Screencasts for Enhancing Chemical Engineering Education

Dr. Garret Nicodemus, University of Colorado, Boulder

Senior researcher at the University of Colorado Boulder in the Department of Chemical and Biological Engineering. Received PhD in Chemical & Biological Engineering at CU Boulder in 2009 and B.S. in Chemical Engineering at Lafayette College in 2004. Has taught Material & Energy Balances, Fluid Mechanics, Separations and Mass Transfer, and Senior Process Design.

Prof. John L. Falconer, University of Colorado Boulder

John L. Falconer is the Mel and Virginia Clark Professor of Chemical and Biological Engineering and a President's Teaching Scholar at the University of Colorado Boulder. He has published more than 225 papers and has 12 patents in the areas of zeolite membranes, heterogeneous catalysis, photocatalysis, and atomic and molecular deposition. He has directed the effort at the University of Colorado to prepare screencasts, ConcepTests, and interactive simulations for chemical engineering courses (www.LearnChemE.com).

Dr. Will Medlin, University of Colorado, Boulder

J. Will Medlin is an associate professor of Chemical and Biological Engineering and the ConocoPhillips Faculty Fellow at the University of Colorado. He teaches courses in kinetics, thermodynamics, and material and energy balances. His research interests are in the area of surface science and heterogeneous catalysis.

Mrs. Katherine Page McDanel, Dept Chemical & Biological Engineering University of Colorado Boulder
Dr. Janet L. de Grazia, University of Colorado, Boulder
Dr. James K. Ferri, Lafayette College

James K. Ferri is the James T. Markus '50 and Head of the Department of Chemical and Biomolecular Engineering at Lafayette College.

Dr. Christopher R Anderson, Lafayette College

Chris Anderson is an Assistant Professor of Chemical and Biomolecular Engineering at Lafayette College. He was previously at The College of New Jersey, where he helped found the Biomedical Engineering Department, developed courses in medical imaging, drug delivery, biotransport, and mentored related senior design projects. He led product development at Targeson, Inc., a start-up company where he developed targeted contrast agents for ultrasound imaging of tumor growth. He earned his and M.S. and Ph.D. in biomedical engineering from the University of Virginia, where his research focused on the molecular mechanisms of blood vessel growth, and he earned his B.S. in chemical engineering from Bucknell University.

Michael Senra, Lafayette College

Screencasts for Enhancing Chemical Engineering Education

Abstract

Over 1,000 screencasts have been developed for chemical engineering courses. Screencasts are short videos (typically less than 10 minutes) with narration and are made by digital capture of a tablet PC screen. Screencasts can introduce a topic, solve an example problem, explain a concept, explain a diagram and process, demonstrate software use, review for an exam, or present a mini-lecture. They can be used in combination with textbooks, online reading quizzes, homework assignments, and office hours. They can also be used to create flipped classrooms, where students work under the supervision of the instructor during class and information delivery is outside of class. Their brevity is an important attribute that distinguishes them from video lectures, and they have significant advantages that supplement textbooks and written materials. This personalized method of learning empowers students by giving them control over the rate of information delivery and when they receive information. As of December 2013, these videos were watched/downloaded over 3.2 million times, and they have received an overwhelmingly-positive response from students in our classes and from YouTube viewers. These screencasts are in the process of being validated by chemical engineering faculty. We are also assessing their effectiveness in improving student learning gains and attitudes. Previous research by others showed that screencasts help minimize cognitive overload, increase student confidence, and allow students to take control of their learning. They allow faculty to use class time for active-learning approaches, which are more effective than lectures.

Screencasts

Screencasts are short screen captures (usually prepared on a tablet PC) of material with narration by the instructor. Screencasts allow the instructor to provide an expert's explanation on solving a problem, so that students can observe how to set up and step through the problem and how the problem-solving techniques relate to the underlying principles. They can also be used to explain ConcepTests, provide other perspectives on a topic, serve as tutorials for computer programs, and review for exams. A significant advantage of screencasts is that students control the information delivery; they can stop/rewind/replay at any point; and they can do this on their schedule. After recording, screencasts can be edited by adding information, callouts, and annotations, and by removing recording dead times.

Studies have shown that screencasts improve student learning [1-3]. In addition, they free class time for more active learning, save instructor time, and provide students more control over their learning. Students in an entry-level freshmen chemistry course showed significant improvements in performance and conceptual understanding when screencasts were used [4]. Physics students provided with screencasts significantly outperformed students receiving equivalent textbook instruction in class [5], and when screencasts were used as pre-lectures, student's performance significantly increased [6]. Wouters et al. [7] said that instructional methods where experts solve problems by explaining their actions (i.e., screencasts) are good at teaching performance of the task and mastering of complex skills.

Sugar et al. [8] stated that the inclusion of video-based instruction and online environments can have positive effects on student learning and can be pedagogically equivalent to face-to-face instruction. Mayer [9] indicated that video plus sound results in more effective learning than still pictures and accompanying text. Toto and Booth [4] used screencasts to supplement a general chemistry class for distance learners. Students with access to the screencasts scored 11.2% better overall and 21.8% better on the difficult concepts, and students overwhelmingly liked the screencasts. Similarly, in an advanced chemistry course in high school, screencasts were used for a section on chemical equilibrium [9]. One group of students had a 50-minute lecture, and a second group also watched a 11-minute screencast. The students who watched the screencasts improved twice as much. Of the 14 questions asked on a test, students for both groups answered 3.1 correctly on a pre-test. On the post-test, students who did not watch the screencasts answered 5.2 correctly, whereas the students who watched the screencasts answered 8.1 correctly.

Similarly, Pinder-Grover et al. [1] found that screencast usage correlated with performance in a material science/engineering course as indicated by final grades; students with the least prior exposure to the course material had the largest gains. They found a significant positive correlation between the number of screencasts watched and the final course grade, even after correcting for GPA. Stelzer et al. [10] used web-based multimedia learning modules (similar to screencasts) as pre-lectures for a physics course. They introduced video pre-lectures because studies had shown that multimedia materials resulted in significantly better understanding than the textbook, which their surveys indicated was rarely read by the students. They saw a modest increase in exam performance, and student responses to online questions before class indicated that they were significantly better prepared for class compared to when textbook reading was assigned. More significantly, student attitudes changed. Previously, this course was rated as one of the most difficult on campus by 78% of the students, but this dropped to 43% when pre-lecture videos were used. Also, the percentage of students who had a positive attitude towards physics increased from 39% without pre-lectures to 75% with pre-lectures.

Advantages

Screencasts have unique attributes for information delivery compared to textbooks, classroom presentations, and 50-minute videos of a lecture. Screencasts:

- give students control over their learning; students control when and how fast they receive information. They can pause, rewind, take notes, and replay a screencast so they manage the pace, as opposed to a classroom where instructors cannot go at a pace that is ideal for everyone.
- are short and focus on one topic so they hold students' attention. They do not feature the instructor and they do not contain extraneous material, both of which can hinder learning.
- allow instructors to use class time for active learning (e.g., ConcepTests, clicker questions, peer instruction, group exercises), since information delivery is outside of the classroom.
- minimize cognitive overload by presenting diagrams and verbal explanations simultaneously, which enhances learning [11]. Diagrams and referring text are in different locations (often different pages) in textbooks, and this places significant demands on working memory [12].
- increase student confidence in their ability. Based on our student surveys, 92% of students (440 total in 3 courses) felt more confident about the material after watching the screencast. Student's perception of their own increased understanding following the use of engineering screencasts has been correlated with improved proficiency of course material [13]. The impact was greatest on students with the weakest backgrounds.

- are easily adopted by students and faculty because the infrastructure for viewing videos (YouTube, iTunesU, smart phones, tablets, etc.) already exists.
- are modular, which allows instructors flexibility in their use; they can choose the screencasts that meet their course goals. Students can pick screencasts to watch, independent of the instructor.
- are sustainable; once prepared, they do not require maintenance. New screencasts can be produced, corrections can be made, and clarifications can be added.
- have been reported to enhance learning when students study carefully worked-out examples instead of attempting to do the problems themselves [14].
- can sequentially present figures, diagrams, and equations. Screencasts can also use color to distinguish flow streams and different parts of graphs.

The most effective way to appreciate the screencasts' value for sequentially presenting material and using color is by watching a screencast. A snapshot of a screencast (Fig. 1) can only partially convey the difference. For example, in separations textbooks, a complete triple-effect evaporator diagram is presented in black ink on a white background. In contrast, a screencast can introduce parts of the diagram sequentially with narration and using different colors [15]. That is, the screencast builds up the diagram from scratch, which would take many pages in a textbook. Similarly, introducing and explaining one equation term at a time takes advantage of the ability to write anywhere on the screen [16], rather than from top to bottom. Annotations can be next to the equation, above, below, or on the side. A snapshot from a screencast with equations is in **Error! Reference source not found.**.

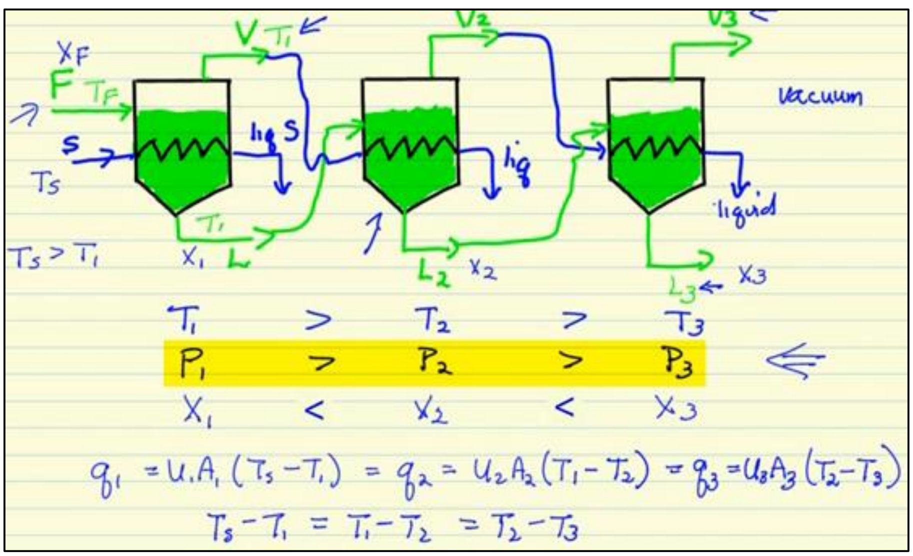

Figure 1. Snapshot of a triple-effect evaporator screencast

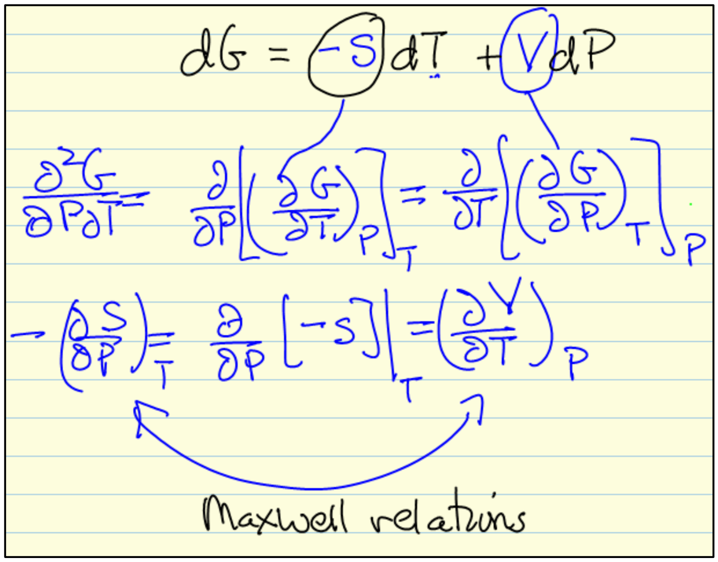

Figure 2. Snapshot of screencast used to explain equation derivations.

How they are used

Faculty and students can use screencasts in multiple ways. Faculty can use them to:

- implement flipped classrooms, where students view 4-5 screencasts before class, and class time is devoted to group problem-solving and active learning approaches that allow more student-student interaction and more directed guidance by the instructor.
- supplement classes and textbooks and to provide material for exam reviews.
- address the needs of different types of students. Commuters and students who work, care for children, etc., and cannot attend office hours or optional recitations/exam reviews can watch the screencasts when it is convenient. One of our undergraduates who was sick in a previous semester told us she would not have passed her courses without screencasts.
- review material in pre-requisite courses for students who are not well-prepared. Because different students have different deficiencies, screencasts provide more individualized learning. There may not be sufficient time within the course to provide background review materials, and screencasts can be used in individualized or modular fashion to provide these reviews.
- incorporate into online courses; such courses have been shown to be as effective as in-class lectures [17].

Students typically use screencasts on their own to review material from class, to look through examples for help with homework problems, and to review for exams. They can also be used by:

- dyslexic students, who comprise 15-20% of the population. Having material presented verbally, particularly when explaining diagrams, can improve their learning [18].
- hearing-impaired and English as second language (ESL) students using closed-captioning.
- students who hesitate to approach an instructor and admit they do not understand something.
- students not satisfied with their current instruction.
- engineers in industry who need to refresh a topic or prepare for the FE or PE exam.

Some faculty have expressed concern that if screencasts are used, students will not attend class. Our experience, however, is that screencasts do not decrease class attendance, but instead make class time more effective for learning.

Preparing screencasts

A screencast should be short, have one main goal, and tell students what they will learn. The preparer should try to animate their voice and stay on topic. Principles developed from studies on learning with multimedia should be used, which include [11]:

- using visual representation that illustrates relationships among content.
- avoiding decorative visuals that do not contribute to instructional goals.
- reducing cognitive load by describing complex visuals with audio only to avoid overloading visual centers of working memory.
- using first/second person pronouns; learners tend to process more deeply in a social-like setting.
- minimizing the length by only using essential content that supports learning goals.
- presenting student misconceptions, since this has been shown to increase learning [12].

We often prepare a script prior to recording a screencast. The screencast is then recorded by screen capture of a tablet PC screen using Camtasia Studio and Windows Journal or Microsoft OneNote. The sound recording is best with an external microphone; either a headset (e.g., Plantronics Audio DSP-400 USB) or a desktop microphone (e.g., Logitech USB Desktop Microphone). We have developed a check-list of suggestions for computer setup/procedures to use during recording that can be found on our website (www.learncheme.com). The screencasts are then post processed by someone who checks for errors, adds a title page, and remove dead time. During recording, if the faculty member realized they made a mistake, they can just repeat that part of the screencast and during post-processing, the mistake can be removed. This reduces recording time and the anxiety associated with recording a perfect screencast. Post-processing can also add annotations, highlights, callouts (text boxes that highlight concepts or present suggestions), and zooms to enhance the screencast. The video is then produced as an mp4 video to post on YouTube and iTunesU. The following suggestions may improve the quality and reception of screencasts.

- Start with a clear goal matching specific learning objectives. Tell students the purpose of the video at the beginning.
- Keep screencasts short. Surveyed students were more likely to watch a 10-minute or shorter video. Avoid long-winded number crunching.
- Clear your environment. Shut the door to prevent external interruptions.
- Speak freely and fix it later if necessary. Mistakes, dead-time, extraneous work, and external noises can be removed later.
- Follow a problem-solving outline. Go through a problem solution in a methodical manner, starting with diagrams, labeling known variables and unknowns, using units throughout, make assumptions explicit, checking solutions at the end, and so forth.
- Use highlights and annotations post-recording to focus a student’s attention. Although these are not necessary, highlighting can help minimize confusion, and callouts can provide alternate explanations, definitions or cross-references to other materials.

Usage and Feedback

Our screencasts are hosted on YouTube (/learncheme) and on iTunesU (University of Colorado Boulder). They are organized by popular textbooks and by major topics on www.learncheme.com. They have been watched or downloaded 3.2 million times since 2011. During the last 3 months of the fall semester 2013, they were played on average more than 45,000 times per week on YouTube.

A significant advantage of screencasts is that students really like them. As we reported, our students have been overwhelmingly positive [19, 20]. When a class with 201 students in our department was surveyed at the end of the Fall semester, 95% of students found the screencasts useful, and 45% of the students rated screencasts one of the best features of the course. Ninety two percent of the students indicated they were more confident about understanding the material after watching a screencast; 94% indicated screencasts were more effective than the textbook at improving their understanding. Some student comments from our end of semester surveys and YouTube posted comments about the screencasts:

"I think the screencasts were great. My only suggestion would be to make more."

"Screencasts are fantastic. I watched some of them twice."

"I learned a lot from the videos. It's hard learning at such a rapid pace in class, so it's really nice to be able to rewind and replay the videos as many times as needed."

"*Thank you very much for your videos. I just passed the Chemical Engineering License Examination. I would encourage everyone to please watch and understand these videos."*

"The 2013-2014 senior class of XX thank you. I pointed my classmates to these videos for our exam and they've helped a ton."

References

1. Pinder-Grover, T.; Green, K.R.; Millunchick, J.M. The efficacy of screencasts to address the diverse academic needs of students in a large lecture course. *Adv. Eng. Ed*. 2011, 2, 1-28.
2. Toto, J.; Booth, K. Effects and implications of mini-lectures on learning in first-semester general chemistry. *Chem. Ed. Resch. Pract*. 2008, 9, 259-266.
3. Oehrli, J.A.; Piacentine, J.; Peters, A.; Nanamaker, B. Do screencasts really work? Assessing student learning through instructional screencasts, *ACRL Conference*.2011, 127-144.
4. Toto, J. The Mini-lecture Movie Effect on Learning in an Online General Chemistry Class, 2007. http://css.rpgroup.org/uploads/Case-360-Joe%20Toto%20Monograph.pdf
5. Stelzer, T.; Gladding, G.; Mestre, J. P.; Brookes, D. T. Comparing the efficacy of multimedia modules with traditional textbooks for learning introductory physics content. Amer. J. Phys. 2009, 77, 184-190.
6. Stelzer, T.; Brookes, D. T.; Gladding, G.; Mestre, J. P. Impact of multimedia learning modules on an introductory course on electricity and magnetism. Amer. J. Phys. 2010, 78, 755-759.
7. Wouters, P.; Paas, F.; Merrienboer, J.G. How to optimize learning from animated models: review guidelines based on cognitive load. Rev. Ed. Resch. 2008, 78, 645 – 675.
8. Sugar, W.; Brown, A.; Luterbach, K. Examining the anatomy of a screencast: uncovering common elements and instructional strategies. Int. Rev. Resch. Open and Distance Learning. 2010, 11, 1-19.
9. Mayer, R. E. Multimedia Learning; Cambridge University Press: New York, 2001, 1-222.
10. Chen, Z. Z.; Stelzer, T.; Gladding, G. Using multimedia modules to better prepare students for introductory physics lecture. Physical Review Special Topics-Physics Ed. Resch. 2010, 6, 010108.
11. Clark, R. & Mayer, R., e-Learning and the Science of Instruction: Proven Guidelines for Consumers and Designers of Multimedia Learning. (John Wiley and Sons: San Francisco, CA, 2011.

12. Muller, D. A., Designing effective multimedia for physics education, PhD thesis, University of Sydney, 2008.
13. Green, K. R., Pinder-Grover, T. & Millunchick, J. M., Impact of screencast technology: connecting the perception of usefulness and the reality of performance. Journal of Engineering Education 101, 717–737, 2012.
14. Sweller, J., van Merrienboer, J. J. G. & Paas, F. G. W. C., Cognitive architecture and instructional design. Educational Psychology Review 10, 251–296, 1998.
15. LearnChemE Triple effect evaporator: introduction. (2012), http://www.youtube.com/watch?v=brxp3Su01UY&feature=youtu.be
16. LearnChemE Using screencasts to explain equations. (2012), http://www.youtube.com/watch?v=c5-zcrVG958&feature=youtu.be
17. Hartsell, T. & Yuen, S. C., Video streaming in online learning. AACE Journal 14, 31–43, 2006.
18. Means, B., Toyama, Y., Murphy, R., Bakia, M. & Jones, K., Evaluation of evidence-based practices in online learning: a meta-analysis and review of online learning studies. U.S. Department of Education 1–96, 2010. http://www2.ed.gov/rschstat/eval/tech/evidence-based-practices/finalreport.pdf
19. Falconer, J.L., DeGrazia, J., Medlin, J. W. & Holmberg, M., Using screencasts in ChE courses. Chemical Engineering Education 43, 302–305 (2009).
20. Falconer, J.L., Nicodemus, G., DeGrazia, J. & Medlin, J. W., Chemical engineering screencasts. Chemical Engineering Education 46, 58–62 (2012).