Implementing a 'Design for Online' Approach for Engineering Courses

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Abstract

The steady growth of enrollments in online higher education courses has prompted many institutions to explore ways of putting their content online. A common method has been to record face-to-face (f2f) lectures and make those videos and corresponding materials available to distance students through a Learning Management System. Few additional measures are taken to increase the levels of engagement and interaction for online students. This model still designs instruction with f2f students as the primary audience. Online students to be observers rather than full participants in the course.

This paper looks at reversing that model by creating courses where the online student experience is the starting point for course design. The authors researched best practices in online education to reinvent lectures, assessments, and interactions and used a Backwards Design approach to reinvent a graduate level materials science course. The process developed became known as the Design for Online (DFO) model.

Lectures were pre-taped in a studio and broken into smaller digestible chunks. Each of the videos was based upon clearly identified outcomes that focused on higher order thinking as defined by Bloom's Taxonomy. In order to facilitate those outcomes, embedded questions were added within the videos to point out vital information as well provide data to the instructor about the students' thinking. Multiple means of assessment were used to help respect diverse talents and ways of learning as well as to provide actionable timely feedback to students. Interaction became a key component in this new course. These interactions focused beyond student-to-content interaction by making sure to layer in meaningful student-to-instructor and student-to-student collaborations.

End of semester survey data showed an increase in student satisfaction for the online version of the course. As a result, another materials science course was tested using the DFO process the following semester with similar results. Through this paper, the authors share best practices and lessons learned as well as a blueprint for any institution looking to go through a similar process. Suggestions are made as to how instructors might leverage the digital assets created through this process to benefit their on-ground students.

I. Introduction

The landscape of course offerings in higher education has shifted greatly within the past decade. One of the greatest changes has been the evolution of online courses. In fall 2015, 29.7% of all higher education students were taking at least one distance education course [1]. Over the past few years, online education enrollments have been increasing at a rate that exceeds the growth of enrollments in higher education overall [2]. This trend has caused institutions of higher learning to take notice and investigate ways to encourage more of these students to enroll in their online programs.

A typical approach to creating an online course has been to take the content previously delivered in a traditional face-to-face setting and upload it to a Learning Management System (LMS) where distance students access the materials. What if the process was reversed? What would happen if courses were initially designed for the online audience? Would online students experience a richer learning experience? Could the digital assets developed be leveraged to help enahnce the learning of the on-ground student population? Boettcher and Conrad note that we are quickly nearing the time when there will few to no traditional face-to-face courses. They feel all courses will contain some digital gathering and communication tools [3].

With those questions in mind, the authors began to design and develop a fully online Materials Science course. The goal was to create a Design for Online (DFO) process that would be valuable in distance and eventually on-ground courses throughout the college of engineering.

II. Background

For the past few years, the college of engineering has offered graduate online course sections as appendages to the face-to-face delivery of those courses. In-person lectures (75 minutes, twice a week) have been recorded and housed in an online catalogue for remote students to access. This area of the course shell in the LMS was only available to students enrolled in the online section. Online students would submit the suggested homework through email to an advisor. The advisor then printed and sent the assignments to the faculty member via inner-campus mail for grading. A similar process was used for exams. The online students were in essence taking a correspondence course with little to now interaction between them and their peers.

The institution's charter measures success by whom it includes and how they succeed. This idea guides faculty and staff as they work to grow the university's programs. As a result, there is a need to increase access to coursework for a variety of possible student populations (e.g., returning students, students who work full-time jobs, underprepared students). As many of these programs look to go online to help them grow, it is important to encourage deeper learning, engagement and community for ALL learners, not just those in physical classrooms. While the research suggests that similar learning outcomes can be achieved in both traditional face-to-face classes and online courses [4] [5], online courses require more of a proactive approach to help them reach levles of engagment and learning that more naturally take place in the on-ground setting.

Danaher proposes that there are seven constructs by which an online engineering course can be assessed for quality. They are information, interface, support, engagment, collaboration, reflection and autonomy [6]. The DFO approach brings these elements as well as those referenced in the Quality Maters (QM) rubric [7] to the forefront before an online course is even developed. With a vision to improve how the college of engineering delivers online education, these courses are now created with the online student's experience and learning as their central

tenets. A Backwards Design [8] approach is being used to leverage current research on best practices in online education to reinvent lectures, assessments, and interactions.

III. Methods - Converting change to design for online

In Summer 2016, the college of engineering began drafting the new process (see below) that would allow online courses to be designed and delivered more specifically for the online student. Many of these conversions began when faculty would contact the Global Outreach and Extended Education (GOEE) group to set up the lecture capture portion of their course. Group members began sharing the college's vision for the future of online education. Over the semesters, interest began to build and several faculty started reaching out to discover more about what could be done to make their courses more online friendly.

The initial course to go through the DFO process was Materials Science & Engineering (MSE) 598: Concepts in Materials Science. Planning began in the latter part of Fall 2016 and continued into the Spring of 2017 when the actual development of digital assets and the building of the course in the LMS. The first iteration of the course under this new process was launched in Summer 2017. It was also run Fall of 2017 with a few edits based upon feedback received in the first run of the course.

Below is a general outline of the process used. A more detailed description with reference to MSE 598 follows.

1. Analysis and Design
    a. Initial Interest Conversation
    b. Kick-off Meeting
    c. Course Design - Course Map
        i. Course Objectives / Outcomes defined
        ii. Module Objectives defined
            1. Sequence by module / week
            2. Map to course outcomes / objectives
            3. Define how each objective will be assessed
        iii. Content Identification
            1. Lectures / Presentations
            2. Activities and Assignments
            3. Supporting Materials
2. Development
    a. Template Unit
    b. Content Development & Media Production
    c. Weekly Meetings
3. Implementation
    a. Course Launch
    b. Course Run
    c. Course Close
4. Evaluation and Debrief
    a. Review Final Course Evaluations

b. Debrief Meeting
c. Notes for future iterations
d. Master shell in LMS

Analysis and design

As stated earlier, initial interest in using a new direction for MSE 598 was expressed in Fall 2016. At that point, GOEE's instructional designer contacted the professor for this course. In the initial contact, the goal was to begin building a collaborative relationship as they discussed some background information on the course and the way it had been run in the past. After that conversation, an official 'kick-off' meeting was held. The discussion centered on the overall redesign process as well as a projected timeline. Roles were defined and a general plan of attack was created. Regular weekly meetings (Thursday mornings) were scheduled with the stakeholders involved (instructor and instructional designer) in order to help keep the project on track.

The first thing done was to begin a document that came to be called the 'Course Map'. It was created as a Google Doc so all parties involved could add items to it as well as pose questions and comments to one another between meetings. The Course Map began with some background information on the course, a timeline of deliverables, and the overall course outcomes/objectives. Since this course had run before, the overall course outcomes/objectives were fairly well defined and just needed to be refined to ensure they would encourage active engagment. Many instructors creating online courses speed through the design process to begin actually building the course. The design phase is key to ensuring alignment and removing the need for time consuming edits later in the process.

The heart of the Course Map was a table where the faculty member and instructional designer actually began 'mapping out' the specific outcomes/objectives that would make up the week to week bulk of the course. Bloom's Taxonomy [9] was used to shape actionable objectives as a list was started describing everything the students would be able to **DO** by the end of the course. Next came the chunking of similar items and the sequencing those into modules based upon the instructor's past experience and how he felt the content would best build to scaffold learning. Each objective was evaluated to make sure it mapped back to the overall course competencies. Dates were considered for the semester of the course's anticipated launch (Summer 2017) and the team began placing modules with in weeks. In general, each module fit into a week of the course. There were a couple modules that ended up overlapping a couple weeks. In the end, the course was organized into 11 Modules with each module contain 2 to 8 sections.

After the flow of the course was set, the group began brainstorming ways each objective would be assessed. Some of the items considered were quizzes, group homework assignments, online discussions and papers. Influenced by the work of Chickering and Gamson [10] each type of assessment considered was evaluated based upon several factors. It needed to elicit dialogue between the students and the instructor. At least some of the assessments should delvelop cooperation among students and encourage active learning. It should also allow for prompt feedback based upon high expectations and be something that would allow all students to participate in some form. A regular rhythm for these items was developed so students could more easily plan their study and work time.

The development team chose to create new lecture materials and not reuse the 'lecture capture' recordings. They began looking at the modules and objectives to identify the number and flow of presentations or 'lectures' to be recorded. Research on elearning shows that those participants who receive segmented presentations of content performed better on tests than learners who received a continuous presentation of identical material [11]. Factors such as maintaing student attention, file loading and difficulty in searching for information encourage shorter chuncked videos [12]. As a result, each recording was planned to consist of a sharing of that section's objectives and about 10 - 15 minutes of content interspersed with embedded examples and interactive questions.

After the lectures were identified, the group began evaluating the current course materials. Were they still relevant to the new objectives and flow? Could they be revised? What might need to be created in order to support the new lecture materials? In the end, many of the supporting instructional materials (textbook, supplementary readings, reference materials) still fit. The chosen materials were then mapped to the specific sections where they might be needed for each module.

At this point, the team started drilling down in each module and/or week. They identified what activities the students would perform (*e.g.,* watch lecture, read textbook section), what assignments would need to be submitted to demonstrate student thinking (*e.g.,* discussion board post, group homework), and how those assignments would be assessed (*e.g.,* rubric, auto-grade). Each module had a row on the Course Map where these details were documented.

Once there was a solid plan, technological tools were considered. What tools could help deliver the plan in a student centered way? What tools would be easy to use at little to no cost? What technologies would blend unobtrusively with the LMS (Blackboard)? What would help to create a similar, if not enhanced, version of what was done in F2F classes? The aim was for students to engage with the materials and deepen their content knowledge as they cultivated relationships with future colleagues without the technology becoming a barrier to those interactions. Several tools were tested until the team felt they had found the few that would facilitate the desired exchanges.

The group began drafting plans for the needed student-facing resources (*e.g.,* tutorials, technology support) to help ensure success. Those items were drafted into a 'Getting Started' module that would give students an overview of the course as well as access to any resources they might need to be successful. It also contained some initial assignments that would help the students build community (*e.g.,* introductions) and orient themselves to the course (*e.g.,* syllabus acknowledgement). This module was placed before the actual first module of content.

Development

With the critical phase of initial planning completed, the team commenced in earnest to develop the actual assets needed for the course. A 'Template Unit' (Module 1) was created to help try out some of the ideas and technology to see if they would really work in the needed environment before building the whole course.

While that unit was being created, the group also worked on creating an easily navigable site within the LMS. Since the course would be completely online, there was a menu item created called ‘Welcome & Start Here!’ so students would know exactly where to go and how to get started in the course. This area would hold assets developed that dealt with an overview of the course, tutorials and resources for technology tools used in the course, and a direct link to the first online interaction - an introduction discussion and syllabus acknowledgement.

For the course at large, the group started with the identified lecture presentations that would need to be recorded. The campus is very fortunate to have several green screen studios and after the initial orientation, a standing appointment was scheduled where the professor could go in and record with the media specialist. The files would then be sent to GOEE’s audio-visual specialist who would composite the presentation feed with the actual image of the professor. An example is shown in Figure 1.

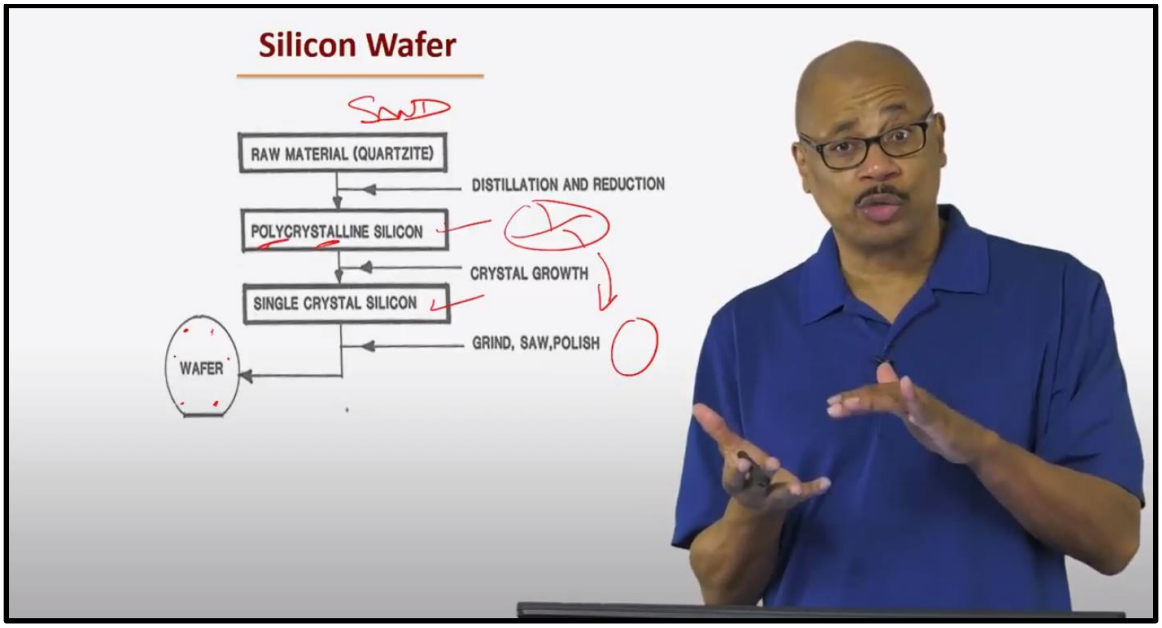

Figure 1. Composite of instructor presentation and instructor lecturing

The instructional designer could then take the file and import it into the third party tool called PlayPosIt. This tool allowed for embedded questions during the videos. An example is shown in Figure 2. This interaction helped to not only break up the monotony of watching a video; it also gave students a chance to demonstrate their understanding. This gave the instructor an easy way to assess their grasp on the topic even though he could not see if they were paying attention. He then would know what items needed to be further addressed in future videos, assignment feedback or announcements.

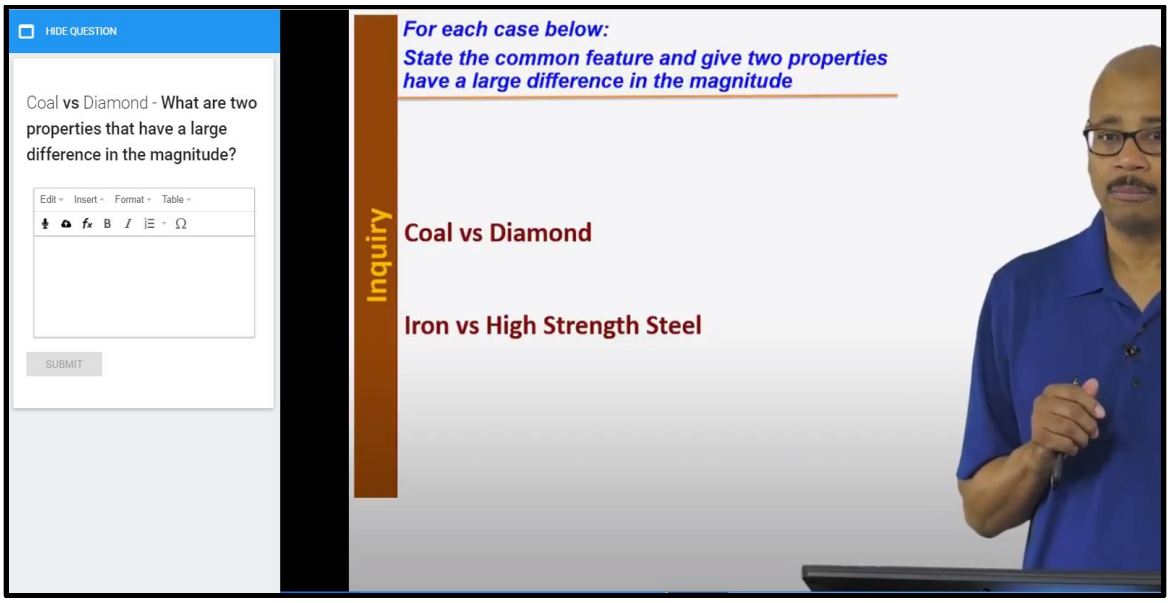

Figure 2. Embedded questions within lecture video

The process to create these interactions was for the instructor to send his PowerPoint files to the instructional designer with the questions clearly identified on slides where he would like them placed throughout the presentation. This made it easy to jump around the recordings to see where to put what questions. Over the course of development, there were 41 videos created that spanned 11 Modules. Videos were targeted to the objectives with real world examples and practice embedded to help increase their effectiveness and interactivity [13]. As a result, most of them were a manageable length between 10 - 20 minutes.

Once the lecture delivery material was decided upon and in production, focus could be directed towards materials and assignments that would support that content. 'Pre-learning' assignments were created to help students have a basic background in the topic before watching the videos. They were identified readings from the textbook with a couple of short questions students would answer through text submission in the LMS. The instructor could grade them easily using the LMS inline grader. Again, these were meant as a formative assessment that could help the professor know not only if the students were getting the points he wanted but if the selected material was appropriate for getting those points across. These assignments were drafted as a word document by the instructor and then passed on to the instructional designer who would build the interaction into the LMS.

After the lectures, the students were provided opportunities to interact with one another. Discussion questions were created that centered on the content from that section and how it applied to the topic of Materials Science at large. Since these were graduate level courses and the students had aspirations in the field, it was important for them to really build a sense of connectedness that they could take beyond the class and school into their professional settings. With that in mind, the team chose a tool called VoiceThread. This tool allows students to have discussions around media (in this case - PowerPoint slides) with questions on them. It also allowed students to respond by text entry, audio (via telephone, audio - telephone or microphone) or video. Students were encouraged to use the video option and many did. An example of this

interaction is displayed in Figure 3. The instructor would draft the PowerPoint slides with the discussion question and the Instructional designer would create the interaction within VoiceThread and the LMS. If embedded correctly, the students would not even have to leave the LMS site to complete the assignment. The instructor can even grade the assignment within this screen and have those grades pass directly into the LMS gradebook.

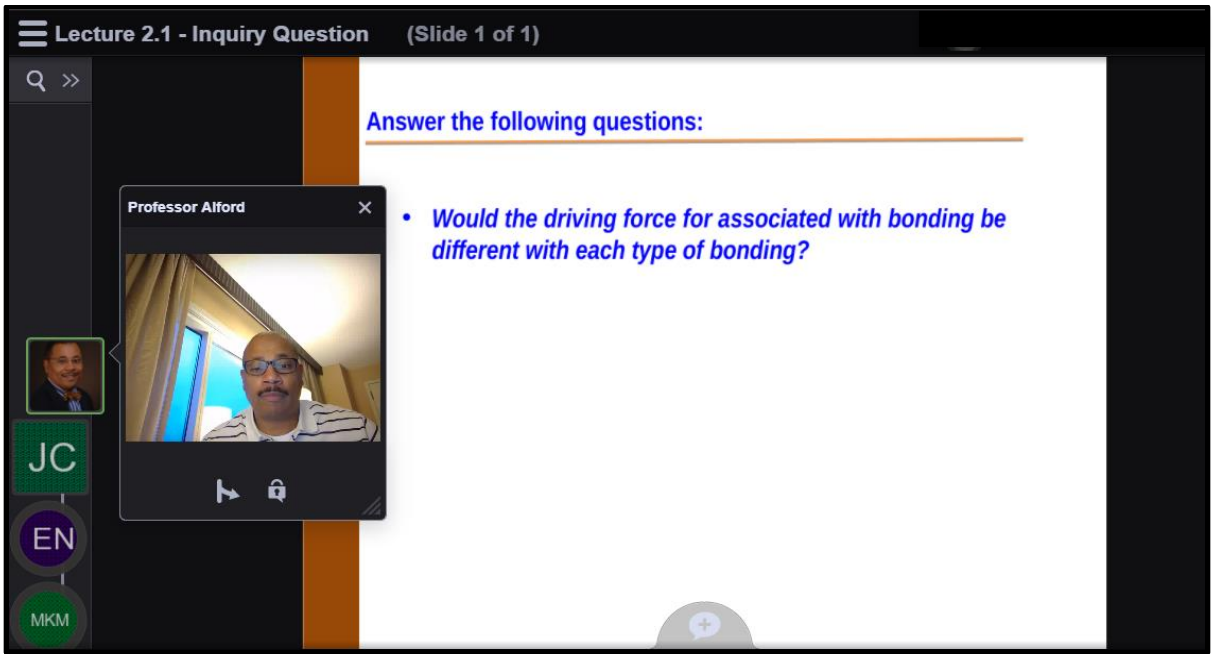

Figure 3. Video discussion within learning management system

Each module also had a group homework assignment. These were text documents that the students would be able to download and fill out as a group. The original design was to have students in groups of 3-4. The idea was that this would once again help to build that professional community as they worked together to solve questions that were developed by the instructor. The Groups feature in the LMS was enabled so students would have a private area to collaborate and then only one version of the assignment needed to be uploaded per group.

There were also a couple of resources that were added to most sections. These did not need too much development. One was an area for practice on the publisher's site. The instructor could select questions and levels of difficulty and the system would auto-grade the assignments and then pass those grades to the LMS. Another resource was a digital bulletin board embedded within the LMS where students could pose questions or ask for clarification on topics.

Rather than exams, the professor created a research paper assignment. He worked with the instructional designer to flesh out the details of the assignment - topic, length, annotations, resources, peer review process, etc. A rubric was also developed to help students understand what was expected. A peer review process for these papers was also built into the schedule. These interactions were built using a tool called CritViz and embedded the links to access the tool within the LMS. Again, directions on how to use the tool were added to the 'Course Tools and How to Use Them' area of the course shell.

During the development phase, the standing Thursday morning meetings continued. Those meetings discussed what elements still needed to be created as well as anything that might require further clarification to be able to build the interactions within the LMS. These meetings were invaluable even though files were constantly being shared through email. It was a time for to focus and actually discuss how the course would run. Some of those meetings were held via a tool called Zoom as the team tested out how to run the 'Virtual Office Hours' component of the course. The group tested out all of the tool's functions and were pleased to see that with a tablet computer the instructor AND the students would be able to share screens and actually do annotations.

Implementation

Inevitably, the time for development ran out and it became time to implement the plan. The first iteration of this redesigned course was launched in Summer 2017 with 12 students enrolled. About half of the students were locally based while the other half were scattered across the United States. The Thursday morning meetings continued in this phase as well but their tone changed. They focused less on the planning and more on the evaluating, maintaining and revising of the processes, tools and materials put in place.

At the very beginning of the launch, much of the time was spent getting used to the new flow and ways of grading - even though many of the tools were embedded within the LMS and connected with the gradebook. The instructor was very diligent in learning the tools so he could ensure that he was able to give formative feedback to the students in a timely manner. Towards the middle and end of the semester, the meetings focused more on ensuring future content and interactions were ready to go.

Because of the high engagement on both the student and instructor side, data (email, grades, discussion comments, muddy points, etc.) received from students helped to continue to refine the sections yet to be released in the LMS. The team did not want to make too many changes as it was felt that this would confuse the students. Notes were made for what might be done differently in future iterations as well as what clarification and resources might be necessary.

One example that can help illustrate the point had to do with the publisher practice materials. Several questions arose via email, muddy points and virtual office hours about the publisher practice assignments. The instructor also noted that the scores tended to be on the lower side. Through conversations with the students and screen sharing, it was determined that there was inaccurate information in the publisher materials. To help remedy this the professor sent out the correct information in announcements and email. He also adjusted scores and further publisher practice assignments. A note was made to possibly find alternative content for future semesters.

As the course entered the last third of the semester, the instructor held some special Virtual Office Hours he called 'Tea with the Professor' with each group. This meeting, unlike the others, was required for all group members to attend. Several options were provided for times. In addition, students needed to have a teacup in hand. It did not matter what or if there was anything in their cup but that they had one. Students were then asked to describe their cup and why they chose it. This helped to open the discussion in a non-threatening way and the instructor was able

to have more meaningful discussions on the health of the groups, the plan going forward for the remainder of the semester as well as answering any questions they possessed.

Evaluation and debrief

At the end of the semester, the team transitioned from the Implementation phase to the Summative Evaluation phase of the project. Students completed a standard Course Evaluation sent out by the university. That data (see below) was used for a Debrief Meeting to discuss the course, how it went, what should be changed, and what should be kept.

The team decided to change the number of assignments. For example, not every video needed a discussion since each video had embedded questions. One per module should be sufficient and allow for deeper/richer discussions. The professor also decided to do away with the publisher materials and source materials from other books that he regularly referred to and knew to be of quality.

Many items worked well and were planned to be used in future courses. The videos with embedded questions were helpful. A small tweak was made that would allow students to go back and explain their answers so they could get full credit once they saw the problems demonstrated. That seemed to solve any concerns in that arena. Students also felt the office hours and muddy points were easy to access although not always used. The team may look into ways to highlight these in the future.

During the debrief meeting the instructional designer asked the instructor if he felt he got to know his online students as well as he had the F2F students in past semesters. He relayed that he felt he got to know them even better. Due to the way the course was structured, there was no sitting in the back and hiding. Students had to interact and any lack of interaction prompted at least an email and many times either a phone or video conversation.

IV. Results

Course Evaluations can be biased but also informative in that they can aid instructors in recognizing what students feel might or might now be working for them in a course. The standard end of course evaluation launched by the university for online courses consisted of three areas. Students rated each statement on a scale of 1 (Strongly Disagree) – 5 (Strongly Agree).

- Overall Online Course Quality
    - The online discussions helped me learn the subject matter.
    - The amount of interaction I had with the instructor was sufficient.
    - The amount of interaction I had with other students was sufficient.
- Technology and the Course Experience
    - The course navigation system was easy to use.
    - The course site typically loaded quickly.
    - The graphics and images were of good quality.
    - The video and audio were consistently accessible.

- Overall Online Evaluation
    - The course met my expectations.
    - I was satisfied with the online experience.
    - I would take another online course.
    - I would recommend this course to others.
    - I will use the skills I learned in this course.
    - Overall, I found the course worthwhile.

Below, Figure 4 shows the scores for the last semester the course was taught in a lecture capture mode (Fall 2016) and the first time it was taught using the new DFO format (Summer 2017).

MSE 598	**Fall 2016**	**Summer 2017**
Overall Online Course Quality	3.4	4.2
Technology and the Course Experience	4.2	4.2
Overall Online Evaluation	3.9	4.1
Average	**3.8**	**4.2**
		* 5 point scale with 5 being the highest

Figure 4. Comparison of course evaluations from the last time course was taught online in the old format (Fall 2016 –9 students surveyed, 4 surveys returned) and the first time the course was taught online using the DFO format (Summer 2017 - 12 students surveyed, 7 surveys returned)

Based upon the limited end of semester survey data, students appear to value the Design for Online version of the course more than the previous lecture capture online version. The authors were pleased to see that the area (Overall Online Course Quality) with the greatest gain was the one having to do with interaction. This feedback in conjunction with data hoped to be gained in the future will continue to build a more complete argument for this type of approach to online education, especially in engineering.

The Fall 2017 release included a mid-semester survey (8 students surveyed, 6 responses returned) to gather additional data. The design team had more control of the questions and targeted them around two main themes.

1. Did students find the interactions with the instructor and their peers to increase their learning?
2. Did students feel the selected digital tools hinder OR allow for engagement comparable to that of a F2F class?

Concerning the first theme, 16.7% strongly agreed and 83.3% agreed that the level of engagement with other class members (group work, discussions, etc.) in this course contributed to their learning. Below are some student quotes from the survey.

- "If anything, I found that by using VoiceThread, it forced me to think about my response to the question presented. In doing so I learned how to solve the problem. And with the subsequent responses from the other students I learned even further in that I had to answer how I reached the solution."
- "The online discussions are excellent and help bring a community feel to the online class. This makes it feel like we are in a classroom discussing about the subject."
- "The engagement with members of the class groups helps in learning, especially while doing the homework."

Regarding the second them, 16% strongly agreed, 66.7% agreed and 16.7% neither agreed nor disagreed that they could easily navigate the course easily to find what they needed to be successful. There were no comments about the technology hindering their interactions. One student commented, "It is the most convenient way of getting a basic overview on material science."

The authors recognize that the numbers from the initial launch of the DFO process are small. They are encouraged though that more and more courses within the college are adopting the process with similar results. Following are some quotes from other courses within engineering that just completed the DFO process.

- "Unique way to present lectures and require students to have active participation."
- "The lectures were very well produced and clearly intended for distance learning from the get-go…"
- "The structure of the pre-recorded lectures are very good. I liked this personal setting much better than the classroom recorded lectures."
- "The course material was organized and engaging. I didn't feel like I was just clicking buttons to "get through" the material. As an online student, I feel many classes leave you to teach yourself the material. This is the first class where I actually felt like I was being taught..."

V. Conclusions and plans for the future

Through this endavor the authors found that designing an online course first led to a better experience for online learners. It helped ensure that there were multiple means of engagement to mirror or enhance what took place in a F2F course. The deliberate planning also allowed for the testing of various tools to find the right fit for what the instructor wanted to accomplish.

The experience also gave rise to several new ideas for leveraging the benefits of digital assets in an on-ground setting. Instructors will be able to minimize disruption of instruction due to things

like conference travel. There can be more consistency across sections as similar resources are used. This also allows for more scalabilty. Increased innovation can be introduced with the use of co-teachers or guest lecturers who are unable to attend in person. Increased use of these items will allow for more flexibility as students can download and stream course content wherever and whenever they like [14]. One of the biggest benefits will be the ability to do more implementation of the Flipped Classroom model and all of its benefits. In one study, results suggest that the flipped classroom was more effective than the traditional classroom in a large mechanics of materials course [15].

As of Spring 2018, the college of engineering has 16 courses launched using this process with another 10 in the pipeline for upcoming semesters. The catalog of courses has moved beyond just Materials Science and now has examples across the Engineering portfolio (BioMedical, Civil, Computer Science, Construction, Electrical, Graphics Information Technology, Industrial, Information Technology, Programming Logic, Mechanical and Aerospace, and Software). The plan is to continue expand the DFO mindset throughout all of engineering at the university. Part of that will be encouraging faculty to leverage the digital assets created to benefit their on-ground classes. It is also a goal to collaborate with other higher learning institutions to continue to improve the process and to better serve all student populations.

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