2014)*. Available at http://groups.csail.mit.edu/uid/other-pubs/las2014-pguo-engagement.pdf.

[28] Enfield, J. (2013). Looking at the impact of the flipped classroom model of instruction on undergraduate multimedia students at CSUN. *Techtrends: Linking Research and Practice To Improve Learning* 57(6), 14-27. doi:10.1007/s11528-013-0698-1.

3.3 Active Learning

The use of videos as instructional tool has its limitations. Of these limitations, two are of particular relevance to student-centered teaching and learning.

- Watching videos, no matter how engaging or entertaining, remains a passive learning activity.
- Information pertaining to the use of assigned videos by students is not available. For example, which students watched the assigned videos, who watched the entire video, and of those who watched, who was able to grasp the concepts presented in the videos?

To help students get the most out of an educational video, it is important to provide tools to help them process the information and to monitor their own understanding. There are multiple ways to do this effectively. The following are a few examples.

1. Use guiding questions. Providing students with guiding questions while watching an educational video is shown to improve retention.[29]
2. Use interactive features that give students control. Provide students with the ability to control movement through the video, selecting important sections to review and moving backwards when desired. This has been shown to improve achievement of learning outcomes and to lead to greater student satisfaction.[30] This level of interactivity can be achieved by using YouTube Annotate or tools to introduce labeled sections into a video.
3. Integrate questions into the video. Several tools, like Zaption and EDpuzzle, allow instructors to incorporate questions directly into video and to give feedback based on student response[31]. These assessment tools allow instructors to assess content comprehension at any given time during the video presentation in such a way that students are required to answer questions successfully before they can proceed to the next sections of the video presentation. Through skillfully crafted questions and interactions, interactive video assessment tools can allow for timely formative assessment. In one study comparing the effect of video with embedded questions to interactive video without embedded questions, it was found that embedded questions improved students' performance on tests. [32]

   The analytics capabilities of interactive video assessment tools make tracking of student use of videos and their learning progress easy. Instructors can see which students have completed watching the assigned videos and assess individual as well as class progress with video assignments. In addition, instructors can get information on the questions that students have difficulty with. This is particularly useful for planning which concept/content to focus on during a flipped classroom session.

[29] Lawson TJ, Bodle JH, Houlette MA, Haubner RR, 2006. Guiding questions enhance student learning from educational videos. *Teachings of Psychology*, 33, 31-33.
[30] Zhang D, Zhou L, Briggs RO, Nunamaker JF Jr., 2006. Instructional video in e-learning: assessing the impact of interactive video on learning effectiveness. *Information & Management*, 43, 15-27.
[31] Yousef, A.M.F., Chatti, M.A. and Schroeder, U., 2014. Video-Based Learning: A Critical Analysis of The Research Published in 2003-2013 and Future Visions.
[32] Vural OF, 2013. The impact of a question-embedded video-based learning tool on e-learning. *Educational Science: Theory and Practice*, 13, 1315-1323.

The important thing to keep in mind is that watching a video can be a passive experience, much as reading can be. To make the most of educational videos, instructors need to help students do the processing and self-evaluation that will lead to deeper learning. The particular way this is done should be guided by goals of the course and the norms of the taught discipline. A meta-research conducted in 2014 has shown that active learning methods lead to better exam scores, better performance in conceptual tests, and a decrease in failure rates in science, engineering, and mathematics courses[33].

4 Practical Recommendations

4.1 Choice of Content

Varying forms of FL can be implemented in the classroom, leading instructors to design instructional videos in a variety of ways. In addition, some videos are designed to be disseminated in a traditional classroom setting. While the following practical recommendations refer to videos specifically designed for a flipped classroom, some suggestions are applicable to educational videos in general.

Flipping an entire course requires the production and use of a large number of videos, a number much larger than when only some parts of the course are flipped. Caroline and Véronique (Cégep André-Laurendeau) tested two flipped models in the chemistry courses they teach: (1) organic chemistry, where the entire course was flipped and (2) General Chemistry and Chemistry of Solutions, where only selected parts where flipped while delivering the remainder of the course contents in a traditional way (lecturing). Regardless of the model used, careful consideration was exercised as to which components of the material to flip and therefore present using video. They chose to produce videos that cover introduction to concepts and procedures involving graphs, diagrams, and calculations. Concepts that they deemed challenging were deliberately delivered in a traditional manner in class. In this way, students prepared for class by viewing videos that cover simple content and procedures, thus allowing for ample time in class for activities that deepen and consolidate student learning.

For certain concepts, Caroline and Véronique have chosen to treat the difficult aspects of these concepts using video. The visuals used in video help students to better understand these concepts. In addition, video has an advantage over face-to-face lecturing as students have full control of video by pausing and rewinding as many times as they want.

As an example of partial flipping of the Organic Chemistry course, Caroline and Véronique have created videos in which they present the two mechanisms of nucleophilic substitution SN1 and SN2. However, it is in the classroom that the instructors explain the factors that predict whether a substitution reaction is of kinetic order 1 or 2. Thus, students come to the classroom knowing the mechanics and how to diagram the two mechanisms (declarative and procedural knowledge). In class, the instructors presented and taught situational analysis of these mechanisms using activities that foster deeper knowledge.

[33] Freeman, S. et al. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, 111(23), 8410-8415.

Research has shown that it was easier to implement the FL model by flipping only certain parts of the content of a course[34]. The time required to create educational videos is quite long. Therefore, it may seem impractical to flip an entire course over a semester-long period of time. It is for this reason that the choice of content to flip becomes particularly important.

4.2 Planning

Once content is selected for video recording, a storyboard is created. As content may not be filmed in the order it will appear in the final video, a detailed storyboard allows the presenters to master the scenario and avoid confusion during the video recording.

Here is an example (Fig. 3) of a storyboard used for the "Oxidation Reduction" video used in Chemistry of Solutions course of Caroline and Véronique.

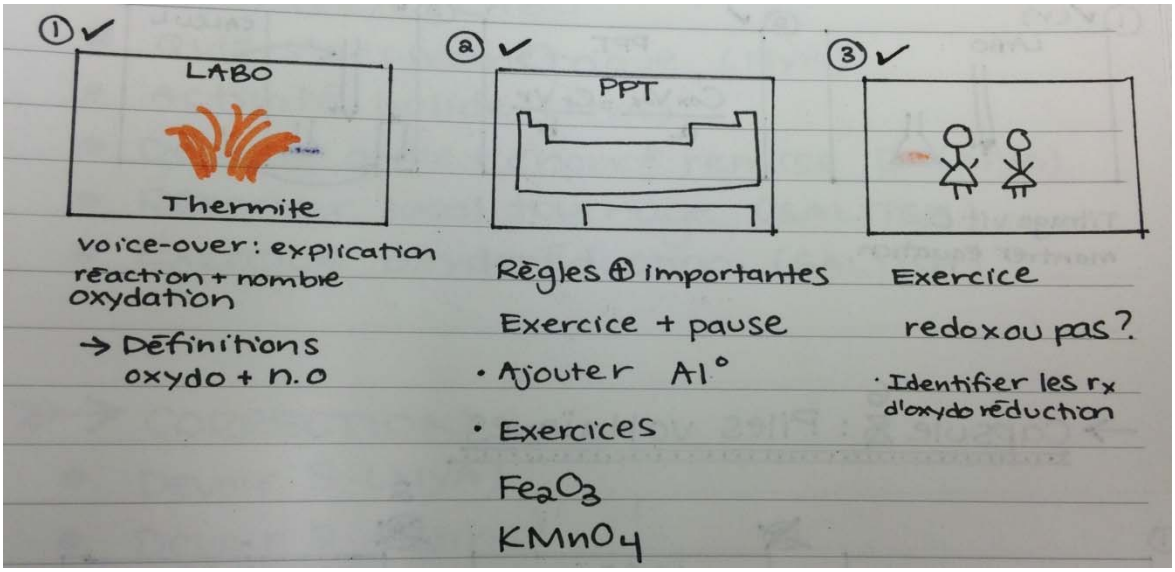

Figure 3. Example of storyboard.

This video consists of three different segments. The three screen shots presented in Figure 4 correspond to the three planned segments shown in the following example of storyboard.

a) The first is a chemical experiment performed in the laboratory, demonstrating a redox process: the thermite reaction. This lab experiment is chosen to introduce the concept of redox but also to explain some basic definitions using a voiceover.
b) Then, a screen capture of a PowerPoint presentation is used to explain the step-by-step process, enabling students to determine the oxidation state of an element in a compound. This segment also includes two short problems to be solved by the viewer. The first one be solved serve as a methodological example. The student is asked to solve the second problem by himself/herself to

[34] O'Flaherty, J., et Phillips, C. (2015). The use of flipped classrooms in higher education: A scoping review. *The Internet and Higher Education*, 25, 85-95.

evaluate his/her understanding. It is also suggested to students to pause the video, solve the problem, and restart the video before the solution to the problem is revealed by the presenters.

c) Finally, the third segment is filmed in class, where the two presenters (teachers) solve a simple problem on a white board. In this case, one teacher asks the other to identify the redox reactions. The teacher who answers the question thinks out loud, thus presenting a learning model to students. The presenting teacher deliberately makes mistakes, thus mimicking the most common ones made by students. The other teacher then explains what is wrong with the presented reasoning.

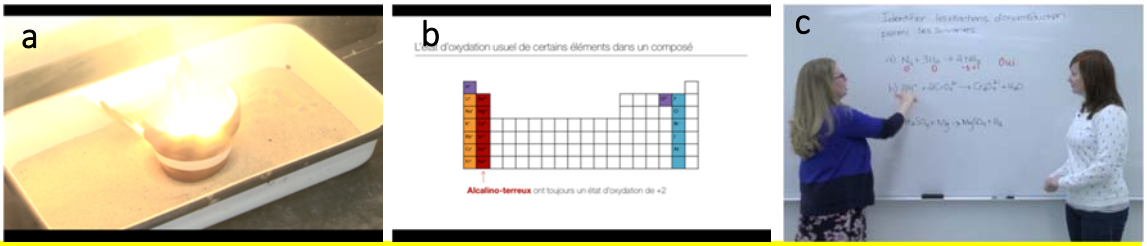

Figure 4. Screenshots from a video created using the storyboard shown in Fig. 3. (a) Thermite reaction; (b) PowerPoint presentation; (c) Problem solving by the teachers.

The time spent on planning and storyboarding allows for more efficient filming of videos. In Caroline and Véronique's videos, theory, examples, and problems are usually presented. Therefore, the proper planning requires a detailed storyboard detailing the explanations and the choice of examples and problems. In some videos, a script was prepared. However, the entire text was not narrated during the filming process. The authors noticed that when the script was efficiently written, the length of the resulting video was shorter because they were less likely to repeat explanations unnecessarily. They actually used the prepared script as a memory-aid when filming.

The examples and problems used in Caroline and Véronique's videos were selected in such a manner that they represented a satisfactory range of possible situations. In addition, the chosen examples differ from the presented problems since the examples are solved by the teachers on a whiteboard, whereas the problems are solved by the students after pausing the video. In most cases, problems are presented immediately following relevant examples.

4.3 Video Duration

Educational videos are best when kept short. Caroline and Véronique generally aim for a clip with a duration of 5 minutes. However, for complex topics, video duration may go up to, but should never exceed, 10 minutes. For contents that would typically take 30 minutes to explain in class, it would be unthinkable to make a 30-minute video; no student would stay engaged watching an educational video for this duration of time. Data collected form 91 videos hosted on Caroline and Véronique's YouTube channel have shown a clear relationship between the duration of a video and viewing time. The longer

the video, the smaller the percentage of the video that is actually being watched ($R^2 = 0.539$, $t = -10.201$, $p < 0.001$).

Overall, explaining a concept or a procedure using video is faster than explaining the material in class. In a video, it is unnecessary to allow time for students to write what is being said, to summarize the content of the video at the end, or to explain in detail the preliminary concepts since links to previous videos may be provided. Unlike a classroom, a presenter in a recorded video does not answer questions from viewers. If students need to take notes, they simply pause the video. If they misunderstood a concept, they can easily rewind the video. In fact, the viewing time is probably longer than the duration of the actual video, mainly because of the number of interruptions and rewinds each student makes. This is one of the main benefits of educational videos: students watch on their own time and at their own pace, and can replay sections as much as needed.

Therefore, it is better to make two or more shorter videos than a longer one. However, careful consideration should be exercised when splitting a topic into different distinct content parts. Each content part to be used in a video should be a standalone with its own distinct objectives, albeit complementary to the other content parts under the same topic. Furthermore, students appreciate being able to easily access the desired content of a short video rather than having to search through a 30-minute video to find the desired section. As described in the recommendations above, in order to make short videos, content must be well defined and presented efficiently, and long, inefficient concept explanations must be avoided.

4.4 Video Styles and Formats

Educational videos used for FL can take many formats. The most common format used is that of a screencast with a voiceover. Examples of such format include PowerPoint presentations and live handwriting on a digital graphic tablet, such as the popular Khan Academy (www.khanacademy.org). In some videos of this type, the narrator's face is also recorded as part of the screencast. Screencasts have multiple benefits, most important of which are:

- Content can be clearly and efficiently presented on screen.
- A presenter who is uncomfortable behind the camera can create a screencast with voiceover only.
- When the presenter’s face is not shown on screen, notes/script can be discreetly consulted while narrating.

For certain concepts necessitating extensive calculations or drawings, using the " hand over the whiteboard" method is recommended. This method consists of simply placing the camera vertically over a whiteboard that is laid flat on a table. This method is technologically simple and offers the same advantages as the method used by the Khan Academy. The rate at which the explanation is written on the whiteboard by the presenter is slower than when characters appear directly on screen. This allows students to take notes in real time, which can be advantageous to them. The experience they get from this method of presenting video content mirrors the one they get from attending face-to-face class.

Some teachers prefer to film themselves, often in “American shot,” in front of a blackboard presenting the concepts, much like in a traditional classroom setup. This format is ideal for situations where two teachers are presenting the content in the video using dialogue. For example, one presenter may suggest

a problem and the other shows how to solve it. Although it is not essential for the teacher to be seen in a video, it provides an affective relationship between the teacher and the students. This may be important for certain groups of students.

In experimental sciences, it is also possible to film laboratory experiments that are too dangerous or complex to be performed in class/laboratory. In addition, capturing them on video allows teachers to save on reagents that are being used only once. Some demonstrations may serve to illustrate concepts that are explained in parallel in the video. In some cases, half the screen shows the lab procedure while the other half is used to present the theory (with screen captures, voiceovers, and/or teacher's faces).

Other videos are filmed entirely in the laboratory and used to present laboratory techniques with the appropriate setups. These videos are usually viewed by students before a laboratory session takes place and therefore serve to decrease the duration of the pre-lab explanations or even eliminate them entirely. The advantage of this type of videos is to give more time for students to experiment in the lab. It also allows them to consult the videos during a lab session and therefore work in a more independent manner.

4.5 Hardware and Software

There are two important components of FL: pedagogical and technological. As mentioned earlier, the pedagogical component refers to the use of class time to engage students in activities that foster active learning in a collaborative manner, while lecture-style instruction is delivered outside of class (online videos). However, the pedagogical benefit of in-class activities is dependent on the proper utilization of technology tools.

Two technology types of tools are necessary for flipping a classroom: content creation tools and content distribution tools.

4.5.1 Content creation tools

Several options are available for creating content (videos) for flipped classroom. These can be generally categorized under four types: screencasting tools, tablet software, video-recording cameras, interactive video assessment tools.

4.5.1.1 Screencasting tools [35]

By far, screencasting is the most popular software category used in FL. It consists of using a software that captures anything happening on computer screens, while simultaneously recording audio, and, if webcam is available, teacher's face. Many teachers use in addition digital pen annotation tools which are especially helpful when describing how to solve mathematical problems. Screencasting is especially popular with teachers who use PowerPoint slides, interactive whiteboards, or other presentation software.

[35] Bergmann J, Sams A, 2012. Flip your classroom: reach every student in every class every day. ISTE & ASCD, USA. P.35-40.

Screencasting tools are relatively inexpensive and consist of the following:

- Screencasting software
- Computer
- Digital pen and graphic tablet
- Microphone
- Webcam

Screencasting software. Screencasting software records whatever is on your screen, including PowerPoint presentations, webpages, and digital pen annotations on the computer. When a microphone and a webcam are set up, the software records narrator's voice and face. Several screencasting programs are available. The most widely used program is Camtasia Studio (www.techsmith.com). Other screencasting programs are Screencast-O-Matic (free; www.screencast-o-matic.com), SnagIt (www.techsmith.com), Office Mix (free extension to PowerPoint; www.mix.office.com), Adobe Presenter (extension to PowerPoint; http://www.adobe.com/ca/products/presenter.html), and Screenpresso (free; www.screenpresso.com/).

Digital pen and graphic tablet. Several options are available for teachers who opt to use pen annotation with their screencast. One of the most popular devices used are graphic tablets that require to be plugged to a computer, such as Wacom Bamboo tablets (www.wacom.com). Other options include the use of wireless tablets (e.g., iPad) and tablet PCs which have the pen functionality built in.

Microphone. Although most laptops and computers nowadays have built-in microphones, they are not usually of high quality. In addition, built-in microphones record typing and mouse-clicking sounds of the computer. High quality, studio-style USB microphones are highly recommended (e.g., Sennheiser EW series wireless microphones).

Webcam. Most newer laptops have built-in webcams. However, if an instructor is planning on recording laboratory demonstrations or events that cannot be done in a classroom, a standalone HD webcam that is plugged to a computer is advisable. Most FL instructors report that students like to see their teachers' faces on screen in a screencast.

4.5.1.2 Tablet software[36]

A new generation of tablet apps is becoming available. These apps allow instructors to crate content in a way similar to videos produced by screencasting tools. Examples of these apps include Educreations (www.educreations.com) , Explain Everything (www.explaineverything.com) , and Knowmia (www.knowmia.com).

[36] Ericson T. Screencasting and video lesson creation tools. Available at: https://edshelf.com/shelf/tandraericson-screencasting-and-video-lesson-creationtools/. Accessed May 1, 2016.

4.5.1.3 Video camera

Some instructors choose video camera for their flipped class. Camera-created videos are especially useful when recording scientific experiments, technical procedures, and other processes that require high quality video recording.

4.5.1.4 Interactive video assessment tools[37]

Over the past 2-3 years, new tools have emerged that allow instructors to easily embed questions into assigned videos in FL. Interactive video assessment tools have multiple features including:

- Embedding custom assessment questions (multiple choice, true or false, open ended, etc.) into an assigned video at any point in the video.
- Searching and using existing video on the Internet (e.g., YouTube).
- Editing and customizing video clips.
- Adding voice narration and other additional information to existing video.
- Collecting individual- and class-level assessment and usage analytics.

Interactive video assessment tools are offered at a basic level for free. Basic-level features vary between providers, while advanced features are available with paid accounts. Examples of interactive video assessment tools include Zaption (www.zaption.com), EDpuzzle (www.edpuzzle.com), eduCanon (www.educanon.com), and Office Mix (www.mix.office.com).

4.5.2 Distribution Tools

The most popular distribution tool is the Internet. Several video hosting sites exist, but the most used one is YouTube. Interactive video assessment tools described above also have their own hosting services (e.g., Zaption, EDpuzzle). Some instructors prefer to use the local institution servers or LMS (e.g., Blackboard, Moodle, Omnivox). When Internet accessibility is a concern for certain students, instructors may opt to provide their videos in the form of physical media such as a USB flash drive or DVD.

4.6 Sparking Students' Interest

Nowadays, students benefit from having 24/7 access to course information in a variety of formats. Instructional videos can enhance learning and be a highly effective educational tool. As mentioned above, if used outside the classroom, instructional videos can serve as supplementing course materials, introducing topics, and reviewing content. Videos appeal to a variety of learning needs and may be used aptly to spark student interest in a variety of ways in or outside of the classroom.

As mentioned earlier, experimental science teachers will benefit from experimental videos to show their laboratory procedures that are either too dangerous, too complex, or too costly to be performed in class/lab. The change in colour or physical state, as well as the production of smoke, gas, or flame are guaranteed features that catches students attention.

[37] Edel S, Brautigam B, Bittner K, Blackstock D, 2015. Investigating interactive video assessment tools for the flipped classroom. International Conference on E-Learning. DOI: 10.13140/RG.2.1.2984.3687.

When used in class, a short video can be shown at the beginning of a lesson to review a previous class theme, to introduce a new topic, or to stimulate discussion and brainstorming. Getting the students' attention with an introductory video canalizes the group's energy on the subject to be discussed.

Videos can be used to get students to appreciate content implications that are normally difficult to convey due to course constraints. These videos make the link between course content and their real-life applications more visual and reachable. Simply employing a different narrative format for the same information also helps students grasp the equation, process, or idea the instructor wishes to convey.

Educational videos may be used to heighten student motivation. They give long classes room to breathe by bridging two subject matters. When used in class, these videos can keep students engaged, and for those students who have become disengaged or confused, these videos can serve as a mean for these students to re-engage and refocus. In addition, infusing educational videos with the presenter's personal aspects and views (e.g., revealing aspects of the presenter's personality) may establish an affective relationship between the teacher and the students, thus favoring a more constructive and efficient exchange in class.

Finally, educational videos may be used at the end of class as a summary, to answer final and concluding questions, or as a segue to the next topic. In other words, they conclude lessons and send student off on a pleasant note.

In conclusion, your students like to watch TV and Internet videos. Why not use educational videos to make them like learning?!

5 Suggested Readings

Bergmann, J. & Sams, A. (2012). *Flip your classroom: Reach every student in every class every day*. Washington, DC: International Society for Technology in Education.

Flipped Institute. http://flippedinstitute.org/.

Flipped Learning Network. http://fln.schoolwires.net/.

O'Flaherty, J., et Phillips, C. (2015). The use of flipped classrooms in higher education: A scoping review. *The Internet and Higher Education*, 25, 85-95.

Service de soutien à la formation de l'Université de Sherbrooke. (2011, Novembre). Faire la classe mais à l'envers : la *flipped classroom*. *Bulletin Perspectives SSF*, Récupéré de : https://www.usherbrooke.ca/ssf/tous-les-numeros/novembre-2011/le-ssf-veille/faire-la-classe-mais-a-lenvers-la-flipped-classroom/.

Yarbro J, Arfstrom KM, McKnight K, McKnight P, 2014. Review of flipped learning. Flipped Learning Network. Available at http://flippedlearning.org/cms/lib07/VA01923112/Centricity/Domain/41/Extension%20of%20Flipped%20Learning%20Lit%20Review%20June%202014.pdf.