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Teaching Freshman Design Using a Flipped Classroom Model

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Abstract

Faculty at Rice University are creating instructional resources to support a flipped classroom model for first-year multidisciplinary engineering design. By delivering the lecture content of the design process using videos and other media, class time is freed up for concrete progress on a team's specific project with support of faculty.

The first goal of this project is to create educational materials to transfer the delivery of content regarding the design process to an out-of-class environment and to develop in-class active learning modules that clarify, elaborate, and expand on critical design process topics. These materials will be widely available for others to use.

Currently, limited research exists on the impact of the flipped classroom model in engineering, mathematics, or science courses at the university level. Thus, the second goal of this project is to answer the engineering education research question: Are there differences in student performance in executing the engineering design process when comparing delivery of engineering design process knowledge using a lecture format versus a flipped classroom model?

The change in format and the engineering education research question will be assessed by evaluating student performance. In addition, the quality and usability of the developed materials will be assessed by students and faculty at Rice University and partner institutions.

To date, the team has described and planned the work for 2014 and has started making videos. The team is seeking feedback on developing materials that will be helpful for the community teaching engineering design.

Emergence of Flipped Classroom Model

To address changing educational needs of our nation's technologically savvy students, a new curriculum model has emerged that inverts the traditional instructor-centered, lecture-based approach. The flipped classroom or inverted instruction model shifts course content with low cognitive load outside of the classroom, thus freeing class time for students to focus on high cognitive load tasks.[1, 2] A defining characteristic of the flipped classroom is its commitment to multimedia technology to deliver time-shifted content via screencasts, audio podcasts, and other forms of rich media. Using technology to time-shift lectures outside the class is one tactic in a comprehensive instructional strategy, which typically also includes problem-based learning, project-based learning, and/or inquiry learning during in-class time.[3, 4]

Using technology allows educators to spend more time in the classroom facilitating collaboration and higher-order thinking. In a flipped classroom, students prepare for class by completing homework that involves watching or listening to videos, audio recordings, or animations. During class, students engage in active learning. Teachers lead students to discover, apply, and then explain important concepts to each other. For example, students may work together on a difficult problem while the teacher moves between groups giving personalized attention or addressing misconceptions. This classroom model is consistent with best practices in engineering education.[3-6]

Educational outcomes associated with the flipped model build upon the successes of other active learning environments, including problem-based learning and project-based learning courses. K-12 STEM teachers have been early adopters of the flipped classroom; although, assessment of this method for high school instruction is limited.[7, 8] Likewise, few university-level examples, especially in engineering, have been published in peer-reviewed literature.[9-12] At the University of Michigan at Ann Arbor, research on their long-running flipped introductory calculus courses shows gains at about twice the rate of those in traditional lectures at other institutions who took the same calculus concept inventories.[13, 14]

Motivation and Overall Project Aims

In most design courses, a traditional lecture format is used to teach students about the design process, and students spend significant amounts of time outside of class applying the design process by developing appropriate design criteria, brainstorming and selecting a solution, and then building a physical prototype for testing. The flipped classroom model shifts course content including steps in the engineering design process to videos or other forms of rich media. Therefore, class time is freed up for concrete progress on a team's specific project with support of faculty. In our comprehensive review of available materials, no publicly available sets of videos exist for supporting the engineering design process at any undergraduate level (first year through capstone).

While many university administrations and faculty are eagerly preparing videos to be used in flipped classroom instruction or for MOOCs on EdX, Coursera, or other platforms, assessment of the learning outcomes of these models is in its infancy. Our literature review found that no one has measured the impact of the flipped classroom model of instruction in an undergraduate engineering design course (first year through capstone).

Thus, building on best practices in engineering education, faculty at Rice University are creating instructional resources to support a flipped classroom model for first-year multidisciplinary engineering design. Our funded NSF proposal (DUE grant #1244928) seeks to address the following three specific aims:

Specific Aim #1 Develop flipped classroom instructional materials for sections of the design process including design criteria, brainstorming and evaluation solutions, and initial prototyping.

Specific Aim #2 Assess the effectiveness of the flipped classroom model for a first-year engineering design course.

Specific Aim #3 Collaborate and partner with the first-year engineering community to receive critical formative feedback on materials and then disseminate developed materials.

Status of Specific Aim #1 - Creation of Educational Materials

During the duration of the grant, the authors will develop:

- Forty to fifty web-based videos (5-10 min in length) produced by faculty and students that focus on steps of the engineering design process. Table 1 lists the topics for these videos.
- Ten online quizzes that monitor students' understanding of the information in the videos. A series of multiple choice and open-ended questions test students' knowledge and application of the technical content presented in the videos.
- Thirty in-class exercises that support active learning in the classroom that strengthen students' understanding of the design process and direct students to apply the design process to their team's specific project.

Table 1. Web-based Videos. Completed videos are in italic.

Overview of engineering design process	*Engineering decision making*
Attributes - What do you want?	*Making a Screening Pugh Matrix*
Constraints - What you must have!	*Screening Pugh Matrix - Examples*
User-designer-client triangle	*Making a Scoring Pugh Matrix*
Questioning strategies to elucidate attributes and constraints	*Scoring Pugh Matrix - Examples*
Conducting research	What is a prototype and what makes a good prototype?
Identifying current and existing solutions/techniques	Building fast when making prototypes
Design criteria - What are they and what's their purpose?	Using simple materials for prototypes
Design criteria - Examples	Types of prototypes
Establishing user-defined criteria	Prototyping - Examples
User-defined criteria - Examples	Testing a prototype while building
What is brainstorming & rules for brainstorming	Direct testing
Methods of brainstorming	User defined testing
Brainstorming - Examples	Failure
Purpose of and setting up a pairwise comparison chart	What is a Gantt chart and how does it work?
Pairwise comparison chart- Examples	Constructing realistic Gantt charts, with examples
Decomposition - How can I break this project down?	

To date, the team has completed more than 20 videos. The completed videos are marked in Table 1.

The videos are short (5-10 min), visually engaging, and effective. The instructional videos are a mixture of the instructor talking, slide-show panels (e.g., PowerPoint), and the instructor talking with text added to the side. The example videos have been made by engineering design teams at Rice University based on the project that they completed in ENGI 120.

One quiz associated with pairwise comparison charts has been made. Figure 1 shows a model of how the instructional videos, example videos, and quiz material will be linked. The materials will be hosted on the STEMScopes website (http://stemscopes.com/).

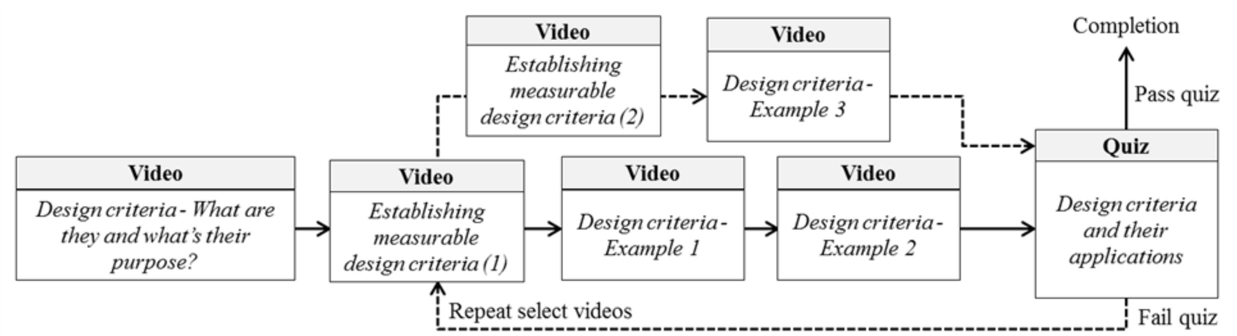

Figure 1. Example flowchart for instruction and testing regarding design criteria.

Status of Specific Aim #2 – Evaluate Effectiveness

As part of the project, the team will evaluate two major strands of assessment data:

1) Pre- and post-testing of students' knowledge and application of the design process as measured by their critiques of a Gantt chart laying out a 14-week design process.
2) Students' technical memos that capture key steps in the design process.

To date, the team has collected and assessed data on student performance for courses taught using a lecture format. This pre- and post-tests using the Gantt chart has been analyzed for several years and is reported elsewhere.[15-17] Technical memos have been collected since the inception of the course in spring 2011 and will be assessed during the summer of 2014. Data collection will continue for the lecture format through spring 2014.

Data from the flipped classroom model will begin in fall 2014 and continue for four semesters. This data will be analyzed in the same way as the lecture format data described above.

Status of Specific Aim #3 - Collaborate to Receive Feedback and Disseminate Materials

For the materials to be of high value, it is important to partner early with other members of the first-year engineering community. For this reason, we hope to present at the 2014 ASEE and FYEE meetings to receive specific feedback on developing materials that will be helpful for the community teaching engineering design. In the future, through more formal collaborations and partnerships, we will gather feedback about the quality and usability of the developed materials, including videos and quizzes.

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References

1 J. de Haan, "Technology With Intention," [Online]. Available: http://technologywithintention.com. [Accessed 17 03 2012].

2 E. Pascarella and P. Terenzini, How college affects students (vol. 2): A third decade of research, San Francisco: Jossey-Bass, 2005.

3 R. Beichner, "The SCALE-UP Project: A Student-Centered, Active Learning Environment for Undergraduate Programs," National Academy of Sciences, Washington, 2008.

4 "Creating a Culture for Scholarly and Systematic Innovation in Engineering Education," American Society for Engineering Education, Washington, DC, 2009.

5 M. Prince, "Does active learning work? A review of the research," *Journal of Engineering Education,* vol. 93, no. 3, pp. 1-10, 2004.

6 M. Prince and R. Felder, "Inductive teaching and learning methods," *Journal of Engineering Education,* vol. 95, no. 2, pp. 123-138, 2006.

7 J. Bergmann and A. Sams, "The Daily Riff - How the Flipped Classroom Is Radically Transforming Learning," 15 April 2012. [Online]. Available: http://www.thedailyriff.com/articles/how-the-flipped-classroom-is-radically-transforming-learning-536.php. [Accessed 23 May 2012].

8 F. Learning, "Flipped Conference 2012 - 5th Annual Flipped Conference," 2012. [Online]. Available: http://flipped-learning.com/?page_id=5. [Accessed 23 May 2012].

9 R. Toto and H. Nguyen, "Flipping the Work Design in an Industrial Engineering Course," in *39th ASEE/IEEE Frontiers in Education Conference*, San Antonio, TX, 2009.

10 L. Barba, "This CFD class is flippin',", Boston University , 1 February 2012. [Online]. Available: http://people.bu.edu/labarba/Lorena_Barba/Blog/Entries/2012/2/1_This_CFD_class_is_flippin.html. [Accessed 21 May 2012].

11 U. o. C. Boulder, "Screencasts and Conceptests for Chemical Engineering Courses," [Online]. Available: http://www.learncheme.com/. [Accessed 15 04 2012].

12 L. Deslauriers, E. Schelew and C. Wieman, "Improved learning in a large-enrollment physics class," *Science,* vol. 332, pp. 862-864, 2011.

13 D. Berret, "How 'Flipping' the Classroom Can Improve the Traditional Lecture," 19 02 2012. [Online]. Available: http://chronicle.com/article/How-Flipping-the-Classroom/130857/. [Accessed 18 05 2012].

14 "7 Things You Need to Know about Flipping the Classroom: A White Paper from Information Technology Services at Penn State," The Pennsylvania State University, University Park, 2011.

15 A. Saterbak, M. Embree and M. Oden, "Client-based projects in freshman design," in *American Society of Engineering Education Conference Proceedings*, San Antonio, 2012.

16 A. Saterbak and T. Volz, "Assessing Design Capabilities Following a Client-Based Freshman Design Course," in *4th First-Year Engineering Experience Conference*, Pittsburgh, PA, 2012.

17 A. Saterbak and T. Volz, "Assessing Knowledge and Application of the Design Process," in *American Society of Engineering Education Conference Proceedings*, Indianapolis, 2014.