# Embedded Content Assessment

Jacqueline Burgher
*School of Engineering*
*Campbell University*
Lillington, NC, USA
burgher@campbell.edu

Anastasia M Rynearson
*School of Engineering*
*Campbell University*
Lillington, NC, USA
amrynearson@campbell.edu

***Abstract*—This work-in-progress paper presents initial work in technical content assessment practices embedded into and integrated throughout the curriculum of a new engineering program. These practices range from program-level evaluation to combatting persistent misconceptions in foundational courses. Specific cases are presented from current practices and future work is described. The methods and considerations presented in this paper can be used as a model for other institutions looking to understand students' technical content knowledge beyond course-specific homework, exams, and other assessments.**

***Keywords—assessment, learning outcomes, conceptual change***

## I. Introduction

Assessments are a critical part of any educational effort, and embedding technical assessment throughout a four-year degree is an effective method to track progress of students. In the United States, ABET accreditation is the most formal and well-known assessment metric [1], followed by the NCEES FE exam [2] and for individual classes, exams and homeworks can be useful tools. Campbell University provides a unique place to embed assessment as it is developing a new program with faculty committed to employing evidence based practice throughout the curriculum. The initiation of a program allows high-level design, especially for elements of technical content. Year-to-year benchmarks are critical for successful ABET accreditation, and for internal review of what learning objectives are included in each class. Also of interest is the content learned in science and math classes, as these are tools engineers need to for student success in engineering courses. A framework and strategy is critical to effectively embed and weave assessment throughout the 4-year program.

Assessment can be used to reveal technical content misconceptions. Throughout engineering school, students are exposed to a great deal of conceptually difficult knowledge. Knowledge that is considered to be conceptually difficult is: abstract rather than concrete; continuous rather than discrete; dynamic rather than static; simultaneous rather than sequential; organicism rather than mechanism; interactiveness rather than separability; conditionality rather than universality; and nonlinearity rather than linearity [3 cf 4]. Engineering content knowledge often involves abstract, continuous, dynamic, simultaneous, interactive systems that may depend on specific conditions and involve nonlinearity. Students bring prior knowledge to their engineering studies and may pick up additional misconceptions throughout their studies, especially in content areas that are conceptually difficult. These misconceptions may be strong misconceptions that are difficult to displace. One of the best ways to combat a misconception is to expose students directly to their incorrect beliefs [5]. A persisting misconception inhibits student learning in subsequent courses because of their initial incorrect understanding of an idea.

## II. Background

### A. Assessment Framework

As a new program, it is critical for faculty to both initiate assessment efforts individually in courses and collectively across the program. To differentiate these efforts, we can use Terenzini's matrix of assessment (Fig. 1) to consider individual and aggregate assessment, the purpose of the assessment, and the object of the assessment [6].

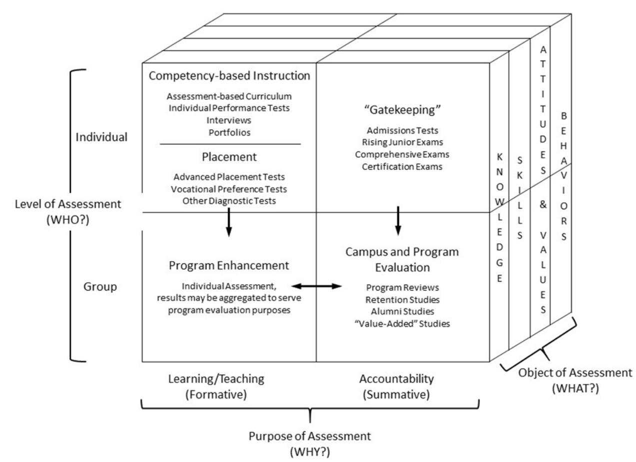



Fig. 1. A Taxonomy of Approaches to Assessment, adapted from [6].

All programs and faculty participate in assessment at a variety of levels. Faculty assessment of individual student knowledge and skills allows them to provide course grades for students (upper left quadrant in Fig. 1). These performance tests, projects, and portfolios feed into program-level evaluations of groups of students, including data like DFW rates (grades of D, F, or withdrawals, all considered subpar performance) and overall performance goals like those reported to ABET during accreditation (lower left quadrant in Fig. 1). These two assessment methods tend to be tied to formative assessment measures; students are able to improve their work habits in that course or subsequent course while ABET's continuous improvement criterion mandates that programs use the information gathered to improve their curricula. On the right-hand side of Fig. 1, summative assessments are found, those that generally do not allow for immediate improvement. Accreditation and exams like the NCEES FE exam [2] assess at the group and individual levels, respectively, providing (or not) a seal of approval for engineering programs or early career engineers in training. This engineering program assesses all aspects of the Terenzini's Taxonomy, including individual and group assessments, formative and summative assessments, and assessments of knowledge, skills, attitudes & values, and behaviors. The technical content assessments of this program focus on the knowledge and skills the undergraduate engineering students are expected to learn. Technical content is the knowledge and skills that are commonly assessed through examinations, presentations, and portfolios and does not include physical skills or values and beliefs. This work in progress paper focuses on the technical content knowledge aspects in particular.

In our efforts to integrate technical assessment throughout the curriculum, we are going to apply Terenzini's framework to describe the level, purpose, and object of assessments we use. Thus, levels of assessment across the four years will be both formative and summative, to inform us of the specific and broad ways in which we can enhance our program. In the methods below, we will go through several assessment strategies we are using across the curriculum and present a case study on utilization of the AIChE Concept Warehouse [7] to date.

### *B. Assessment and Student Learning*

Assessment is not strictly done to inform an instructor or to evaluate a course or program. Assessment can have an impact on student learning. One of the best ways for students to study is Retrieval Practice, a technique where students attempt to answer questions regarding the material instead of re-reading the textbook, their notes, or reviewing already-solved problems [8]. When testing is used as formative feedback, for example in quizzes, "clicker questions" where an entire class might vote on answers to a question in the course of a class period, or tests that include material they will see again in the future, students have the opportunity to learn from their mistakes and reinforce their knowledge of the material [8].

## III. METHODS AND RESULTS

In this section, the methods and results are presented together. The assessment methods currently employed are presented and case studies for existing data are given where appropriate.

### *A. High Level Assessment*

Assessment for ABET accreditation is arguably the most important high-level assessment done across the curriculum. Using Terenzini's framework [6], this assessment is done on a group level within the program evaluation space. This falls in the lower right hand corner of the matrix, indicating it is a summative type of assessment that broadly assesses skills and knowledge, a critical part of technical growth. As a School, we work on ABET assessment together, where each professor is accountable for pre-assigned assessment deliverables within the courses s/he teaches. Guided by a master matrix that links ABET EAC Criterion 3 outcomes A-K [1] to the courses we offer, professors know at the inception of the term the outcomes for which they need to report upon. This assessment process is premediated across the curriculum and before each individual semester in an effort to legitimize the new School to ABET standards.

Every year at our retreat we revisit assessment outcomes from each course. As a faculty, we decide if standards need to be more rigorous and report upon changes based on how students performed within the year. This aspect of ABET assessment likely shifts into the bottom left-hand corner of the matrix, whereby we form an assessment loop for program enhancement.

### *B. Midlevel Assessment*

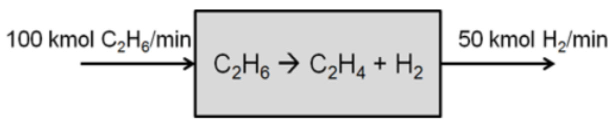
Midlevel assessment strategies center on concept inventories. Concept inventories are instruments used to evaluate student understanding of basic concepts. These instruments are typically multiple choice, do not require calculations, and have common incorrect questions to gauge true student understanding [9]. This evaluates courses and learning across a semester and focuses on individual assessment of students. To date, we have implemented the materials science concept inventory within the second-year course we offer. Professors have plans to utilize the transport and fluid mechanics concept inventories for assessment in third-year courses, which we will offer starting next fall of 2018. These assessment metrics are for internal review of the course and the learning objectives over the semester. Additionally, because each of the courses is uniquely designed with integrated laboratory equipment, passing information from one professor to the next is helpful in ensuring student exposure to labs and equipment.

### *C. Course Level Assessment (Case Study: AIChE Concept Warehouse)*

The final level of assessment is course-level throughout the semester. Periodically, checking in with student progress and misconceptions is important to offer more homework or tasks on a learning objective. This type of assessment also reveals any misconceptions students have from previous engineering, science, or math courses. These types of assessment fall within the upper left-hand corner of the matrix, showcasing individual assessment and competency.

Within the material and energy balance (MEB) course, the American Institution of Chemical Engineers (AIChE) Concept Warehouse [7] was utilized on a weekly basis to achieve a myriad of goals: help students work through example problems, assess baselines of student knowledge when introducing new topics, and combat misconceptions that may have been introduced during the MEB course. The example problems were useful in encouraging students to work together as teams and to give students more practice with immediate feedback on example problems. By the end of the semester, students were requesting concept warehouse questions in reference to specific concepts, indicating the students believed these questions helped them to better understand the material in the course.

In assessment of student knowledge from other courses, a problem focusing on conservation of moles was uniquely helpful. This problem titled “Moles Conserved in Reactor?” in Fig. 2, was given to students about 5 weeks into the course, as we were incorporating reactions into mass balances. Only 1/3 or 33% of students got the correct answer for this problem, a basic principle that they all should have learned in general chemistry. This data enabled the engineering department to have a discussion with the chemistry department about learning objectives in general chemistry, especially because long-term retention of basic concepts like conservation of moles were not retained. Follow-up data is not currently available and will be collected as part of future work.

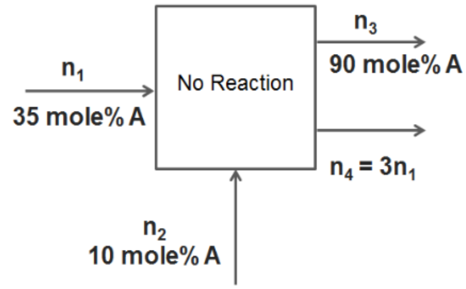



Are moles conserved in this process?

A) Yes
B) No

Fig. 2. AIChE Concept Warehouse problem titled, “Moles Conserved in Reactor?”

AIChE concept warehouse questions were also heavily utilized to combat misconceptions that students developed throughout the semester. On the second quiz (only quizzes were given in the course) one question asked students if a basis could be set for a system. We discussed this concept several times in class, and homework was given on the concept of a basis and when it is and is not appropriate to set one for a system. For the quiz problem, only 60% of students achieved the correct answer. To better communicate this concept, the problem titled “Mixer degrees of freedom II” shown in Fig. 3 on the AIChE concept warehouse page was administered to students. The first attempt yielded a correct answer of 40%. Since so few did well, we discussed how the problem should be solved, and after administering it again that same day, 90% of students achieved the correct answer. It is important to note that the answer was not given in our discussion, but we went over conceptually how to approach and think about the problem. This type of transformation only occurs when students are directly faced with their misconception [5]. Obviously, catering the AIChE concept warehouse questions to address student misconceptions, as indicated by quiz results or otherwise can be a useful tool in combat misconceptions.




A non-reactive, steady-state process is shown. If choosing a basis, it is ________. Every stream contains components A & B except stream 4 (only contains B).

A) Overspecified
B) Underspecified
C) Perfectly Specified
D) Impossible to determine

Fig. 3. AIChE concept warehouse question “Mixer degrees of Freedom II”

## IV. Conclusions

This work-in-progress paper discusses assessment as a critical part of any undergraduate engineering program. We focus one institution’s approach to assessment strategies. A framework categorizing the level, purpose, and object of assessment, focusing on knowledge and skills, was utilized to characterize the foci of our assessment efforts. By distinguishing between high, mid and course-level technical assessment we are able to strategically focus on different aspects and layers of assessment. These include strategies we use for ABET accreditation, the use of concept inventories in midlevel assessment, and the utility of the AIChE concept warehouse in course assessment. Another feature of the AIChE concept warehouse is the ability to assess baseline data of students enrolled in a course, fostering conversations between ourselves and the chemistry department regarding expected learning outcomes.

## V. Future Work

The use of concept questions to combat student misconceptions requires further study. Student responses to test questions after taking part in concept question interventions will be analyzed to see how well students have learned the concepts presented to them. Longitudinal study through the use of concept inventories or similar questions in subsequent courses will also be employed to understand how persistent the misconceptions may be and how well the interventions work.

Future work for assessment also includes embedding questions across the curriculum from old NCEES FE exams to track student understanding and retention of technical content. This longitudinal assessment of technical content will be embedded throughout the curriculum as a formative assessment for instructors in addition to tracking student responses across the curriculum. Concept inventories will be given to students in relevant courses as well as at later dates to explore the longitudinal effects of conceptual change and persistent misconceptions.

Results from these assessment methods will add to the literature regarding conceptual change and retention across an undergraduate engineering program. In addition, the aspects of embedded longitudinal technical content assessment that prove to be useful for student learning, instructor guidance, and program evaluation will be shared through publications and workshops. At this stage, few results are available, however publication and presentation of the current state and the goals of the program are important to gain feedback from the engineering education community to better guide the program and solicit feedback as to outcomes that are important to the engineering education community at large.

## REFERENCES


[1] ABET: Accreditation. [Online]. Available: http://www.abet.org/accreditation/,

[2] NCEES: Advancing licensure for engineers and surveyors: FE exam. [Online]. Available: https://ncees.org/engineering/fe/

[3] R. J. Spiro, R. L. Couson, and P. J. Feltovich, “Learning, teaching, and testing for complex conceptual understanding,” in Test theory for a new generation of tests, N. Frederiksen and I. Bejar, Eds. Mahwah, NJ: Lawrence Erlbaum, 1993, pp. 181-217.

[4] D. Perkins, “Work on the hard parts,” in *Making Learning Whole: How Seven Principles of Teaching can Transform Education*, San Franciso, CA, USA: Jossey-Bass, 2009, ch.2, pp. 79 - 108.

[5] G. J. Posner, K. A. Strike, P. W. Hewson and W. A. Gertzog, “Accommodation of a scientific conception: Toward a theory of conceptual change ,” *Science Ed.,* Vol. 66, no. 2, 1982.

[6] P. Terenzini, “Assessment with open eyes: Pitfalls in studying student outcomes,” *J. of Higher Ed,* Vol. 60, no. 6, 1989, doi:10.2307/1981946

[7] AIChE Education Division: Concept Warehouse [Online]. Available: http://jimi.cbee.oregonstate.edu/concept_warehouse/

[8] R. M. Felder and R. Brent, *Teaching and learning STEM: A practical guide.* San Francisco: Josesey-Bass, 2016.

[9] T. Reed-Rhoads and P.K. Imbrie, “Concept inventories in engineering education,” National Academy of Sciences [Online]. Available: https://sites.nationalacademies.org/cs/groups/dbassesite/documents/webpage/dbasse_072625.pdf