Chemical Engineering Undergraduate Curriculum Reform, Development and Assessment: A “Strings” Approach

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In a time of rapid change, academic programs must experiment and evolve in order to keep pace with advances in knowledge, changes in professional practice, and shifting conditions in society. The need for responsive academic programs is particularly a concern in scientific and technological fields where the growth of knowledge is exponential. Three chemical engineering departments at Texas A&M University System are continuing their efforts to restructure their four-year undergraduate curricula to achieve four objectives. Students will be able to a) apply fundamental ideas in chemical engineering over a greatly expanded range of time and length scales; b) apply ChE fundamental ideas to emerging application areas; c) construct solutions for more complex, more open-ended synthesis tasks with greater facility; and d) transfer fundamentals and knowledge to novel challenges. Three major strategies for project implementation include (1) curriculum content reform and development; (2) integrated student assessment, and (3) faculty and student development initiatives. The two key strategies for curriculum content reform and development are (i) the process of reformulation of part of the curriculum using four course strings and (ii) construction of interlinked curriculum components. This paper will describe the process and implementation of the “strings” approach to curriculum reform and development and in particular to assessment.

The “strings” approach involves organizing undergraduate ChE courses into four course strings: (1) thermodynamics and kinetics; (2) emerging fundamentals and applications; (2) transport phenomena; and (4) systems design. Course string faculty committees formed address the following key issues: what must undergraduate engineers learn/accomplish in the course string to be successful throughout their academic career and in the next generation professional settings; what obstacles exist to providing the necessary educational experiences; and how can we effect change and what changes (integration) need to be made to an existing curriculum. Course string faculty committees hold regular meetings to address these questions. Strategies for implementation of course portfolios and integrated assessment of course objectives and outcomes in preparation for ABET review are also part of discussions by faculty committees. In the past academic year, the committee members redefined expectations of each course as well as educational goals of each course and measurable outcomes. The alignment of each course’s educational objectives and outcomes and expectations of courses from students was evaluated. Syllabi analysis provided invaluable information to enhance the alignment of the courses. The end-of-semester faculty and student evaluations provided direct and indirect feedback for assessment. The process, experiences, and findings will be presented.

Course String Processes

The renewed chemical engineering curriculum is intended to provide a unified, coherent, effective, and efficient learning experience for students. Curricular reform often flounders because there is no consensus about shortcomings or strengths in the current curriculum due to lack of empirical data. Even if everyone wants a change, the absence of commonly shared evaluation data makes it difficult to come to consensus about the direction the changes should take. The goal of the course strings is to provide evaluation and assessment data for the current curriculum so that faculty decision making is empirically based. To achieve the desired unity and coherence, the chemical engineering department initiated a process of reformulation as part of the curriculum using four course strings. Four explicit course strings are:

String 1 - Thermodynamics and Kinetics – This string is the heart of chemical science and fundamentals and includes material and energy balances course, the two thermodynamics courses and the kinetics course.

String 2 - Emerging Fundamentals and Applications – This string provides fundamentals and applications in emerging technologies.

String 3 – Transport – The transport string builds on the current classical fluid mechanics, heat transfer, and mass transfer unit operations approach but is reinforced by new and emerging applications.

String 4 - Process Systems Engineering – This string provides an integrated approach to process synthesis, integration, and multi objective optimization.

Course string faculty committees include faculty members whose research and teaching interests reflect one of the four course strings topics. Course string committees (CSC) address the following key issues:

- What do students need to know before coming to the courses in a course string? What are the input skills of students?
- What do you want students to get out of the courses in a course string? What is important for them to learn and retain, 2-3 years after the course (s) is/are over? What kind of thinking or application abilities do you want them to develop? What the students should be able to do? What are the output skills of students?
- How are we going to get students to desired outcomes?
- How do courses in a course string fit together?
- How are courses in a course string aligned?

Course string faculty committees function like curriculum and assessment subcommittees distributing the activities related to continuous improvement of the curriculum and assessment to the appropriate faculty. Course string committees meet several times throughout a semester to discuss curriculum design and enhancement activities. First of all, faculty members discuss overall learning objectives for a course string and then proceed with discussing input skills and learning outcomes for chemical engineering courses that are part of this or that string. Figure 1 shows a schematic picture of the process for String 1.

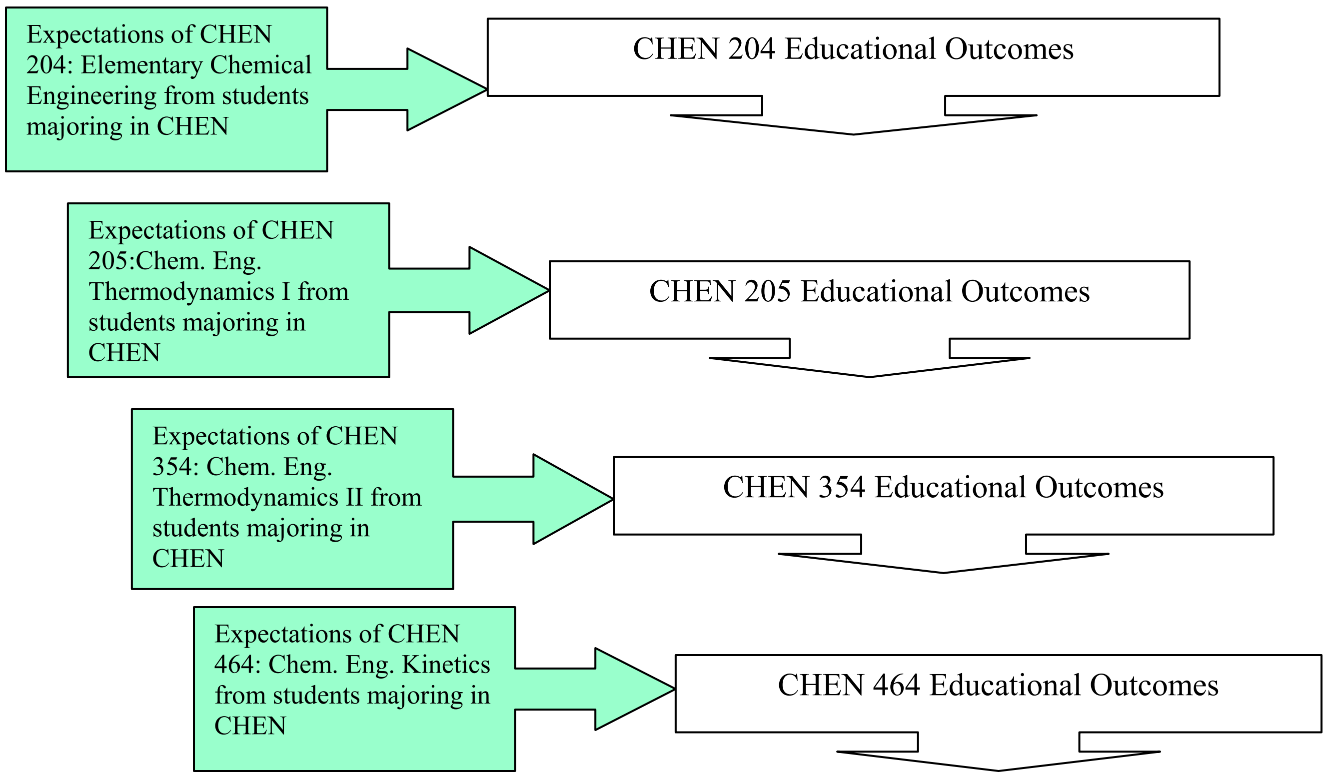

Figure 1. Thermodynamics and Kinetics Course String Input Skills and Educational Outcomes Process Flow Chart

Course string committee members define/redefine educational outcomes (intellectual content and students' skills/attributes) of each course. Faculty members discuss measurable outcomes and performance tasks following Bloom's taxonomy of educational objectives. The next step is to evaluate the alignment of each course's educational outcomes: curriculum mapping--linking each course outcomes to curriculum. CSCs identify where within the current curriculum our educational objectives and outcomes are addressed. The goals are (1) to connect what we are currently doing, whether all organizing principles are operative and move from simple to complex and (2) add new skills that are important.

Implementation

During Summer - Fall 2007 semesters CSCs met frequently to align each course content in a string, eliminate repetitious material, and add new material when it was necessary. CSCs established course string learning objectives and also defined input skills and educational outcomes for each course in a string. Most difficult step proved to be the removal of material from the content of a course to add new material. As originally proposed, thermodynamics and kinetics string was to be reduced to three courses from four current courses. Lengthy deliberations among the faculty showed the difficulty of actually removing the content material from the courses and the idea was not pursued eventually. New material was added in a few places but was decided to be done mostly by incorporation of Interlinked Curriculum Components (ICCs) (2). ICCs are Web-based resources for teaching and learning and contain relatively smaller material than a typical semester course. The scope of ICCs may range from molecular modeling to fundamental concepts such as conservation of mass. Currently, several ICCs are being constructed and tested for usability (1).

At the end of the Spring 2008 semester, the direct and indirect course assessment data were collected. The Department's annual assessment plan and the assessment instruments used may be viewed at http://www.che.tamu.edu/assessment/assessment-tools. Each course string committee evaluated the data and made a series of recommendations to the Departmental ABET Committee. Departmental committees and mode of operation are shown in Figure 2.

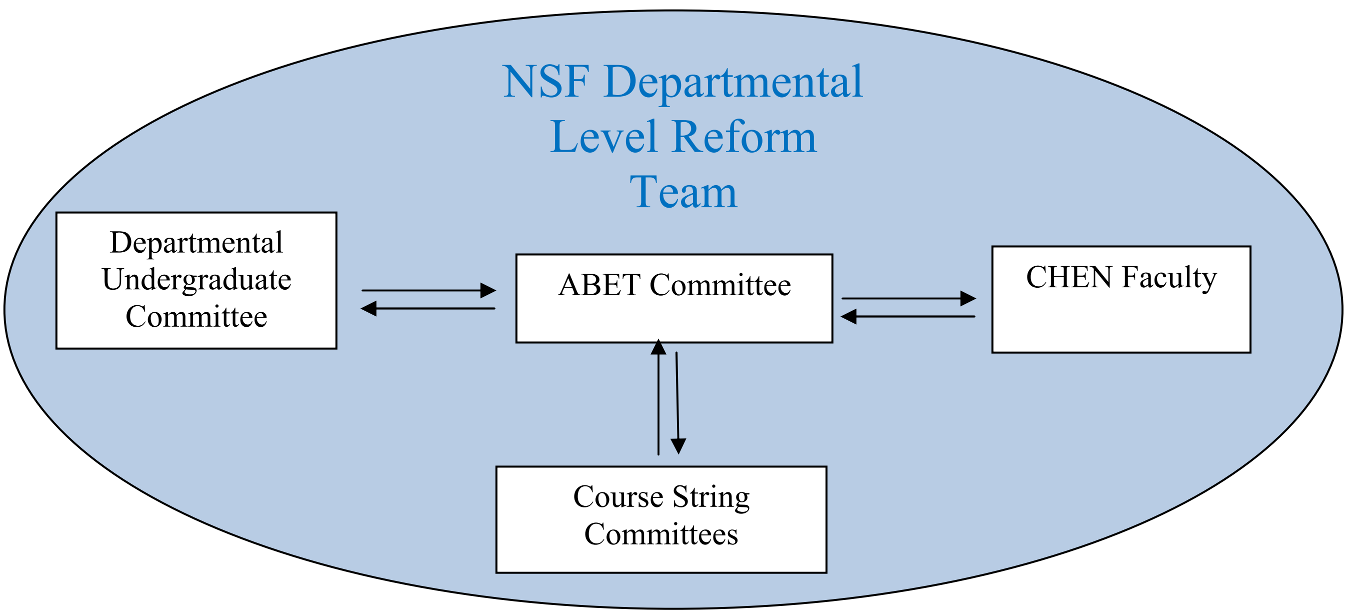

Figure 2. Departmental Committees and Mode of Interaction

Findings and Considerations

To achieve the goals of the "course string" process the faculty members first discussed overall learning objectives for a course string (e.g., Thermodynamics and Kinetics). Table 1 presents a brief example of a table that faculty members discussed and filled out together using the following assessment matrix key: "Introduced"- an objective is introduced in a class; "Emphasized"- an objective is emphasized in a class; "Utilized" - an objective is utilized in a class; and "Assessed" - an objective is comprehensively assessed in a class. The next step was to discuss how students at the department are doing against each expectation.

Table 1. Curriculum Assessment Matrix.

Course String 1 Learning Objectives	**CHEN 204**	**CHEN 205**	**…**	**Assessment**
1. Relate thermodynamics properties to observables.	Introduced	Introduced Emphasized Assessed		Meet Expectations
…	…	…	…	…

The following table provided a basis for discussing recommendations for courses and curriculum improvements. Some important recommended changes included:

1. Reinforce an important learning outcome related to demonstrating the ability to design experiments. As a result of this recommendation a Course Coordinator for a Numerical Methods course introduced this component to a course. Additionally, as part of assessing the students' ability to design experiments, Course Coordinators for this course and a Unit Ops Lab selected one of the experiments from a Lab class to use as a case study in Numerical Methods class.

2. Strengthen an important learning outcome related to statistically analyzing and interpreting data. The department is currently discussing an opportunity to develop such course as an elective to CHEN students.

3. Add an important task of writing technical memoranda to other team members as well as synthesizing a large project report in the form of an executive summary to a Plant Design Course.

4. Provide more feedback on students' speaking skills and create new assessment rubric for CHEN 481: Seminar.

5. Encourage individual instructors to provide examples to facilitate discussion of the ever-increasing interdependence of global economies and how societal issues impact the chemical engineering profession. Include a lecture on the topic of societal impact of technology, contemporary issues affecting chemical engineering and life-long learning to a Seminar course.

Department's ABET and Undergraduate Curriculum Program committees discuss all recommended changes and actions are taken to improve current curriculum.

Conclusions

This paper described a process and implementation of the “course strings” approach to curriculum reform and development and in particular to assessment. The “course strings” approach developed through DLR project would serve as a basis for a continuous process of reviewing and improving course learning outcomes at the department. Course string faculty committees will function as assessment and curriculum subcommittees and will provide important information for a program review and assessment processes.

References

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