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A transition from face-to-face to an online delivery, in nano steps

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Online learning offers new and unique ways to engage the students. Online learning appeals to a broader set of students. Students who are part-time or prefer more flexible schedules particularly benefit from the online accessibility. As a result, there is a recent trend towards offering online engineering courses in addition to the on-campus experience. Often the challenge when developing an online course is to leverage the unique aspects of online learning and overcome the obvious deficiencies, i.e., face-to-face interaction. A direct digitization of the existing course content likely accentuates the deficiencies. Instead, a systematic developmental approach is recommended to remaster an existing course to better suit its new digital habitat. Here we study such a transformation, detail the steps, and compare the outcomes. A senior engineering elective was selected for the transition into an online course. The course titled, *Introduction to Nanotechnology*, was previously taught by the same instructor as a face-to-face course. This course was regularly evaluated using student feedback. For the Fall 2018 term, the course was transitioned to be delivered entirely online. It was subsequently offered again during the Summer session in 2019. The student learning outcomes and feedback from two traditional lecture offerings and two digital offerings were compared. The direct measures of course assessments revealed no difference between the traditional and the online offering. The absence of any noticeable difference in learning outcomes is an important baseline for the effectiveness of the online course. The indirect measures based on student surveys reflected a similar endorsement of the online approach. Besides the learning outcomes, the exercise of transforming an existing face-to-face course to online delivery, highlighted: effective transition strategies, assignment types, and engagement methods to build a successful course. This case study proposes a staged transition to test lecture content and assignments within a traditional lecture-based setting. The outcomes of this work provide valuable guiding principles for the engineering education community considering the growing demand for online learning fueled by the generational learning preferences.

Introduction

According to USNEWS, more students have taken online courses than ever before and that number continues to climb as more programs augment their on-campus offerings with online learning opportunities [1]. Besides the obvious advantages, numerous studies have demonstrated that online learning can have the same or better learning outcomes as face-to-face courses [2]. A report on the emerging engineering education leaders identifies blended learning practices as a cornerstone of these programs [3]. In fact, an argument can be made that instructors who teach an online course improve their teaching because every element of the online learning experience needs to be deliberately designed to engage [4, 5]. Yet the transition from face-to-face courses to online learning for engineering courses has been a fringe exercise at most campuses [6, 7]. There may be a number of sources for the resistance, including a preexisting deficit model (see Background) or the challenge of developing online content for highly technical topics within engineering. In fact, the quality of online learning experience can be varied just like its traditional counterpart. Nevertheless, there are many examples of effective online engineering courses for on-campus students. Studying these successful examples can be beneficial in developing a starter-kit for faculty considering a transition.

Literature is abound by successful transitions that satisfy diverse student needs and successfully achieve the learning outcomes [2, 6, 8-10]. Most document broad strategies for developing online content [11]. Others are case studies for specific subjects. In addition, university resources exist to guide instructors for developing effective online courses. Given all the resources, the number of decisions an instructor must make for a transition can be daunting at first: How to create online lectures that are engaging? What content or assignments can be easily transitioned? What is the best format for the content? What about collaborative work? Where does one begin? The answers to these questions are further complicated by the time-delay in feedback. The content is often developed in advance of student consumption and feedback. How do online instructors test their content for effectiveness? In addition to providing elements of an effective online course there is a need to provide a developmental strategy that presents sound guiding principles for faculty.

This work provides a case study on an effective transition. We document a transition of a face-to-face engineering elective course to an online course for students enrolled in the on-campus engineering program. As an extension of the transition process, key guiding principles were identified for an effective developmental strategy. These principles were successfully applied to a chemistry elective course that was developed from the ground-up. A detailed account of the development process, decisions made, and their implications, is presented. Both direct and indirect measures are used to compare the outcomes. This work is designed to serve the engineering community as a resource for effective transitions by providing a specific case study and a broad set of principles. This work, at minimum, can help engineering faculty architect their transition; and potentially seed future innovations in online engineering education.

Background

There is a general resistance on campuses to convert an existing and effective face-to-face course to an online course [12]. The thinking is, why risk the change when the traditional model is working? This mindset is another form of the previously addressed deficit model [13]. There is a sense that academic decision makers within engineering still subscribe to this model when approaching this new educational paradigm. The model's persistence may be attributed to previous poorly executed online courses. The deficit model assumes face-to-face instruction is the best approach because online delivery removes a critical component, the instructor, from this environment. Ineffective online courses corroborate the model prediction and allow the decision-makers to restrict innovations related to creating new and engaging online learning experiences. This skewed perception is compounded by the low course completion rates for distance learning students (typically taking MOOCs) compared to face-to-face students [14]. How do we approach a switch in the mindset to adopt online delivery when veteran academics themselves are skeptical of their role in the new digital landscape? To begin a mindset switch, we must identify the bright spots where the transition has worked [15]. Specifically, what are the features of an on-campus online course? This idea and author's experiences served as a motivation for the work presented here. This work documents a successful transition and provides a positive model for developing an effective online course. Namely, by embracing the unique aspects of online learning and highlighting the benefits from students' perspective. The work presented may help other faculty avoid the common pitfalls that inadvertently reinforce the deficit model that the academic decision-makers possess. By embracing common guiding principles for online learning, we can ensure a viable student experience.

Transformation to online learning

The Nanotechnology Course

Introduction to Nanotechnology course was designed as an undergraduate engineering elective to expose students to the material opportunities offered at the nanometer scale. The course content is divided into (a) fundamentals, (b) tools for synthesis and characterization, and (c) applications of nanomaterials within devices and more broadly technology. *Principles of Nanotechnology* course is a graduate level course that is combined with the undergraduate course. Graduate students complete additional assessments that go beyond the undergraduate level assignments. The lecture content, however, is identical between the undergraduate and graduate sections.

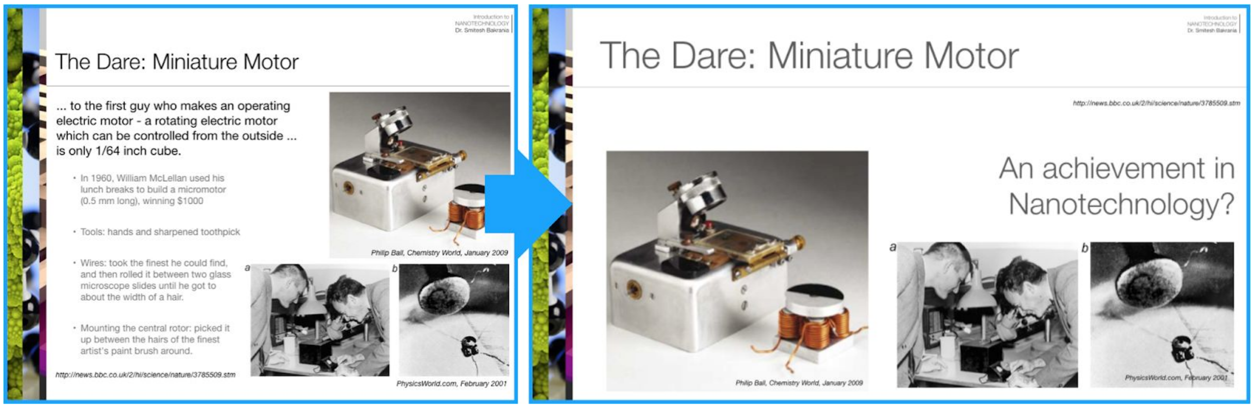
The course content details are presented in Bakrania, et al. [16], but briefly described here for context. The original face-to-face course lectures were slide-based due to the highly visual nature of the content. Each lecture required students to read handouts and answer the provided questions prior to lectures. The questions were collectively answered during the lectures and often prompted discussions. The assignments relied heavily on students' ability to review nanotechnology-related scientific journal papers and evaluate the outcomes. The assignments culminated into a term project where students selected an application area and presented their research to the class. In the end, each student prepared a research proposal related to their application area.

The Transition

For the Fall 2018 term, the face-to-face course was transitioned to an online course using the Canvas LMS supported by the university. The course content was broken into modules that corresponded approximately to 2 weeks worth of content in the traditional format. The transition process spanned approximately 4 months of intensive development prior to the course start date. This is a major difference between the time invested in preparation. For a face-to-face course, instructors can usually prepare a week or a lecture ahead of the class schedule. For an online course, all the content, lectures and assignments must be completed *before* the term begins. Any changes after the term begins must be avoided. Therefore, it is recommended that such transitions are planned over the summer to allow time for development. Instructors must be aware that a substantial amount of content must be prepared for the online course compared to a face-to-face delivery [17].

The following is a list of content that was transitioned and the decisions made to create a high impact online student experience for the Nanotechnology course. Aspects of each were refined during the face-to-face offering of the course. Later this list was used to develop guiding principles for transition.

Lectures. Since the lecture slides had been revised several times during the previous six offerings it was easy to envision converting this content into lecture videos. Lecture slides were converted to videos with instructor voice-over. There are few attributes of the slides that helped this transition for screen-based consumption. Using an already established template [18], the slides had minimal text to begin with. Heavy text content can distract viewers who are trying to listen. Slides with substantial text or equations were either eliminated or broken down into several sub-slides. The aspect ratio of slides was also changed to the 16:9 aspect ratio common for videos. Figure 1 presents the visual changes to the slides.



Introduction to
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The Dare: Miniature Motor

... to the first guy who makes an operating electric motor - a rotating electric motor which can be controlled from the outside ... is only 1/64 inch cube.

- In 1960, William McLellan used his lunch breaks to build a micromotor (0.5 mm long), winning $1000
- Tools: hands and sharpened toothpick
- Wires: took the finest he could find, and then rolled it between two glass microscope slides until he got to about the width of a hair.
- Mounting the central rotor: picked it up between the hairs of the finest artist's paint brush around.

http://news.bbc.co.uk/2/hi/science/nature/3785509.stm

Philip Ball, Chemistry World, January 2009

PhysicsWorld.com, February 2001

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http://news.bbc.co.uk/2/hi/science/nature/3785509.stm

An achievement in Nanotechnology?

Philip Ball, Chemistry World, January 2009

PhysicsWorld.com, February 2001

Figure 1. *Face-to-face slide lectures were transitioned for video delivery by eliminating text, changing the aspect ratio, and prompting inquiry into the content.*

Particular attention was paid to the audio quality of the voice-over. Audio recording generated using a laptop microphone can be a nuisance to hear for a prolonged period. The poor audio quality is especially noticeable when heard through headphones or laptop speakers. A microphone recommended for recording podcasts was used to prepare the audio.

Each lecture was broken into multiple lecture videos with discrete subtopics, also known as chunking [19], interspersed with either discussion questions or external short video links. The original 18 lecture slides were divided into 31 lecture slides to produce the videos. Lecture video length was kept at approximately 20 minutes per video to avoid fatigue.

Class Discussions. When students were asked to read the handouts or review critical lecture content, they were asked to answer multiple-choice questions to ensure completion. This exercise was frequently followed by a Discussion Board exercise. Here each student submitted their response to a prompt related to the reading or the lecture video on a Discussion Board post. The post was visible to the rest of the class. Discussion prompts were also embedded in the videos as demonstrated in Figure 1. Various other collaborative exercises can be used to embed a social element to the class.

Instructor Engagement. Traditionally, face-to-face lectures naturally lead to students being engaged with the content being delivered. Often, online delivery becomes a passive exercise from students' perspective. Therefore, the instructor regularly broadcasted feedback and thoughts on nano-related media items, discussions, assignments, and common questions. Occasionally, students were able to talk to the instructor over a phone call or during office hours. Being available to students on-campus was important.

Project Assignment. The written assignments changed little from the traditional offering. Additional guidance and samples were added to clarify expectations. Major overhaul was experienced by the final project where students in the past had to prepare a presentation on a nanomaterial application for the class. For the online course assignment, students were asked to prepare a voice-over video of their presentation, similar to the lecture videos, and share it with the class. Next students had to pick at least three student videos to review and comment. This last step ensured the content was prepared for the appropriate audience and not just for the instructor.

Content Overviews. Besides content, several structural elements were prepared to support and present the content. Each module was supported by an overview of the content, assessment plan, rubrics, assignment instructions, supplemental information, hints, checklists, etc. This support document came in the form of Weekly Overviews that captured all aspects of the content typically handled verbally within a class lecture. This aspect of the course is typically the weakest during the first offering of the course and quickly improved over time with student feedback. Majority of the planning is associated with this structural component that also functions as a checklist for students.

Comparison of Outcomes

To test the effectiveness of this transition both direct and indirect measures were selected for comparison. The validity of the comparison can be justified by the following aspects that remained constant. Both the face-to-face and the online versions of the course were taught by the same instructor. The class size and the student make-up (undergraduate vs. graduates, majors, class year, etc.) remained nominally the same. The time gap between the two versions was a single academic year. And most importantly, the course content and course load remained the same.

Direct Measure

A specific assessment could be used to compare the learning outcomes from the face-to-face and online delivery of the course. The obvious choice would have been the course project where students were required to prepare a short presentation on a selected topic. The course project constituted almost a third of their final grade. There were two aspects that made the course project unsuitable for such a comparison. First, the new video-based presentation made an objective comparison to an in-person presentation challenging. The students quickly learned to edit the video and pre-record their delivery before final video production. Therefore, the video presentations yielded a more polished product. Second, assessment of this assignment lends itself to a degree of subjectivity related to presenter confidence and visuals. It would have been challenging to objectively assess the mastery of content within the course. A similar argument could be made for the research proposal. Instead, a knowledge test that was common between the face-to-face and online delivery of the course was selected to test content mastery.

The course can be divided into instructor-driven, where students learn about the fundamentals and the tools used in the broad field of nanotechnology, and student-driven, where students present nanomaterial applications. At the end of the instructor-driven portion a 60-question multiple-choice test was administered that transitioned easily and unmodified to the online version of the course. The averages from this test indicate mastery of the content delivered via instructor lectures. The averages were used as a direct comparison between the face-to-face or online delivery of the content. Figure 2 presents the test averages of student performances from the most recent face-to-face versions of the course and compares them to the online versions of the course along with single standard deviations. The enrollment for each term was as follows: 19 students for Fall 2013, 17 students for Fall 2017, 18 students for Fall 2018, and 21 students for Summer 2019.

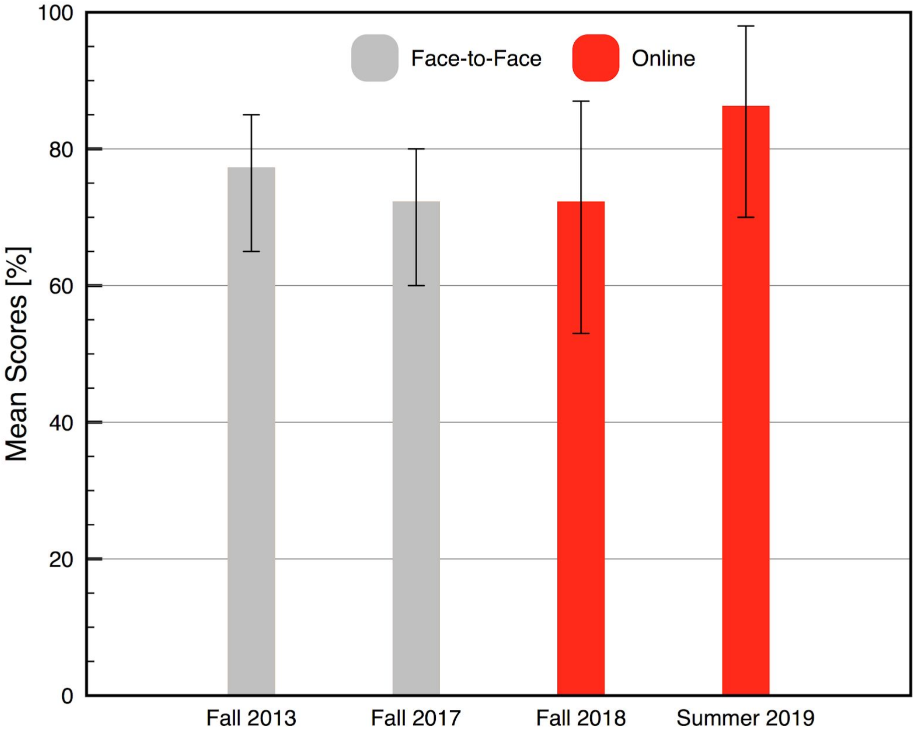

Figure 2. *Knowledge Test 1 mean scores compared for the face-to-face and the online delivery of the Nanotechnology course. The error bars represent a single standard deviation in the student scores.*

The mean score comparison from Figure 2 shows very little deviation in student performance after the transition. In fact, there is a slight improvement in score for the summer session of the online course that can be attributed to time extension for the test. The lack of any significant deviation in learning outcomes is an important baseline for the effectiveness of the online delivery. It is expected further refinement in lectures has the potential to yield better outcomes.

Indirect Measure

As an indirect measure of the learning outcomes a final survey from the two versions of the courses were compared. The original survey was developed to test the effectiveness of the content and assignments to introduce the students to nanotechnology and scientific literature review skills within a traditional elective course [16]. The anonymous survey has been administered every term since Fall 2008. Table 1 presents a list of 24 questions that students were asked. For each question, students were asked to rate their response to generate a numeric value between 1 and 5. The scale was bound by a rating of 1 representing 'Not at all' and a rating of 5 representing 'Very/Highly'. The means and standard deviations are tabulated for each question across the four semesters. The participation was 100% for each term because every student was required to submit their responses as part of their assessment.

Table 1. *A comparison of the final survey of student perceptions of the course learning outcomes. The Fall 2013 and Fall 2017 courses were taught using face-to-face delivery. The Fall 2018 and Summer 2019 courses were taught with online delivery. Rating Scale 1 for 'Not at all' and 5 for 'Very/Highly'.*

	Survey Question	F 2013	F 2017	F 2018	Sm 2019
1	How comfortable are you at describing to someone what nanotechnology entails and its significance?	4.6 ± 0.6	4.4 ± 0.6	4.2 ± 0.7	4.4 ± 0.8
2	How comfortable are you at identifying physical or chemical aspects important at the nanoscale?	4 ± 0.6	4.1 ± 0.7	3.6 ± 0.8	4 ± 0.6
3	Do you feel comfortable to (a) classify (b) suggest a possible synthesis route and (c) recommend a characterization technique for a given nanomaterial?	3.9 ± 0.6	3.7 ± 1	3.6 ± 1	3.9 ± 0.8
4	Do you feel comfortable to discuss various research areas (such as sensors, transistor technology, batteries, medicine) emerging from nanotechnology, including their importance and progress?	4.2 ± 0.7	4.4 ± 0.8	4.1 ± 0.7	4 ± 0.9
5	How effective were the lecture slides towards understanding the material?	4.3 ± 0.7	4.2 ± 0.9	4.4 ± 0.6	4.2 ± 1
6	How would you rate your preference towards absence of a course textbook?	4.5 ± 0.8	4.1 ± 0.9	4.5 ± 0.8	4.1 ± 1.1
7	Were the assignments effective towards helping you understand the material?	4.3 ± 0.8	4.1 ± 0.8	4.3 ± 0.7	4.3 ± 0.8
8	Was the instructor accessible to help you with the material or assignments?	4.3 ± 0.6	4.4 ± 0.8	4.7 ± 0.6	4.2 ± 1.1

9	Did the course project (AppTalk & Research Proposal) help you get more familiar with nanotechnology?	4.8 ± 0.4	4.6 ± 0.6	4.4 ± 0.8	4.5 ± 0.8
10	Did the combination of instructor lectures and student presentations provide a broad overview of nanotechnology field?	4.4 ± 0.8	4.9 ± 0.3	4.3 ± 0.6	4.5 ± 0.8
11	How would you rate your knowledge in the general field of nanotechnology?	3.7 ± 0.5	3.8 ± 0.7	3.5 ± 0.7	3.8 ± 0.7
12	What portion of your learning was directly a result of your instructor? (1 for Minimal and 5 for Almost all)	3.7 ± 0.7	3.5 ± 0.8	3.9 ± 0.8	3.6 ± 0.7
13	What portion of your learning was a result of your own research? (1 for Minimal and 5 for Almost all)	3.4 ± 0.6	3.6 ± 0.8	3.4 ± 0.9	3.9 ± 0.7
14	What portion of your learning was from other presenters during AppTalks? (1 for Minimal and 5 for Almost all)	2.9 ± 0.6	2.9 ± 0.9	2.7 ± 1	3 ± 0.9
15	How did this course affect your comfort for researching a topic via scientific journals? (1 for Very negatively and 5 for Very positively)	4.4 ± 0.6	4.3 ± 0.9	4.2 ± 1.1	4.4 ± 0.7
16	How would you have rated your ability to research a topic via scientific journals BEFORE this course? (1 for Very low and 5 for Very high)	2.7 ± 0.7	3.1 ± 1.2	3.2 ± 1.3	3.6 ± 1.1
17	How would you rate your ability to research any topic via scientific journals AFTER this course? (1 for Very low and 5 for Very high)	4.5 ± 0.5	4.3 ± 0.9	3.9 ± 1.1	4.6 ± 0.5
18	How applicable do you think the skill of researching via scientific journals is?	4.5 ± 0.6	4.4 ± 0.9	4.4 ± 1	4.7 ± 0.7
19	How comfortable are you at reading nanotechnology-related journal papers?	4 ± 0.7	4.2 ± 1	3.9 ± 0.9	4.2 ± 0.6
20	How were your expectations (that you shared at the beginning of the term) addressed by this course? (1 for Not addressed and 5 for Completely addressed)	4.2 ± 0.6	3.9 ± 1	3.8 ± 0.7	4.1 ± 0.9
21	How comfortable are you at reading, summarizing and critiquing journal papers?	4 ± 0.9	3.9 ± 1	3.9 ± 1.1	4.1 ± 0.8
22	How many scientific journal papers did you read for this course? (1 for 1-5, 2 for 5-10, 3 for 10-15, 4 for 15-25 and 5 for >25)	3.8 ± 0.6	3.9 ± 1.1	3.6 ± 0.8	4.4 ± 0.5

23	Do you feel current with the progress in the field of nanoscience and nanotechnology?	4 ± 0.6	4.1 ± 0.9	4 ± 0.7	4.3 ± 0.6
24	Would you recommend this course to a fellow student?	4.5 ± 0.7	4.2 ± 0.7	4.1 ± 1	3.9 ± 1.4

The *before* and *after* comparison of student perception of their learning yielded nominally the same mean rating for all the questions. At least within the margins of the standard deviation. The results suggest the online version of the course was just as effective as the face-to-face version in the past.

The first four questions and questions 10, 11, and 23 related to the course learning objectives and the students' familiarity with the field in general. The mean ratings for these questions ranged 3.8-4.5 for the Summer 2019 online delivery. Question 23 asked: Do you feel current with the progress in the field of nanoscience and nanotechnology? The mean rating for this question was 4.3 out 5.0. The high rating could be attributed to the numerous assignments that required students to review current scientific literature. In fact, the rating for Question 22 was 4.4, suggesting students read between 15-25 journal papers during the term (or more). Naturally, Question 18 garnered the highest rating of 4.7. It asked: How applicable do you think the skill of researching via scientific journal is? Students clearly seem to value this skill and felt that the course prepared them well as confirmed by Question 17.

The rated numeric responses were supported by the open-ended feedback. For this portion of the survey, students were provided with three prompts:

1. Besides learning about nanotechnology, what were some other things that you think you gained from this course?
2. What were some of the things that worked this term?
3. What were some of the things that could be improved for next term?

Again, comparison was made between the previous face-to-face courses and the online course responses. Majority of the students from both the online terms identified 'literature research', 'presentation', and 'time-management', as skills they acquired from the course. Interestingly, 'time-management' was the only skill that was rarely highlighted in face-to-face delivery. Without regular in-class lectures to drive deliverables, one can imagine the challenge of time management around the deadlines set by online delivery. This additional burden of time-management has been well-documented in the literature [20].

When asked: What worked well? Responses ranged from 'lectures' to the 'term project'. However, a look at the responses for the prompt, 'What were some of the things that could be improved for next term?' proved insightful in what was absent from the comments. None of the responses indicated the method of delivery as an issue. Students were well aware of the new online delivery method considering the course was taught as a face-to-face course during the previous term. The instructor also emphasized in Fall 2018 that this was a trial run of the online delivery. Instead, a majority of the responses focussed on the heavy workload. Specifically, the assignment load exceeded their expectations for an online course. For the online delivery, a final rating question was added to the original twenty three questions: How would you rate this online course compared to others that you have taken at Rowan. This question received an average rating of 4.5 and 4.1 for the Fall and Summer sessions, respectively.

Indirect Measure with an Ultimatum

A separate survey was prepared to further probe student perception of online delivery of a course. For this survey, besides asking: what worked, what did not, and how the course could be improved, students were asked to select between three alternatives as a potential solution to the deficiencies they just identified. The three alternatives were designed to elucidate their preference for the mode of content delivery: face-to-face, hybrid, or online.

This survey was not confined to the *Nanotechnology* course. Instead, students from a newly developed online course in Chemistry were solicited for the survey. The course titled *Regulatory Affairs* focussed on regulatory processes common to the pharmaceutical industry. This course was developed as an online course and offered for the first time in Spring 2019 as an elective to Chemistry, Biochemistry, and Pharmaceutical Sciences students. This course was developed in consultation with the *Nanotechnology* instructor. As a result, the lecture delivery, assignments, structure, and instructor engagement mapped very well to the approach followed for the *Nanotechnology* course. In other words, the same guiding principles (described later) were used for developing the online chemistry course. For the Spring 2019 term, a total of 34 undergraduate and graduate students were enrolled to take *Regulatory Affairs* online.

For this second survey, students were asked to ‘Select how the deficiencies you indicated earlier can be addressed in the future’. Instead of an open-ended response, three choices were offered: (a) Minor adjustments and improvements can be made to the existing online course, (b) Adopt a hybrid model with online and in-class components, or (c) Eliminate online delivery completely. Replace with only in-class lectures. Both *Nanotechnology* and *Regulatory Affairs* courses received approximately 90% response rate when compared to the enrolled students. Figure 3 presents student choices as a percentage of total responses.

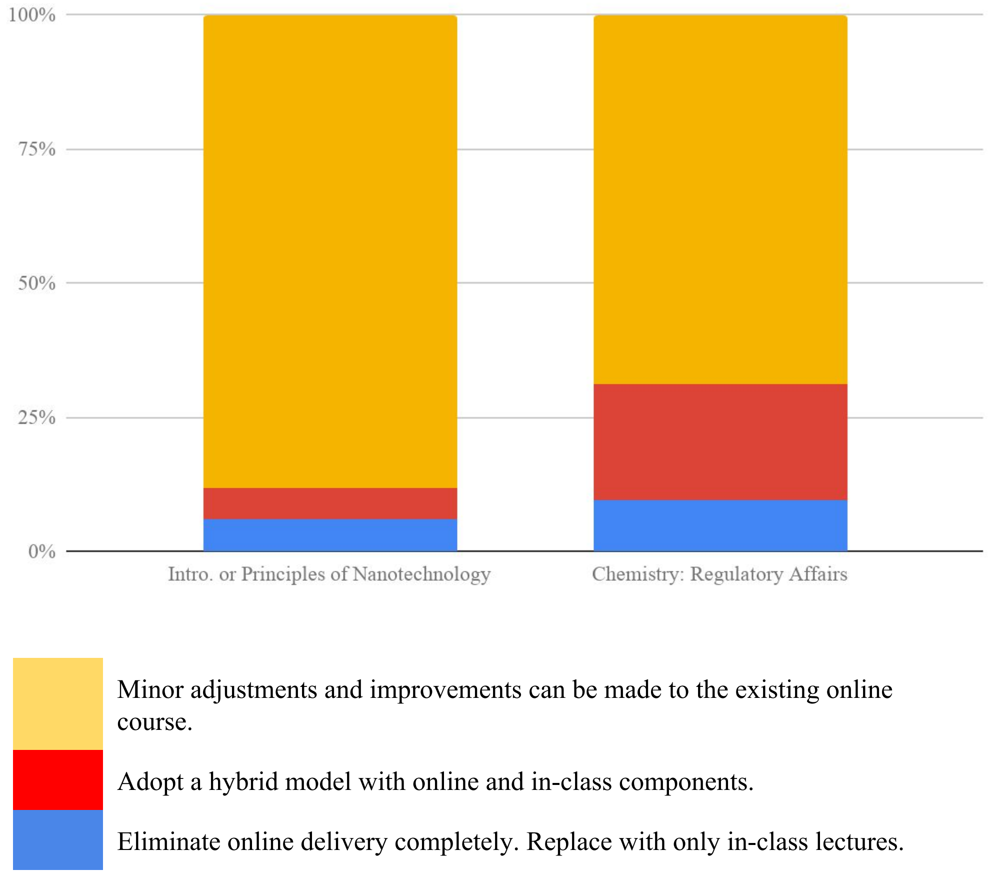

Figure 3. *A summary of responses from a survey for the two courses: Mechanical Engineering, Introduction or Principles of Nanotechnology and Chemistry, Regulatory Affairs. Students were asked after they identified some deficiencies with the online offerings: Select how the deficiencies you indicated earlier can be addressed in the future.*

Figure 3 shows for the *Nanotechnology* course, 88% of students selected ‘minor adjustments and improvements can be made to the existing online course’. For the *Regulatory Affairs* course, about 70% of the students selected the same option. The results are strong endorsements for these online versions of the elective courses. Especially, considering only less than 10% of students selected the ‘Eliminate online delivery completely. Replace with only in-class lectures’ option. It is expected that the results would be more favorable for the second offering of the *Regulatory Affairs* course. A majority of the deficiencies that were highlighted in the open-ended portion of the survey within the chemistry course were associated with the clarity of expectations for the assignments. This is expected for the first offering of an online course.

Teaching Evaluations from Online Delivery

The teaching evaluations corroborated the results from the indirect measures. The following are all the responses from Fall 2018 offering of the *Nanotechnology* course to the prompt: Tell a future student about this instructor and course. This portion of the teaching evaluation was optional and thus yielded a lower response rate.

> *"This course was very well-structured and well-organized. It requires many of the skills taught through Rowan's engineering program; reading to understand technical content, synthesizing technical content, written communication, verbal communication, etc. I would definitely take it again. I do wish however that we had access to the course project description earlier in the semester. Having the research proposal locked until December 4th was rough, especially when that was the only thing I had left for the course."*
>
> *"Dr. Bakrania is an excellent professor and always tries to get the most out of his students. I learn a lot through his teaching methods however he expects a significant amount of work and effort in return. At times it can feel overwhelming as no other class has nearly the same workload. The lectures were well prepared but it was difficult to take notes on the speaking points and the written notes. This course has been very challenging and required a lot of my time. Overall I enjoyed learning about nanotechnology but I thought the course projects were too much."*
>
> *"Be prepared for a very hefty back end of the semester. Most of the content and assignments are in the last few weeks of the semester."*
>
> *"Very important class for students who want to stay connected to the modern world of nanotechnology and help understand the future of nanotechnology"*
>
> *This is not an easy course, but it is very interesting and current, as the course material is still a relatively new field. The workload is fair, as are the quizzes. However, the final quiz is fairly difficult and you are not given much time to complete it. Overall, this is a great class and I would recommend it to another student.*
>
> *"Very interesting course that will keep you up to date on state of the art research in nanotechnology. It may sound like a difficult subject for an online class, but Dr. Bakrania does an excellent job of connecting with students and making it work."*

While there are clearly aspects that can be improved, the majority of the concerns are minor and can be easily addressed for the next offering. 'Heavy workload' is a recurring theme as identified earlier in the 'time-management' discussion. The combination of measures and the outcomes suggest a successful transition from a face-to-face to an online delivery for the *Nanotechnology* course. It is important to note that the results here are not a full endorsement of transitioning every course to online delivery. Instead, this work highlights deliberate steps that can be taken to produce a successful online course. Informal discussions with colleagues, the Chemistry Elective instructor, and self-reflection on the effective strategies can be distilled into specific ideas that work for the online course. These are documented in the next.

Guiding Principles for Transition

The following is a list of guiding principles that were developed as an extension of this transitioning. These principles are not meant to be an exhaustive list but they identify key ingredients and strategies necessary for producing an engaging online experience. It is recommended that instructors use the following as guiding principles for transitioning an existing face-to-face course.

Develop Content in Nano-Steps. Assuming the primary lecture content for an online course is a voice-over slide presentation, make sure you test these slides first within a face-to-face course. It is not recommended to transition from a whiteboard directly to a slide-based delivery. Refine your slides after each lecture by imagining limited interaction with the audience. The same applies for the assignments. Prepare clear written explanations for assignments and provide samples to set the expectations. This will limit the back and forth that is often easily handled within a face-to-face course. The staged rollout ensures the course has a robust structure to deliver the content online [9].

Be Mindful of the Content Type. Interaction is an expected feature of whiteboard-based lectures. Online lectures must often stand alone. Highly mathematical courses can be challenging to transition, especially if they were previously taught using a whiteboard. Therefore, information-driven courses like *Nanotechnology* or *Regulatory Affairs* are better suited for online delivery. Such courses are designed to provide the necessary context for the subsequent assignment. For a mathematically intensive course it is recommended that the course is first taught face-to-face with slides to test the material. Followed by a deliberate refinement process for the eventual online delivery. Common challenges for transitioning a Statics course has been studied by Sorby, et al. [10].

Create Lecture Overviews. Prepare a document that captures every aspect of a lecture. This includes: videos that are used to prompt discussion, reading assignments, possible classroom discussions, reviews of the last lecture, and assignments. This document will naturally transition into the structure that is necessary for an online platform. The overviews provide the scaffolding for the content in the new digital habitat.

Make Compelling Lecture Videos. Videos emphasize audio-visual elements. Pay particular attention to the audio delivery in terms of what is being said and how [21]. Audio quality is paramount during recording. Invest in a microphone and be aware of the acoustics of the space. It is helpful to think of the narrative as an engaging podcast. For the visuals, be ruthless about reducing text from your slides. Titles and labels are fine but it is better to say something meaningful with a relevant visual than have the complete text displayed. Keep the videos short by focusing on one subtopic at a time. Having multiple videos for each traditional lecture is ideal for later review [19].

Create Discussions that Promote a Sense of Community. Course discussions are an excellent way to create a sense of community [7, 17, 22]. It is often this sense of belonging that drives student motivations. Develop discussions that invite diversity of ideas. Open-ended discussions are better than single answer prompts. Incentivise students to select one student post to reply to. Highlight good discussions as models for interaction. Summarize discussions to emphasize that they are valued. Incorporate other forms of collaborative work to create student interactions off-line.

Establish presence. For an online course, minimal face-to-face interaction is expected. However, it is critical for the instructor to create a sense of presence. It is easy to set the course in motion and await the assignments for grading. This approach quickly disengages the student from the instructor. Begin with a welcome message, issue notices for assignments, frequently post feedback, and comment on relevant course content. Provide summary feedback for assignments and highlight stellar performances by sharing their work with the class. This practice is not unlike what happens in a traditional course. This not only reinforces the expectations but also transmits a sense of community [23].

Set Time Management Expectations. Students struggle to manage their time well particularly with online courses [20]. Be upfront about this challenge with your class: "This class will test your time management strategies." Regularly alert them to start their assignments early and warn them against the slippery slope of procrastination. A detailed overview or a checklist can go a long way to help with time management [5].

The foregoing principles can not guarantee a successful online course but they highlight elements that are conducive to one. Of course, the combination of content, instructional style, and assignments also play an important role. The principles discussed assume one has an effective face-to-face course to begin with. However, this prerequisite alone does not guarantee a successful outcome. A systematic and staged developmental approach is necessary to remaster an existing course. Besides, transitioning an ineffective face-to-face course will likely accentuate the deficiencies of the course. An effective online course demands significant upfront time during development and may require comparable time administering the course. The students and the institutions are often the primary beneficiaries of an online course. Students prefer the flexibility that online courses offer, thus attracting a more diverse student population. The institution benefits by opening up resources tied to an in-class lecture. Therefore, campuses often incentivise instructors to develop online courses by paying developmental fees. Such incentives need to be combined with training and course release. It is our hope that this work lowers the barriers for engineering faculty to meaningfully contribute to the next wave of educational opportunities.

Conclusions

Often the root cause for a failed online course is the same as the root cause for a failed face-to-face course: execution. This work demonstrated two successful executions of senior-level and graduate-level online courses. The learning outcomes remained the same when compared using both direct and indirect measures for a course that was transitioned from a face-to-face to an online delivery. The assessment instruments were compared over multiple terms. This work also documented developmental guiding principles that contributed to a successful execution. The principles have the potential to seed future innovations in instructional technology and possibly serve to change the conversation around online learning opportunities within engineering.

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