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Developing a Curriculum Mapping Tool for Outcome Integration and Accreditation Alignment

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Abstract

As chemical engineering programs respond to simultaneous demands for efficiency, accountability, and continuous improvement, maintaining a coherent and well-documented curriculum has become increasingly complex. Frequent changes in faculty teaching assignments, institutional efforts to streamline degree programs to 120 total credit hours, and the convergence of multiple external review processes—from ABET accreditation to regional and state-level accountability reviews—have created new pressures on departments to clearly demonstrate where and how students achieve program outcomes.

In response, our department undertook a comprehensive effort to trace learning outcomes throughout the entire chemical engineering undergraduate curriculum and construct a dynamic curriculum map linking courses, performance indicators, and evidence of student learning. Each course's learning outcomes were aligned to program-specific performance indicators derived from ABET outcomes (1–7), tagged according to Introduce–Reinforce–Master milestones, and connected to signature assignments using common rubrics. The resulting map reveals how disciplinary and professional skills progress across the curriculum, identifies gaps and redundancies, and provides a unified foundation for multi-agency reporting.

Beyond meeting accreditation requirements, this mapping process has supported curricular renewal, promoted transparency among faculty, and ensured that core competencies are developed intentionally even as course assignments and institutional structures evolve. This paper presents the mapping framework, tools, and lessons learned, offering a replicable approach for programs seeking to integrate continuous improvement with broader institutional accountability.

Introduction

Chemical engineering programs continuously balance the tension between expanding technical content and the constraints of efficiency and accountability. As the profession evolves to include sustainable engineering, biological processes, and computational tools, curricula must adapt without exceeding strict credit-hour limits (typically 120 hours) mandated by state and institutional policies [1,2]. Simultaneously, the demand for transparent accountability has intensified. Engineering departments are no longer answering to a single stakeholder; they are navigating a complex web of requirements from specialized accreditors like ABET, regional bodies such as the Northwest Commission on Colleges and Universities (NWCCU), and state-level oversight systems [3].

Maintaining a coherent curriculum amidst these pressures is increasingly difficult. As faculty teaching assignments rotate and specialized electives are added or removed, courses often become 'siloed,' with learning outcomes functioning as isolated checklists rather than interconnected developmental milestones [4]. This fragmentation poses a risk to student learning, particularly in the development of professional skills (ABET Student Outcomes 4 through 7) which rely on repeated practice and reinforcement across multiple semesters [5]. Without a systemic view, gaps in the curriculum can go unnoticed until an external review cycle exposes them or even provides unintentional redundancies.

The administrative burden of reporting to multiple agencies often leads to duplicative assessment efforts. For many departments, the ‘continuous improvement’ processes required for ABET accreditation (Criterion 4) are treated as distinct from the learning outcome assessments required by regional bodies or state system governing boards. This separation is inefficient and often results in ‘assessment fatigue’ among faculty [6]. There is a critical need for integrated frameworks that can map a single set of student performance data to multiple reporting standards, ensuring that data collection serves the dual purpose of satisfying external reviewers and genuinely informing curricular renewal.

This paper presents a comprehensive curriculum mapping framework developed by the Department of Chemical Engineering to address these challenges. Moving beyond static spreadsheets, we constructed a dynamic map that aligns course-level learning outcomes with program-level performance indicators using an ‘Introduce-Reinforce-Master’ (IRM) taxonomy. By linking these outcomes to ‘signature assignments’ with common rubrics, the department created a unified foundation for multi-agency reporting. This approach not only streamlined the accreditation process but also fostered greater transparency among faculty regarding the vertical integration of technical and professional skills throughout the degree program.

Methodology

This study utilized a comprehensive dataset encompassing every required technical course within the Chemical Engineering undergraduate curriculum. To ensure the curriculum map reflected the current instructional state, course learning outcomes (LOs) were extracted directly from the most recent syllabi, drawing from the Spring 2025 and Fall 2025 semesters. Each LO served as a fundamental unit of analysis. To characterize cognitive expectations, LOs were categorized using Bloom’s Taxonomy, assigning an integer level to quantify the depth of student understanding required. To connect course-level pedagogy to accreditation requirements, each LO was also coded with a set of binary indicators corresponding to the seven ABET Student Outcomes. This structure enabled calculation of an “ABET distribution” for each course, representing the proportion of outcomes aligned with accreditation criteria relative to discipline-specific technical content.

To manage and maintain curriculum information in a format that was both transparent and collaboratively editable, all learning outcomes and metadata were stored in a shared Google Sheets spreadsheet. One sheet contained course-level learning outcomes for each core course, identified by university course number and catalog title. Additional columns captured Bloom’s level, ABET outcome associations, and the intended semester placement within the four-year degree plan. To support finer-grained temporal alignment across co-requisite courses, additional sheets were created for selected courses to document learning outcomes at the resolution of individual class meeting periods (weekly lectures, discussions, or laboratories). Only two courses were mapped at this level of detail in the current implementation.

Each learning outcome was assigned an abbreviated title and a unique identifier autogenerated from the course number, Bloom’s level, and abbreviated text. Dependencies among outcomes were encoded through a “Support” field, listing the identifiers of prerequisite or reinforcing outcomes from earlier courses or earlier points within the same course. To promote consistency in outcome formulation, a separate reference sheet of Bloom's Taxonomy verbs—categorized by level—was included and implemented as a dropdown menu for faculty entering or revising learning outcomes.

Following classification and data structuring, learning outcomes were visualized as nodes within a curriculum network. Links between nodes were established using the encoded support relationships and reviewed against the four-year degree plan to preserve the intended curricular sequence. Sequential progression was prioritized over direct leaps; for example, recurring concepts such as mass and energy balances were mapped through successive introduction, reinforcement, and mastery stages rather than linking early exposure directly to advanced applications.

All sheets were published as public CSV files to enable automated ingestion by a custom-built interactive visualization tool. Using OpenAI's large language model (ChatGPT, version 5.2), an interactive website was developed to render the curriculum-wide network and, where applicable, detailed course-level subgraphs. Users may explore outcome dependencies through force-directed layouts or constrain node placement by semester or instructional week to visualize temporal alignment. Search and filtering functions allow highlighting by Bloom's level, course, or specific class periods. Nodes are color-coded by Bloom's Taxonomy level, scaled by the number of dependent outcomes, and annotated with directional arrows indicating prerequisite relationships. Hover interactions reveal detailed outcome descriptions and their supporting and supported-by connections.

During implementation, substantial variability in learning outcome specificity across courses was identified. Some syllabi listed dozens of narrowly defined technical outcomes, while others articulated only a few broad goals. Additionally, professional competencies such as teamwork, design, and communication—often embedded in project-based activities—were frequently implicit rather than explicitly stated.

Results and Discussion

The curriculum mapping process identified a total of 211 unique learning outcomes across the required technical core courses. As expected for a rigorous engineering program, the distribution was heavily skewed toward technical competency. ABET Outcome 1 (Engineering Problems) was the dominant focus, accounting for 64% of all mapped outcomes (136 out of 211). In contrast, professional skills appeared less frequently in the explicit syllabus text. Outcomes 3 (Communication), 4 (Ethics), and 5 (Teamwork) each represented approximately 6–8% of the total outcomes. Notably, Outcome 7 (Acquire and Apply New Knowledge) was the least represented, with only two explicit occurrences across the entire core curriculum, suggesting that while lifelong learning may be implicit in many assignments, it is rarely codified as a measurable syllabus outcome. These data are shown in Table 1 and Figure 1.

Table 1 Global Frequency of ABET Student Outcomes

ABET Student Outcome	Count	Percentage (%)
1. Engineering Problems	136	64.5%
2. Design	24	11.4%
3. Communication	16	7.6%

4. Ethics	13	6.2%
5. Teamwork	16	7.6%
6. Experimentation	28	13.3%
7. Acquire New Knowledge	2	0.9%

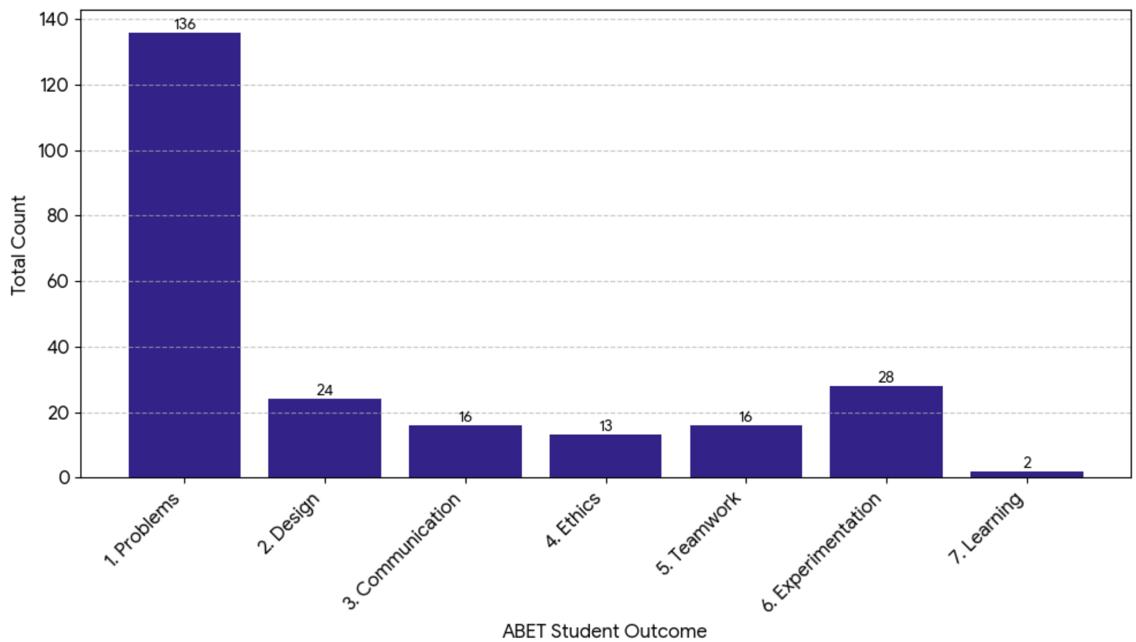

Figure 1: Total frequency of ABET Outcomes in the core curriculum.

When analyzing the outcomes by year level, a distinct "hollow middle" emerged regarding professional skills (Outcomes 2–5) and shown in Figure 2 and supported by data displayed in Table 2. The introductory courses in the first year (1000-level) provided a broad exposure to the profession, touching on design, ethics, and experimentation. The curriculum narrowed significantly in the Sophomore year (2000-level) to focus on fundamental technical derivations. Of the 63 outcomes mapped to sophomore courses (e.g., Mass & Energy Balances, Thermodynamics), 60 were linked to Outcome 1. During this year, explicit outcomes for Design (Outcome 2), Communication (Outcome 3), and Teamwork (Outcome 5) dropped to zero in the official syllabi.

Professional skills re-emerged strongly in the junior and senior years (3000+). The third-year curriculum introduced significant laboratory work, accounting for 50% of the program's total Experimentation (Outcome 6) milestones. The fourth-year culminated in a resurgence of Design (Outcome 2) and Teamwork (Outcome 5), driven largely by the capstone sequence.

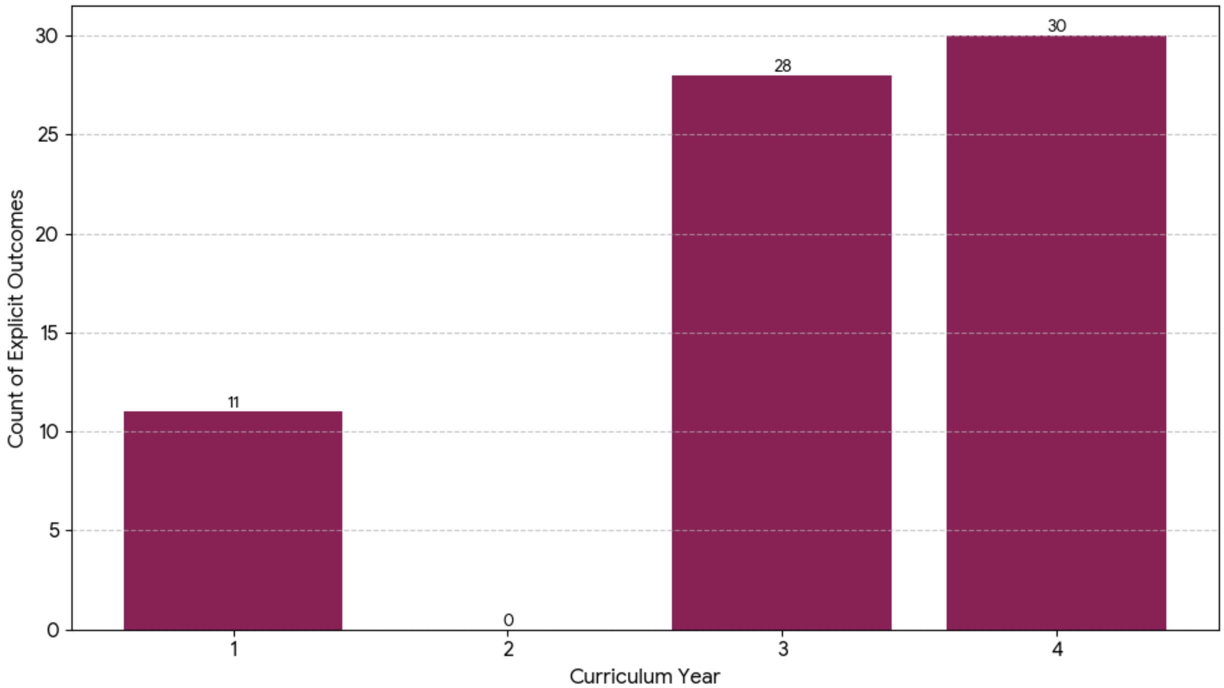

Figure 2: Distribution of professional skills (ABET 2-5) by year.

Table 2: Distribution of Outcomes by Curriculum Year

Year	1. Problems	2. Design	3. Comms	4. Ethics	5. Teamwork	6. Exper.	7. Learning
Year 1	8	5	1	3	2	6	0
Year 2	60	0	0	0	0	2	1
Year 3	50	6	10	6	6	14	0
Year 4	18	13	5	4	8	6	1

The mapping process also quantified the inconsistency in how faculty define learning. Course-level granularity ranged widely: some courses, such as Numerical Methods (CH EN 2450), provided highly detailed lists of over 20 specific technical competencies. In contrast, other core courses like Mass Transfer and Separations (CH EN 3603) summarized the entire semester's goals in as few as three broad outcome statements. These data from core courses are shown in Table 3. This variance highlights that while the coverage of ABET topics may be adequate, the documentation style varies significantly between instructors, potentially obscuring where specific skills are assessed.

Table 3: Granularity of Learning Outcomes by Course

Course No.	Course Title	LO Count
1703	Introduction to Chemical Engineering	13
1705	Chemical Engineering Design & Innovation	15
2300	Thermodynamics I	14
2450	Numerical Methods	23
2550	Statistics for Chemical Engineers	15

Course No.	Course Title	LO Count
2800	Fundamentals of Process Engineering	9
3253	Chemical Process Safety	10
3353	Fluid Mechanics	9
3453	Heat Transfer	15
3553	Chemical Reaction Engineering	10
3603	Mass Transfer and Separations	3
3701	Project Lab I	12
3702	Project Lab II	11
3853	Thermodynamics II	6
4203	Process Control	9
4253	Process Design I	10
4701	Control Lab	6
4706	Chemical Capstone I	16
4707	Chemical Capstone II	5

These data are connected via dependencies to produce a network as shown in Figure 3. Here, the courses are connected via topics that higher level courses build upon. One example is that variance and confidence intervals are taught in sophomore-level Statistics (2550); these fundamentals are then applied in junior-level projects lab courses (3701 and 3702). The colors in the graph correspond to the six levels of Bloom's Taxonomy. The inconsistencies mentioned above in learning outcome determination necessitate additional work in aligning core courses with accreditation criteria. Work includes standardizing the granularity of outcomes and taking an objective view of what needs to be taught in each class. While this is already happening at the instructor level, it needs to be performed at the department level to benefit our students and optimize effort of faculty.

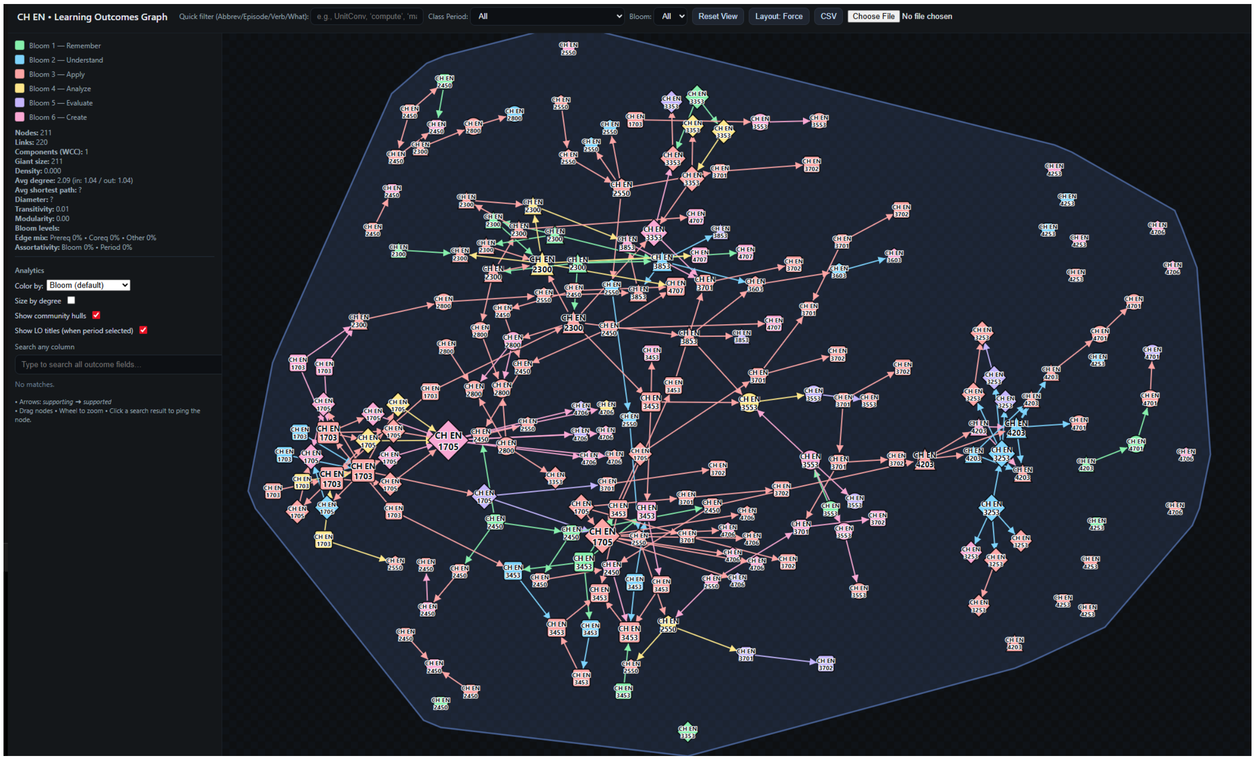

Figure 3: Screen grab of nodal network dependencies.

Conclusion

As engineering programs navigate the convergence of credit-hour constraints and increasing accountability demands, the need for integrated curriculum management has never been greater. This study demonstrated that a systematic mapping process—moving beyond static checklists to a dynamic, node-based network—can effectively reveal the structural reality of a curriculum.

Our analysis of the Chemical Engineering core highlighted two critical insights. First, the curriculum possesses a robust technical backbone, with over 60% of learning outcomes dedicated to engineering problem-solving (ABET Outcome 1). Second, the mapping exposed a "sophomore gap" in professional skill development, where explicit instruction in design, ethics, and teamwork vanishes during the intensive fundamental coursework of the second year. Identifying this gap allows the department to intervene strategically, not by adding new courses, but by threading professional milestones into existing sophomore technical assignments.

Ultimately, this framework offers a replicable model for other engineering departments. By standardizing outcome granularity and visualizing curricular progression, programs can transform accreditation from a periodic compliance burden into a continuous driver of pedagogical coherence and student success.

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