

Resources to Implement Flipped Chemical Engineering Classrooms: Course Packages

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Abstract

The main hurdles for faculty to implement more effective teaching methods in their classrooms are a lack of resources and/or a lack of experience with the techniques. In an effort to reduce these hurdles and encourage more faculty to use these methods, we have created a digital, open-access course package for two chemical engineering courses, thermodynamics and material and energy balances. These course packages can also be used as templates for faculty who want to develop other courses that are student-centric and involve active learning. Many of the resources within the package stem from our online inventory of over 1,400 ConcepTests and 1,000 screencasts. These encompass topics in core chemical engineering courses, but many topics are also common to other engineering disciplines (i.e., fluid mechanics, heat transfer, thermodynamics, material science, and computing). The course packages use Microsoft OneNote, which allows the user to centralize all materials in one document. These course packages contain ready-to-use class templates, suggested readings and screencasts for students to complete prior to class, in-class ConcepTests, homework problems, and exam questions. The materials are aligned to popular textbooks but allow flexibility because they can be easily rearranged to meet individual needs. Resources and guides on implementing the methods in a class are also provided. These resources provide literature, best practices, and suggestions on using the course materials. The objective is to make it easier for faculty to convert to active learning instruction and towards a flipped class, where most of the information delivery is outside of the classroom.

Towards a Flipped Class

Most students expect to have a teacher lecture and then they attempt to apply this information by completing homework assignments outside of class. Reversing this is known as the flipped classroom and has become an approach that allows an instructor to use class time more effectively [1-4]. Bergmann and Sams [4] argued that this model allows students to be engaged and take responsibility and ownership for their learning. Their model utilizes short videos that introduce a topic to the students and then present a worked out example or conceptual problem. Students watch these before class and then spend class time discussing the material, working on conceptual questions using peer-instruction, or problem solving, all being afforded instructor support and interactions [5]. Bergmann and Sams [6] found that students who watched screencasts outperformed students who had traditional lectures.

Videos are not the sole solution to flipping a class. Faculty adopting this approach have to modify their role from a lecturer to a collaborative and cooperative facilitator of learning. The flip side is that students cannot be passive participants in class and instead become members of an active learning environment. The flipped classroom results in a shift from merely covering curriculum to a collaborative effort to master concepts and problem solving techniques. Flipping a class has been implemented widely in K-12 education. Recently two medical school professors flipped medical school courses [7] and highlighted initial improvements in class attendance when they flipped their biochemistry course compared to the same course taught by traditional lecturing.

The success of adopting the flipped classroom model starts with resources and learning to integrate these resources appropriately into the course. Screencasts must illustrate concepts in a clear fashion, address common misconceptions [8], and work through examples to provide the greatest learning potential [9]. Class time must be spent utilizing active-learning strategies, such as peer instruction, cooperative group problem solving, just-in-time teaching, and interactive demonstrations. Creating these materials takes time and that has likely limited adoption of these methods.

The Course Package

The overall course package structure is a digital and dynamic notebook that combines textbook resources with those of a practiced and effective professor. The dynamic nature of this course package allows for modifications and updates as classes and resources are improved. Combining active learning tools into one central, user-friendly, digital notebook provides faculty with a valuable teaching tool. Microsoft OneNote is used because it is user friendly, simple to learn, easy to access because it is a component of Microsoft Office, and it can be used in class with a tablet PC instead of PowerPoint. Thus, class presentation materials, homework assignments, exams, and instructor explanations are all included into one education suite. A new faculty member could simply open a section, become familiar with the topic (i.e., the learning goals, student misconceptions, areas of difficulty), and then use the class notes that utilize active learning methods. For example, a section for a given day includes pre-class reading questions, course notes to use in class (ConceptTests, explanations, diagrams, etc.), hyperlinks to online resources, additional ConceptTests, and suggested homework problems. Information for distribution to students is assembled so that it can be easily configured to post online. Since the notebooks are dynamic, they provide desired instructor flexibility [10]; faculty can easily customize them by removing or adding to the sections and pages, building assignments, and modifying what to present in class. Faculty can easily see materials used in previous courses and add or modify as desired. Older materials can simply be moved out of sight of the page (depending on the view/zoom). Additional sections on active learning and good teaching practices help frame the importance of these methods, and help explain to faculty the reasoning behind the proposed approach. A section on exams that contains 6-8 sample exams (with solutions) in a format such that individual questions can be compiled/configured/modified in order to create an original exam.

Figure 1 represents a screenshot of the notebook. This notebook is organized by popular textbook table of contents. The main layout is that of a binder with tabs and pages. A “Getting Started” tab contains pages on the project, a table of contents, resources on flipping classrooms and using ConceptTests, tutorials on using OneNote and the course package, and class materials (e.g., checklist, syllabus, schedule, and participation form). A “Resources” tab contains information and links to resources on active learning techniques, as well as suggestions and best practices for implementing these methods in the class. These two tabs are ubiquitous to any course and form the base template for faculty designing other courses using this package layout. The “Assessment” and “Chapter #” tabs contain relevant materials to the course, including homework problems and solutions, exam questions and solutions, class outlines with notes and ConceptTests, suggested readings and screencasts to assign prior to class, and learning outcomes for each topic.

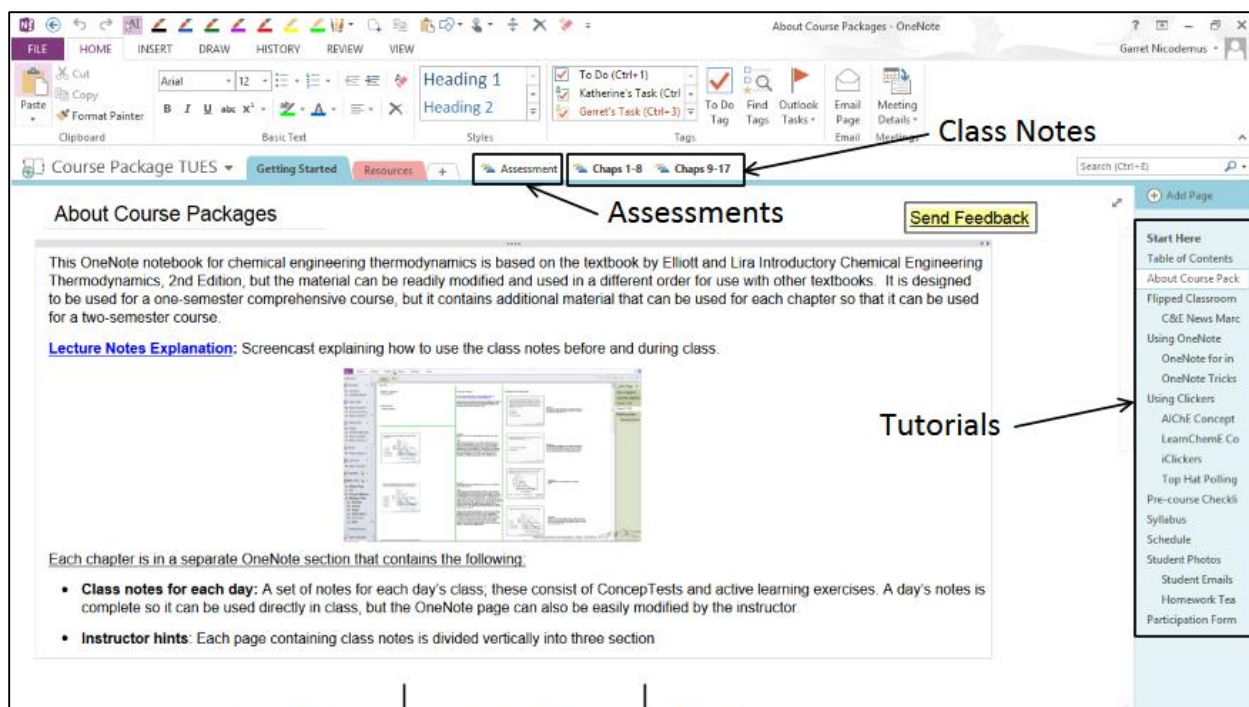


Figure 1. Example screenshot showing overview of information provided in each course notebook.

Part of the first day of class is dedicated to showing students the motivation for using ConcepTests and peer instruction in class. Note that although the course package includes a large variety of tools that can be used in instruction, instructors are able to tailor them to their own style. For example, although the resources provided will be sufficient to institute a true flipped classroom approach, instructors can personalize their notebooks to make only periodic use of active learning techniques. We expect that instructors who are new to active learning approaches may use a more modular approach as they gradually adopt new teaching practices.

Initial versions of the thermodynamics course were made available for faculty to use in fall 2013. This package contains the following:

- **Daily class notes:** A set of notes are included for each day; this consists of announcements, daily topics, ConcepTests, and active learning exercises. A day's notes are complete so they can be used directly in class, but the OneNote page can also be easily modified by the instructor.
- **Instructor hints:** On the right side of the class notes are explanations of each ConcepTest, including why an answer is correct and what might confuse students about wrong answers. Also included on the right side are suggested readings before class, suggested screencasts to watch, hints, and substitute ConcepTests. At the top of each page is a link to the AIChE Concept Warehouse [11], which has more than 2,000 ConcepTests for chemical engineering courses.
- **Chapter learning objectives:** These are of the form described by Felder [12] and indicate what students should be capable of doing after completing the chapter.
- **Hyperlink index (table of contents):** This index contains hyperlinks to pages in OneNote that are used often (e.g., course schedule, syllabus, grading scheme, student list, information for teaching assistant, resources on teaching styles, etc.).

- Screencasts: These YouTube screencasts can be used to provide a starting point for understanding the chapter and can be used to create flipped classrooms. They include introductions to topics and explanations of concepts that traditionally have been presented in class. They also include example problems worked out completely. Links, with descriptions of the screencasts, are provided on the appropriate OneNote pages. Note that these screencasts are short (average of 7 minutes) so that they focus on one aspect to minimize cognitive overload.
- Reading quizzes: These are questions that the students answer online *before class* to motivate them to read the assigned sections or watch the assigned screencasts. When students are motivated to prepare for class, class time can be used to help students with difficulties in the material, rather than presenting it for the first time. Quizzes also make the ConcepTests in class more effective, as the ConcepTests are based on material that students would have read or view prior to class. The reading quizzes are organized by textbook sections.
- Homework assignments: These are located under the assessment section and include suggested book problems as well as a variety of other problems with solutions. Distribution of the solutions will need to be controlled to make them useful. If the solutions become available to students, the assignments will be less effective.
- Sets of exams: As with the assignments, 5 or 6 sets of exams (exam #1, exam #2, final exam) and their solutions are included.
- Exam study guides: Detailed study guides related to the learning goals are included.
- Exam preparation: Some suggestions on preparing exams (so they are easier to grade, are of the appropriate length, and test the appropriate material) and preparing students to take exams are provided [13, 14].
- Suggested syllabus and schedule: This includes pages with suggested schedules, suggested grading scales, and course policies.

Why OneNote?

Microsoft OneNote is a powerful software program for improving faculty efficiency by providing a means to organize a large amount of information, but many faculty are not aware of it. It is a component of Microsoft Office and consists of digital notebooks that are divided into sections, and the sections are further divided into pages (and sub-pages). Text can be added to a OneNote page just like in a word processor, figures can be copied onto pages, files can be printed to them (or saved as icons that can be opened from the page), emails can be readily sent to them from Microsoft Outlook, handwritten text or figures can be added using a tablet PC, and links can be inserted to other OneNote pages, to web pages, or to files. A page can be essentially any length. Some advantages of OneNote include:

- It is easy to learn how to use; a recent book is useful for taking advantage of all its options [15].
- All text in the notebooks is searchable.
- Everything is saved automatically, and backup copies are created automatically.
- Moving between pages, sections, and notebooks is much faster than opening new Word, PowerPoint, or other files.

- Notebooks can be shared with others, and this can be much more efficient than email for working with graduate students, teaching assistants, or staff. It is an efficient method to delegate that is easy to follow up.
- Files are easily printed to OneNote; it shows up as a printer in the printer list.
- A new project is easily started by creating a new OneNote page.
- A OneNote page can be converted into a Word or PDF file or it can be directly e-mailed.
- Files, programs, or websites that are used repeatedly can be opened from OneNote by creating a link on an OneNote page. Opening a Word file that is used often is much faster from OneNote than searching through file folders and subfolders for the Word file.
- It can be viewed on PCs, iPads, and phones and synced between them. Mac users can access the notebook with an online browser or with the App for OneNote (limited capabilities).

OneNote is an excellent program to use with a tablet PC to present material in class instead of PowerPoint. Slides from a PowerPoint file can be printed to a OneNote page so that during class, handwritten notes, drawings, and calculations can be added to the page with a tablet pen. Blank space of any length can be readily inserted between slides. A page can be zoomed to focus on some aspect of a figure. The page, with all the notes added during class, is automatically saved and can be posted online after class as a PDF file.

Initial Feedback and Obtaining Access

A beta version of the thermodynamics course package was used by two faculty in Fall 2013. Feedback has been initially very positive. A new faculty at another institution who was teaching thermodynamics for the first time said: “I am so thankful that I had the thermo course package you developed. It certainly helped a lot! I have shared this with other faculty in my department and they are interested in it as well.” Other faculty have expressed their gratitude for the materials in helping them to design their course. Further assessments to collect faculty suggestions are being done to strengthen the collected materials.

Complete packages are posted online via a Microsoft SkyDrive account. Interested faculty can email us at learncheme@gmail.com to request access. The online notebook is read-only and needs to be copied to personal computers to have editing capabilities. Specific updates are highlighted by tabs and pages changing to **bold** to help users realize updates have been made. Registration also allows us to contact users for feedback. All ConcepTests and screencasts as well as more information regarding these resources can be found at www.learncheme.com.

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