

STUDENT EVALUATIONS OF U.S. CHEMICAL SAFETY BOARD CASE STUDY VIDEOS USING A CHE PROCESS SAFETY ASSIGNMENT

MATTHEW E. COOPER

North Carolina State University • Raleigh, North Carolina 27695-7905

INTRODUCTION

The U.S. Chemical Safety Board (CSB) is an independent federal agency with a mission to “drive chemical safety change through independent investigation to protect people and the environment” through “root cause investigations of chemical accidents at fixed industrial facilities”.^[1] Though the CSB does not have punitive authority to issue fines or citations, the board provides official recommendations to industry, regulatory agencies, and labor groups based on its findings.^[1] As part of the documentation of its investigations, the CSB also produces case study videos detailing the circumstances surrounding process safety incidents. These case study videos are posted for free viewing on the CSB website at www.csb.gov.

Process safety education is considered a critical part of the ChE curriculum, with ABET requiring process safety content as part of accreditation requirements for ChE programs beginning in 2011.^[2-3] Specifically for ChE programs, ABET requires that “the curriculum must provide a thorough grounding in the basic sciences including chemistry, physics, and/or biology, with some content at an advanced level, as appropriate to the objectives of the program. The curriculum must include the engineering application of these basic sciences to the design, analysis, and control of chemical, physical, and/or biological processes, *including the hazards associated with these processes*”.^[3] CSB case study videos represent useful tools for incorporating process safety content into ChE courses through classroom viewing accompanied by discussions and assignments. The author has used CSB videos to inspire in-class discussion in courses for the better part of the past decade. Initially, case study videos were simply viewed in class and discussed as a group, with the author as instructor leading classroom discussion using a series of active learning activities—for example, an active learning question prompt after viewing a video could be, “*There were a number of factors that contributed to cause this industrial disaster rather than only one. Turn to your neighbors and come up with as many of these causes as you can.*” In order

to assess student knowledge, the author would ask students to recall these incidents discussed in class on an exam, asking them to explain (a) what happened in the incident; (b) what caused the incident; and (c) what safeguards/measures could have prevented the incident.

Initially, the author chose the same videos for classroom discussion and assignments each semester, but over the years the content became a bit stale for the author as an instructor. The CSB releases new videos regularly, and these videos are regularly uploaded to the CSB website’s Video Room.^[4] As an instructor the author wanted to know which videos are most well received by students in order to make informed choices for the classroom. In particular, it seemed important to use videos with modern high-quality visuals in classes. It was thought that CSB videos with poor visual quality may lead to an effect similar to antiquated informative videos such as “Red Asphalt”^[5] viewed by many students (including the author) in driver education courses, where very low quality visuals led students to spend more time ridiculing the video rather than focusing on the quite serious subject matter. This deleterious “hokey visual” effect is well researched in contemporary communication rhetoric literature, where it is ascribed to the rhetorical strategy of ethos.

The term “rhetoric” was defined by Aristotle as “an ability, in each [particular] case, to see the available means of persuasion”.^[6] One of these means of persuasion is ethos, which can be generally defined as a strategy of persuading through the credibility or authority of the persuader.^[7] Aristotle believed

Dr. Matthew Cooper is a Teaching Associate Professor in the Department of Chemical and Biomolecular Engineering at NC State University. After receiving a Ph.D. in Chemical Engineering from Ohio University, Dr. Cooper served as a researcher at RTI International before joining the NC State faculty in 2011. Dr. Cooper’s research interests include effective teaching, process safety decision-making skills and best practices for online education.



that ethos “should result from the speech, not from a previous opinion that the speaker is a certain kind of person”.^[6] In other words, a well-communicated argument can *create* ethos for the speaker.^[8] While Aristotle was referring to oral argument in this particular quote, its meaning is arguably congruent for arguments made through other media, including visual media.^[8] It is well known that when communicating through visual media, high-quality visuals lend credibility to the communicator through “visual ethos”.^[8-10] This effect is commonly experienced when one visits a website that has an antiquated presentation, poor graphics, etc. - people are more likely to consider such a website as untrustworthy compared to one that presents similar content in an attractive and professional manner.^[10]

At one point the author considered including a process safety assignment utilizing CSB videos as part of a laboratory class but with no lecture section, the viewing had to be outside of class. A simple assignment was offered where the same three (a)/(b)/(c) questions from the previous class were included, but students were also asked to rate the visual quality and overall effectiveness of CSB videos. In this way, the instructor could gauge which videos students felt had high levels of visual ethos as well as effectiveness; it was important to solicit these opinions from students since they are in the best position to indicate how students on the whole would feel about the videos. The videos deemed “best” by the students in this course could then be confidently used for in-class viewing and discussion in other courses.

This manuscript has three goals: (1) provide a description of a simple process safety assignment involving CSB case study videos to ChE educators; (2) identify which process safety case study videos available on the CSB website’s Video Room^[4] are most likely to be well-received by students as part of in-class review or in a different assignment, based on the studied students’ perceptions of visual quality and overall effectiveness; and (3) identify criteria that could be useful in selecting CSB case study videos for future classroom use. With this final goal in mind, two hypotheses will be tested: (1) more recently-published CSB videos have higher quality visuals than older videos due to technological advances in the video publishing field; and (2) a correlation between perceived quality of visuals and overall effectiveness should be expected since people attach ethos to visual quality (visual ethos) in graphical presentations.^[8-10]

DESCRIPTION OF STUDY

This study focuses on an assignment completed in a two-credit hour senior unit operations course (CHE 331) taught by the author. In the studied course, 6% of the course grade was attributed to student performance on a “safety paper” assignment. In this assignment, each student in a section was assigned a different CSB case study video to view, and they were given a prompt to guide the writing of a short (less than

two pages) paper in order to verify student viewing of the video as well as assess their understanding. This assignment prompt is provided in the Appendix for faculty who are interested, but in short the prompt asks students to (a) describe what happened in the industrial incident; (b) explain the root causes of the incident; and (c) explain what preventative measures or safeguards could have prevented the incident. Student performance on these measures was assessed on the basis of whether they were correct, as well as the thoroughness of their responses (e.g. overlooking a key cause of the incident while identifying others would result in fewer points awarded). As final considerations, students were asked to rate the video they viewed on a scale of 1-10 in two categories: (1) quality of visuals and (2) effectiveness of the video. These latter two ratings are the data examined here.

A total of 345 assignment submissions from students from semesters spanning Fall 2015–Spring 2019 were studied. Proper human subjects approval was secured as part of the study. In 11 instances students did not provide a rating for either of the two rating categories; these data were removed from analysis, leaving 334 students who provided a rating in at least one of the categories. If a rating was given in only one category rather than both, the single rating provided was included in analysis; this occurred in 10 instances. Release date information for each video was taken as the posting dates for videos posted to the CSB’s page on YouTube.^[11]

DATA ANALYSIS

Student ratings of CSB videos

Figure 1 is a bar plot detailing the average student rating (on a scale of 1-10) for the visual quality of each CSB process safety video. It is seen that the students who viewed the videos “Fire in Baton Rouge”, “Dangerously Close: Explosion in West, Texas” and “Dangers of Flammable Gas Accumulation” rated these videos as having high-quality visuals; however, these videos have a fairly small sample of students providing ratings, at 4, 4 and 9, respectively. “Behind the Curve” and “Filling Blind” similarly had well-above-average student ratings with sample sizes of approximately 20. Regardless of these vagaries, it is likely that any of these five videos would have satisfactory visual ethos for modern ChE students. In contrast, the videos “Inherently Safer”, “Dangers of Propylene Cylinders”, and “Preventing Harm from NaHS” received the lowest ratings from students on visual quality and may not have the visual ethos necessary for students to take them seriously.

Figure 2 details the average student rating of perceived effectiveness of the studied process safety case study videos. Again, the video “Fire in Baton Rouge” received the highest rating by students who viewed the video. This video recounts a fire at an ExxonMobil facility resulting from an isobutene leak that CSB investigation contends occurred due to a lack of safety hazard analysis. The video uses modern computer-rendered images of the plant to allow clear views of the fa-

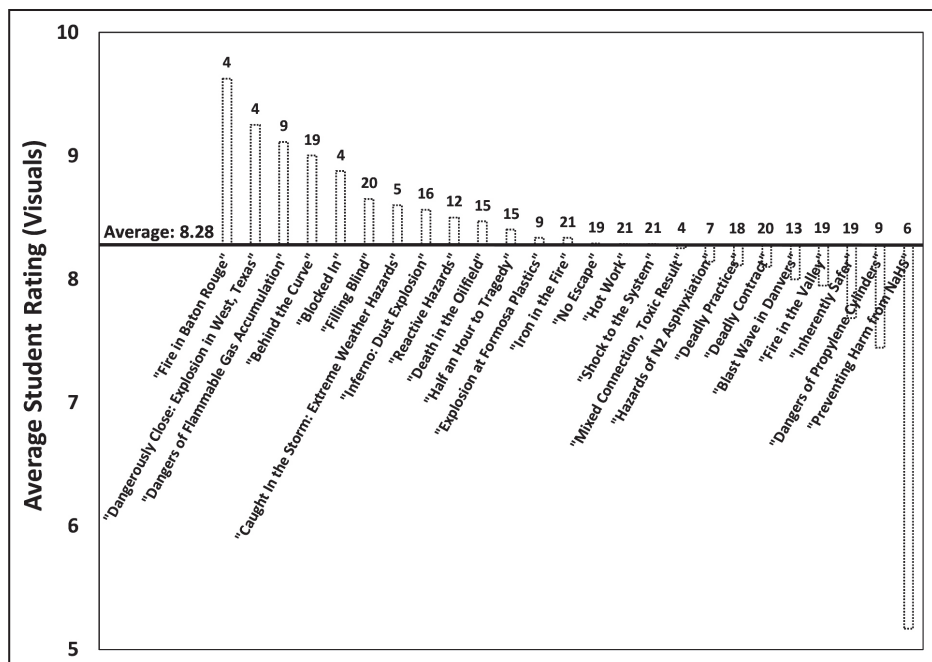


Figure 1. Average student rating of visual quality on 1-10 scale for selected CSB process safety case study videos. Sample size of ratings for each video shown as numbers above bar.

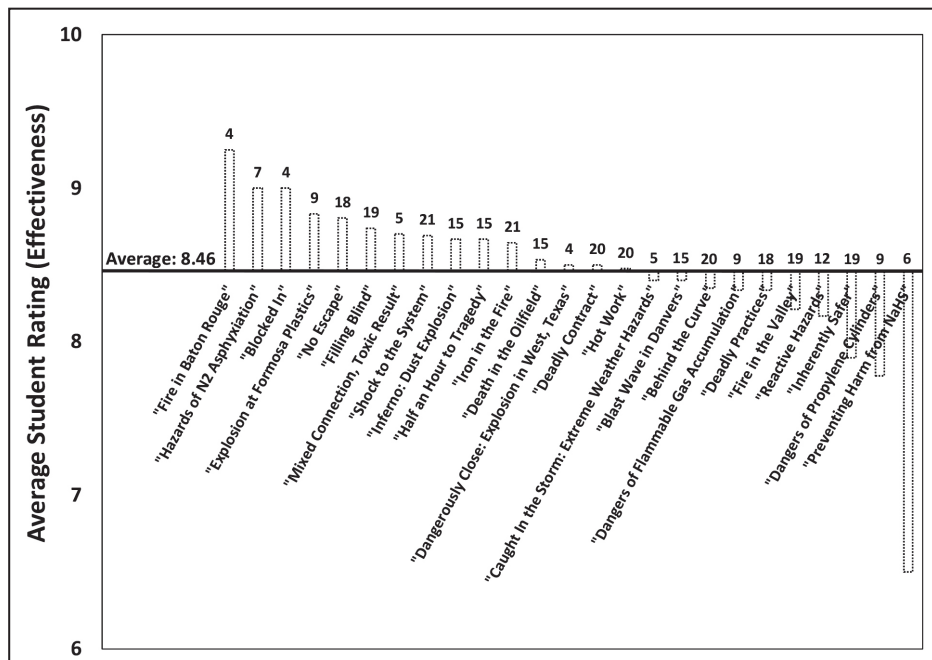


Figure 2. Average student rating of effectiveness on 1-10 scale for selected CSB process safety case study videos. Sample size of ratings for each video shown as numbers above bar.

cility and equipment used. The video graphically highlights balance-of-plant items such as valves and bolts relevant to the incident to plainly indicate equipment construction and procedures. From the data collected, it appears the "Fire in

Baton Rouge" video was particularly well received by students and would make a good choice for instructors wishing to view and discuss a single video as part of an assignment or class activities. The videos "Dangerously Close: Explosion in West, Texas" and "Filling Blind" are also seen as rated above-average by students in effectiveness; since these videos also received high ratings for quality of visuals as shown in Figure 1, it seems these videos would also be excellent choices for ChE instructors to consider using in their courses.

When looking at the lowest ratings for perceived effectiveness, it is seen that students again gave poor ratings to the videos "Inherently Safer", "Dangers of Propylene Cylinders", and "Preventing Harm from NaHS." The latter two of these videos were released in 2007 and have somewhat grainier video, leading to lower visual quality. It is possible these videos do not have the requisite amount of visual ethos necessary for students to take them seriously, and thus ChE faculty may want to consider choosing other CSB videos for in-class viewing or assignments. These same videos appearing at the bottom of both sets of ratings supports that visual ethos theory applies to ChE student perspectives of CSB process safety case study videos.

In order to test the visual ethos theory that better CSB video quality will lead to better perceived video effectiveness by ChE students, Figure 3 was produced that shows a simple linear regression between the two measures. A meaningful R^2 value of 0.684 is found, indicating that 68.4% of the variance in students' effectiveness ratings is determined by the variance in students' ratings of visuals in the video. A small p-value of 3.5×10^{-7} accompanies this correlation, and along with a Pearson's r of 0.827, it can be stated at greater than 99.9% statistical confidence that there is a strong positive correlated relationship between the two

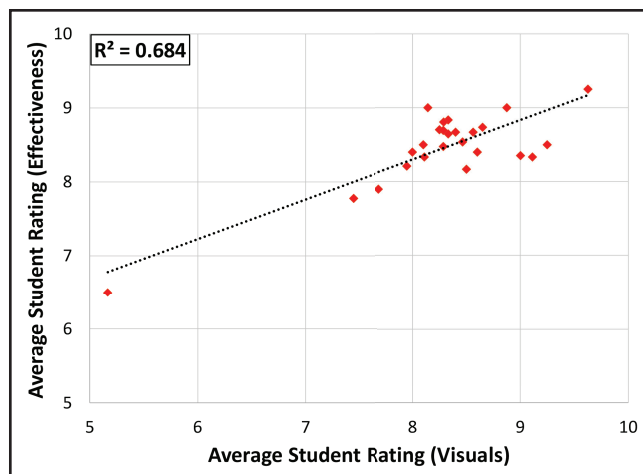


Figure 3. Dependency of students' perceived video effectiveness rating on their rating of video visual quality.

ratings. From a practical perspective, this finding implies that students will perceive a CSB process safety case study video with high-quality visuals to be effective, which agrees with the visual ethos theory previously discussed. A more pessimistic perspective could be that students will judge a process safety case study video that features high-quality visuals as effective regardless of the quality of its process safety content. In any event, given the importance of incorporating process safety content into the ChE curriculum, understanding what factors will encourage positive student perception of the content is important.

Relationship between visuals/effectiveness ratings and release date

It was previously hypothesized that video quality would improve with time due to advances in video and computer graphics technology. With visual ethos theory in mind,^[8-10] it would follow that as perceived video quality improved with time, student perception of video effectiveness would likewise be higher for CSB videos with more recent release dates. Each of these trends is shown in Figure 4. For each of the correlations between (1) visual quality ratings and release date, and (2) effectiveness ratings and release date, R^2 values are low at 0.183 and 0.145, respectively, while the relevant p -values are 0.033 and 0.060. Meanwhile, the Pearson's r values for these respective correlations are 0.428 and 0.381, which each fall below the >0.7 value typically associated with a "strong" relationship, instead falling in the 0.3-0.5 "weak" relationship range.^[12]

On the whole, these data indicate that visual quality has a correlation at the 95% confidence level with release year, somewhat confirming the reasonable hypothesis that visual quality increases as technology advances with time. Similarly, the relationship between effectiveness and release date (though following the trend of increasing visual quality in agreement with aforementioned visual ethos concepts) does

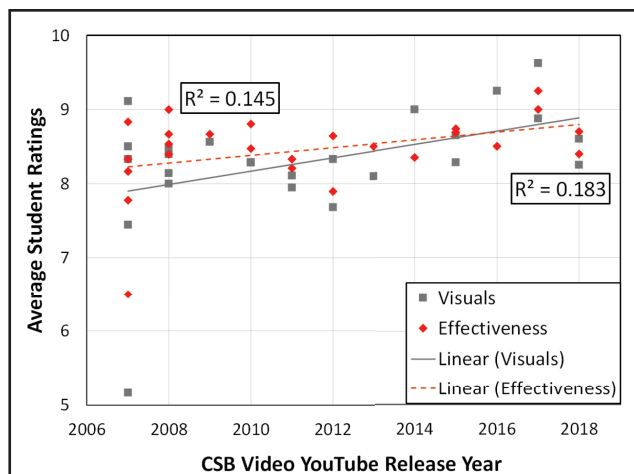


Figure 4. Correlations of student visual and effectiveness ratings with CSB video release date.

not quite reach the 95% confidence level nor a high Pearson r value and, thus, has a weaker relationship. These data indicate that while release date has some relationship with visual quality and effectiveness of videos, the relationship is not abundantly strong.

Regardless, this study indicates that without any additional information, when in doubt the visuals present in a more recently released video will tend to be better received by students, and there is some evidence to indicate that they will perceive a more recently-released process safety case study video to be more effective as well. If one chooses to extrapolate this data, this implies that future videos released by the CSB will be well received by students and would make good choices to accompany ChE instruction.

CONCLUSIONS

A ChE process safety assignment utilizing U.S. CSB process safety case study videos has been described. As part of data collected, it was found that student ratings of perceived quality of visuals and effectiveness showed that the videos "Fire in Baton Rouge", "Dangerously Close: Explosion in West, Texas", and "Filling Blind" were the most highly-regarded; based on the data collected, students feel any of these videos would make good choices for ChE instructors wishing to use CSB process safety case study videos as part of in-class discussion or assignments.

It was identified that student ratings of CSB videos' visuals and effectiveness have a highly statistically significant positive correlation ($p = 3.5 \times 10^{-7}$; Pearson's $r = 0.827$). These findings are congruent with visual ethos theory from contemporary communication rhetoric literature which expects students will attach rhetorical ethos to visual quality in graphical presentations. From a practical perspective, this finding implies that a process safety video with high-quality visuals will be perceived by students to be effective.

Since it was found that higher perceived video quality is weakly correlated with the release date of the video ($p = 0.033$; Pearson's $r = 0.428$)—which is sensible since video and computer rendering technology are continually advancing—it seems reasonable for faculty to tend toward selecting more recently released CSB videos (if given no other information) when using these videos as part of process safety instruction in ChE courses.

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APPENDIX

CHE 331 Safety Paper Assignment

Description

Each CHE 331 student has been assigned a safety video from the CSB Video Room, located at:

<http://www.csb.gov/videos>

The video assigned to each student is included in the “CHE 331 Safety Paper Assignment” file posted on the course’s Moodle page. Identify and watch your assigned video, then provide answers to the following prompts regarding the video’s content:

1. (30%) Describe the incident(s) which occurred, including ramifications (damage to property, injuries/deaths, etc.)
2. (30%) Describe what design, maintenance or operational issues caused the incident(s) to occur.
3. (30%) Describe what could be done to prevent the incident(s) from occurring again.
4. (5%) Rate the quality of the visuals used in the video on a scale of 1-10, and briefly explain your rating.
5. (5%) Rate the overall quality/effectiveness of the video on a scale of 1-10, and briefly explain your rating.

Format and Delivery

This paper is intended to be less than two pages in length, but you will not be penalized if you write more than two pages. Your paper should be typed in 12 pt Times New Roman font. Submit your paper to TurnItIn.com using the submission information provided on the Moodle page—if you haven’t already created a TurnItIn.com student account, follow the instructions in the “TurnItIn Upload Instructions” file on the Moodle page to create an account. □