# State-of-the-Art Delivery and Assessment of an Online/Distance Education Chemical Engineering Bridging Course

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## Abstract

This paper describes the delivery of a chemical engineering "bridging" course which intends to span the gap between students' non-chemical engineering background and the knowledge needed to succeed in the chemical engineering field. Steps taken to develop the course will be described, including course specifications as well as development of course-level and lesson-level learning objectives. The delivery of the course was influenced by best practices derived from distance education research, which will be explained. The course is delivered entirely online through course management software, allowing digital submission and grading of quizzes and homework. Screencasts are used to provide video solutions of example problems and homework, with the latter solutions made available to the students in an automated fashion throughout the semester after due dates have passed. Demographics, course experience/engagement, academic performance, learning perceptions and student motivation are measured using objective and subjective assessment tools validated in education literature.

## Keywords

Chemical Engineering, Engineering Education, Bridging Course, Online Course, Continuing Education

## Introduction

As part of their academic and/or career development, students with undergraduate degrees in chemistry or biology also research or work on tasks related to chemical engineering (ChE), and thus desire to attend ChE graduate school to learn more about the field. These students may struggle when challenged with graduate coursework on unfamiliar topics such as material and energy balances, transport phenomena, thermodynamics and reactor design. A typical approach for graduate institutions accepting students with non-ChE backgrounds is to require these students to attend instruction in several undergraduate courses in these "missing" fields to address gaps in the students' background.

As an alternative to this approach, we describe the development and assessment of an online ChE bridging course that is part of an initiative at North Carolina State University to broaden its reach of distance education. Students who complete the two-course, fall-spring sequence will be able to count those courses as six technical elective credit hours toward a MS Chemical Engineering degree at North Carolina State University, which may be attractive to prospective graduate students. These students may be prospective students (i.e. courses taken prior to admission) or newly admitted Master's students. It should be noted that this work is a continuation of a Work-in-Progress paper originally presented at the 2018 ASEE National Conference[1].

## Course Design and Delivery

The course design and delivery are consistent with best practices for online education[2-4] and are described below.

- Divide the course content into brief modules

The course content condenses six current undergraduate courses (material and energy balances, two semesters of thermodynamics, transport phenomena, and reactor design) down to two semesters. The instructors of the graduate core courses provided valuable insight regarding essential elements of the undergraduate content required for success at the graduate level. This exercise also helped prune the list of topics to a manageable number. Interviews with graduate instructors also provided feedback on topics that tend to be challenging for non-ChE students, such as the intensive applied calculus required in transport phenomena courses. Based on graduate instructors' input, some thermodynamics content is integrated into material and energy balances, Course I (offered in the fall) covers the foundational topics of both thermodynamics and transport. Course II (offered in the spring) addresses thermodynamics and transport with a focus on application, in addition to kinetics and reactor design. Table 1 displays the finalized content of the completed fall/spring courses.

**Table 1. Course Contents (*signifies Course I, ^ signifies Course II)**

| **Module** | **Selected Topics** | **Suggested Textbook** |
|---|---|---|
| Material and Energy Balance | - Fundamentals of Material Balances*<br>- Single-Phase Systems*<br>- Multi-Phase Systems*<br>- Energy and Energy Balances*<br>- Energy Balances on Non-Reactive Processes*<br>- Energy Balances on Reactive Processes* | *Elementary Principles of Chemical Processes*, 4th Edition<br>Felder, Rousseau, & Bullard |
| Thermodynamics | - First and Second Laws of Thermodynamics*<br>- Thermodynamic Properties of Fluids*<br>- Application of Thermodynamics to Flow Processes*<br>- Framework of Solution Thermodynamics^<br>- Mixing Properties^<br>- Phase Equilibrium^<br>- Thermodynamic Formulation for VLE^ | *Introduction to Chemical Engineering Thermodynamics*, 8th Edition<br>Smith, Van Ness, Abbott, & Swihart |
| Transport Phenomena | - Fluid Mechanics and Shell Momentum Balances*<br>- Equations of Change for Isothermal Systems* | *Transport Phenomena*, 2nd Edition<br>Bird, Stewart, & Lightfoot |

| | | |
|---|---|---|
| | - Shell Energy Balances and Temperature Distributions^<br>- Diffusivity and the Mechanisms of Mass Transport^<br>- Concentration Distributions in Solids and in Laminar Flow^ | |
| Reaction and Reactor Design | - Mole Balances^<br>- Reactor Sizing^<br>- Rate Law and Stoichiometry^<br>- Isothermal Reactor Design^ | *Elements of Chemical Reaction Engineering*<br>5th Edition<br>Fogler |

- Write learning objectives and structure the content of each module around those objectives

Following the best-practices approach of writing measurable learning objectives for each topic allowed the instructors to focus the lecture content, examples, and homework around these objectives[5]. Each module features learning objectives, lectures, homework, and conceptual quizzes adapted from AIChE Concept Warehouse[6] and/or LearnChemE.com[7]. The lecture portion of each module is comprised of a series of short video lessons (2 to 10 minutes) by an instructor. Example problems and homework solutions are illustrated using video screencasts.

- Use clear, consistent organization and navigation

The course is housed in Moodle, the standard learning management system for the authors' university. The home screen features an extensive Course Orientation section which contains the course documents (syllabus, content outline), welcome videos from the instructors, links to online office hour sessions, and survey prompts. The students' first assignment is to complete a "Getting Started" orientation module which ensures that they can navigate through the Moodle course site. They also complete a short syllabus quiz.

Consultants from the university's DELTA (Distance Education and Learning Technology Applications) organization assisted the instructors in developing a course navigation bar (shown in Figure 1) which allows students to quickly move to different sections which are color coded

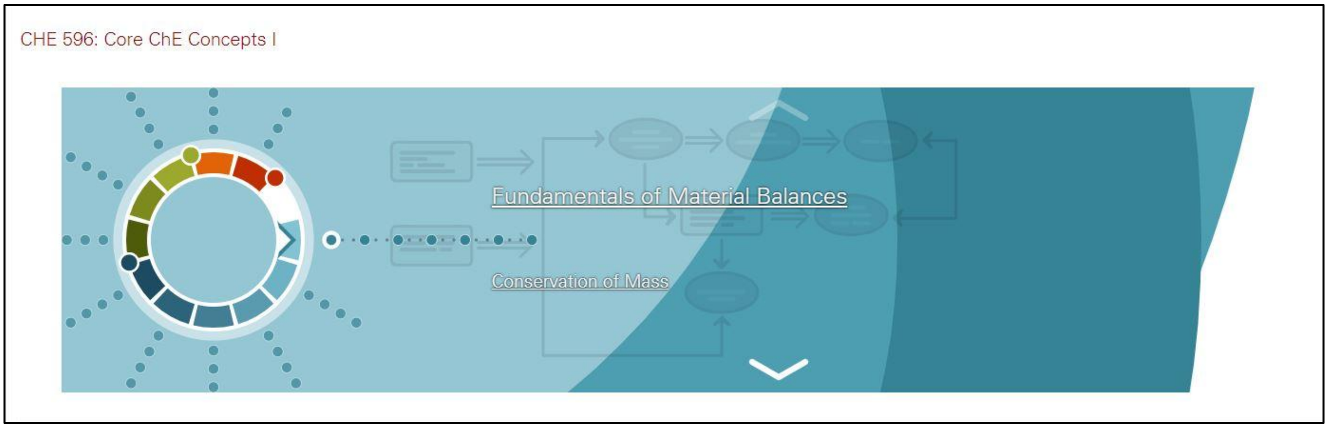


**Figure 1. Course navigation bar**

(material and energy balances in blue, thermodynamics in green, transport in red). The spinning "gauge" rotates with the drag of a mouse to allow students to move between sections and view how many sections are contained in each topic. By clicking directly on the heading displayed, the student can go directly to that section. Each section also has a unique color-coded navigation bar (linked to the navigation bar) which has an illustration relating to that section. Each module is laid out in a consistent format with icons indicating lectures, examples, homework, and quizzes.

- Focus all materials (i.e. "content chunking")

"Content chunking" is breaking down large amounts of information into smaller components that are easier to digest. Having separate videos for lectures, examples, and homework solutions allows students to decide which videos to play (or replay) according to their needs. This also allows the faculty to revise short lecture videos as needed and add examples based on student performance and feedback. Each lecture video focuses exclusively on one or two learning objectives. The example videos and homework solution videos provide an annotated description to help the students identify how to approach the problem, explain why certain equations are appropriate to use, and clarify assumptions.

- Show, don't tell

In addition to the short video lectures, the instructors integrated modern "lightboard" videos which use visualization technology (Figure 2). An on-campus company, STEMbrite, produced

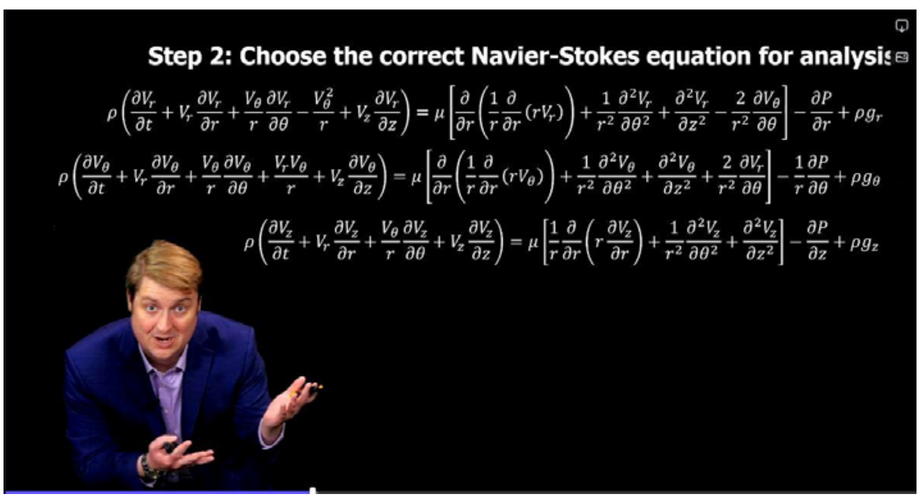


**Figure 2. Example of a lightboard-enabled lesson**

the videos. The lightboard content was chosen to feature visual concepts which are well suited to illustration or complex equations which could be stepped through in a visual process.

- Office hours: distance education students can present additional restrictions

Students enrolled in this course reside in different states and time zones, so being mindful of the needs of all distance education students is important. Office hours were initially offered virtually using the Blackboard Collaborate program available through the authors' available course management software (Moodle). The Blackboard Collaborate program provides an audio/video conferencing interface, including the ability to draw on a virtual notepad using a touchscreen-enabled device - this is especially helpful in to instructors and students in sketching diagrams and flowsheets while submitting or answering questions. Regarding timing of office hours, the instructors attempted to schedule office hours in such a way that all students had an opportunity to attend. This meant that even though the instructors (and many students enrolled in the course) were located in the Eastern Time Zone (ETZ), office hours were offered 7:30 - 9:00 PM ET one day a week to accommodate students in western time zones or who have daily responsibilities working or caring for family, as well as a more typical 9:00 - 10:30 AM ET time frame to accommodate ETZ graduate students. Audio and video of office hour sessions are also recorded for future use in course development.

While office hours were used by several students early in the semester, most students preferred to communicate directly with the instructors via email. After several weeks in which no one attended the virtual office hours, the instructors made the decision to handle student question via email. This may differ in future semesters based on the size and composition of the class. Note that for this offering of the course, there was one graduate TA, who graded homework assignments and assisted in grading exams. The two instructors handled all office hour questions.

- Foster community

Strategies for fostering community in an online course include posting welcome videos and instructor "portrait" videos[8-9]. These help put a human face on what can be an impersonal virtual interaction between the instructor and student. The co-instructors include a short video on the Moodle site in which both instructors welcome students to the course and provide a personal overview of the course purpose and content. In addition, the instructors worked with campus video production personnel to develop a short "portrait video" which introduces them and their teaching philosophy. One of the instructors talks about how his hobby of growing tomatoes is like nurturing students[10], and the other instructor highlights the rocking chairs in her office to emphasize her personal approach to student advising[11]. If other instructors teach the course in the future, a similar portrait-type video could be added to feature them and provide a personal touch.

An initial assignment asks students to introduce themselves to their classmates and instructors through the Discussion Forum. They are invited to share their disciplinary background, whether they are a full time student or working part time/full time, and their goals in taking the course. This allows students who may be in a nearby location to collaborate with one another and also informs the instructors about the composition and background of the class.

Students have access to a course discussion board for direct communication among class members. While the academic integrity policy specifies that students cannot directly discuss answers to homework, quizzes or the final exam, they can use the typing option or voice talk to share ideas and ask general questions regarding homework problem approach and assumptions. This mechanism allows students to practice working in an interactive group work environment in a professional, collaborative environment.

## Assessment

The focus in Fall 2018 and Spring 2019 is to collect initial baseline data which will then be compared with equivalent data collected in future course offerings. This approach will allow the instructors to evaluate the effectiveness of changes made in later semesters against the initial baseline data for statistical comparisons. Direct assessment data is collected through scores on homework, quizzes and exams as well as final grades, while indirect assessments are collected through course evaluations and responses to constructional inventories of qualitative metrics such as task value, student engagement and application of learning.

Data measures include[12-25]:

- Academic performance: grades in the bridging course, direct evidence used to assess skill attainment in subject areas, and performance in students' later CBE graduate courses (for students who continue at the authors' institution)
- Student demographics: undergraduate degree discipline, professional experience
- Course experience and engagement: average time to complete each module, time spent on homework, engagement with content/materials, engagement with other students and the instructor
- Learning perceptions: feedback on the effectiveness of the course content (videos, homework/examples, lectures and readings, online learning site)

## Next Steps

Twenty-one students enrolled in the first offering of Course I in Fall 2018, and nineteen completed the course. Eleven students were enrolled in either the on-campus or on-line MS Chemical Engineering degree program at NC State, and one student is enrolled in the Master of Engineering (MR) program at NC State. (Both on-campus and online students accessed all the course material online). Eight students are taking the course as non-degree post-baccalaureate students, of whom several with expressed plans to apply to a ChE graduate program. Nine students are working part time or full time, and two students are seniors in BS Chemistry degree programs.

A key objective during the first offering of the course in Fall 2018-Spring 2019 will be to validate the choice of core content, confirm the level of detail and pace of the material, and determine the efficacy of improvements to the online interface used by students. Inevitably, the first offering of a course generates a long list of items to change, and the authors are documenting necessary edits, which will occur in Summer 2019.

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