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Weaving Hands-On Learning Throughout the Chemical Engineering Curriculum: 10 Years of Continuous Improvement

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Abstract

Campbell University is an undergraduate-focused, Baptist-heritage, liberal arts school of opportunity that serves its local rural North Carolina community in the shadow of NC State. Ten years ago, Campbell started a School of Engineering to diversify offerings and meet the needs of the local manufacturing and pharmaceutical industry. Chemical Engineering was one of the first two concentrations offered in this general degree program. Campbell's philosophy has been to focus on evidence-based best practices in engineering to offer opportunities to underserved populations, including rural, first-generation, and mathematically underprepared students. Hands-on active learning is at the core of what Campbell offers, and the curriculum in the Chemical Engineering concentration has incorporated multiple projects and activities in our innovative Class-Lab offerings beyond what is often seen in traditional engineering programs. Experiential learning promotes student success for all students, particularly for underprepared and underrepresented students. Campbell has infused the curriculum with experiential learning opportunities, leveraging best practices to create industry-ready students that are highly sought after by employers. The purpose of this paper is to share the curriculum development of the chemical engineering concentration during the first ten years of an engineering program in a small, rural, teaching-focused liberal arts institution. This paper is a retrospective look at the development of the curriculum and how the hands-on projects are integrated throughout the entire program. Student surveys, ABET course evaluations, and comparison of curriculum will be shared to support the faculty narrative describing the development of the current version of the hands-on curriculum. Student success metrics are also provided, including internship and employment statistics and FE exam passing rates. Hands-on projects support student learning and have evolved over the years based on student feedback and evaluations. The current curriculum features hands-on projects across the years, with later classes building upon the skills learned in prerequisite courses. The evolution of these methods has supported the Campbell University School of Engineering student population, graduating high-quality students who are well prepared for their future careers. A high-quality hands-on education should be continuously evolving to provide quality education for all students. Infusing active learning throughout the curriculum can promote industry-ready students at all levels, including small, liberal-arts focused institutions. Even new programs that have been designed with best practices in mind can benefit from continuous improvement to better serve their students, future employers, and community.

Introduction

This paper presents a retrospective case study of the first ten years of a Chemical /Pharmaceutical (CHPH) Engineering concentration within a general Bachelor of Science in Engineering program at a small, rural, teaching-focused liberal arts institution [1]. The program was established to serve regional industry needs while expanding access to engineering education for rural, first-generation, and academically underprepared students. From its inception, the curriculum emphasized hands-on, experiential learning as a core pedagogical strategy. As the program matured, faculty engaged in continuous improvement utilizing various feedback mechanisms, including a Community of Practice to discuss best practices and challenges, peer observation feedback, student input, ABET assessment processes, institutional constraints, and external influences such as the KEEN Entrepreneurial Mindset framework and the COVID-19 pandemic. This paper documents how hands-on projects were introduced, refined, scaffolded, and in some cases removed, to better align with learning objectives and student capacity.

The sections that follow describe the institutional context and retrospective methodology used to examine curricular evolution, followed by reflective case examples. These cases are used not to catalog activities, but to highlight design decisions and lessons that informed ongoing curricular improvement, which can be used for future growth [2].

Background and Institutional Context

The CHPH concentration operates within a general engineering degree structure. This model affords flexibility but requires careful curricular coordination to ensure students develop disciplinary depth while meeting accreditation and institutional requirements. Class sizes are capped at approximately 24 students, and contact hours exceed those of many peer institutions, creating opportunities for close faculty-student interaction and intensive project-based learning. The vision and design of the program is to integrate best practices of engineering education into undergraduate engineering education, with the goal of producing students with both excellent technical and hands-on expertise by graduation. Faculty are charged with preparing students to pass the FE exam and graduate with professional skills that would mirror a second-year postgraduate.

Methodology

This study employs a retrospective case study methodology to examine the first ten years of curricular development within a CHPH concentration housed in a general engineering program. Because the program did not initially collect data for research purposes, this analysis reconstructs program evolution using existing documentation and reflective accounts rather than prospectively designed instruments. This approach aligns with retrospective case study methods described in [1], which emphasize synthesizing multiple data sources to develop a detailed understanding of a bounded educational context [2].

Data sources include faculty reflective narratives, curriculum maps, ABET course evaluation summaries, course artifacts (e.g., syllabi, project descriptions, rubrics, and representative student work), limited grade distributions used to contextualize curricular changes, demographic data, alumni perspectives, and selected public-facing documentation [3-5]. All materials were anonymized, and specific calendar years were omitted to protect participants in a small-program setting. Use of these materials was approved by IRB #1005.

Not all data were subjected to formal analysis; some are presented descriptively to support narrative reconstruction. Where appropriate, additional analysis strengthened interpretation. Narrative analysis involved retrospective reconstruction of curricular evolution through synthesis of meeting notes, course documents, and institutional records to identify key decision points and design inflection moments. Basic numerical analysis includes reporting percentages and percent change over time to contextualize enrollment, graduation, and selected assessment trends. Thematic analysis of faculty reflections involved reviewing written responses to shared prompts, identifying recurring patterns related to scaffolding, workload calibration, and conceptual continuity, and collaboratively constructing interpretive summaries of emergent themes.

Given the program's small size and reflective data sources, findings are presented as context-bound insights rather than generalizable claims (limited by recall bias and restricted quantitative numbers, etc.). The intent is not causal inference but documentation of design decisions and lessons learned that may inform other new or developing engineering programs.

Demographics

School Demographics are provided in Tables 1 and 2 for both enrollment and graduating cohorts across the first ten years of the program. The engineering program developed incrementally, with mechanical engineering initially comprising the majority of students while chemical and electrical engineering cohorts emerged and stabilized over time. Because the department operates as a small, general engineering program within a teaching-focused institution, yearly fluctuations in percentages partly reflect cohort-size effects, but structural shifts in curricular intent occurs.

Table 1. Total Engineering Student Population at Campbell University

	% of students by concentration within Engineering				% of Engineering students by concentration or combined within the University				
Year	ChE	ME	EE	EMS	ChE	ME	EE	EMS	All Engineering
1	16	84	-	-	0.3	1.6	-	-	2.0
2	17	83	-	-	0.5	2.2	-	-	2.6
3	16	75	9	-	0.6	3.0	0.4	-	3.9
4	15	72	12	-	0.8	3.8	0.6	-	5.2
5	13	68	18	-	0.7	3.5	0.9	-	5.1
6	16	62	22	-	0.9	3.3	1.1	-	5.3
7	11	70	19	-	0.5	3.5	0.9	-	5.0
8	9	68	23	-	0.5	3.6	1.2	-	5.3
9	13	59	27	1	0.7	3.4	1.6	0.1	5.9
10	13	51	25	11	0.8	3.1	1.6	0.7	6.1

Table 2. First Six Years of Engineering Graduates from the School of Engineering

	% of Graduates by Engineering Concentration				% of Graduates per total of all Institution Graduates				
Year	ChE	ME	EE	EMS	ChE	ME	EE	EMS	All Engineering
1	24	76	-	-	0.8	2.5	-	-	3.4
2	7	74	19	-	0.2	2.2	0.6	-	3.0
3	14	66	20	-	0.7	3.2	1.0	-	4.8
4	19	70	11	-	0.7	2.5	0.4	-	3.6
5	7	70	23	-	0.3	2.7	0.9	-	3.9
6	19	48	26	7	0.7	1.8	1.0	0.3	3.8

Curricular Development and Evolution

Hands-on learning is embedded throughout the curriculum but varies in form and intensity by course and academic year [6-11]. The bookend years include shared engineering courses that all concentrations take. This discussion of curricular evolution is specific to the CHPH concentration. The first course students take specific to CHPH is first-semester sophomore year. Early iterations of the middle and final year CHPH curriculum included a high density of open-ended projects, which students reported as overwhelming. In response, faculty added constraints, scaffolding, and better rubrics to modify the projects.

As a general engineering Bachelor of Science degree with concentrations, the school was very intentional of designing the curriculum to serve the community and target industries. The Southeastern region is considered one of the faster growing pharmaceutical and biotechnology hubs in the United States [12]. The original curriculum included courses with labs in bioprocessing, biology, and pharmaceutical areas (10 total credits). Several major adjustments occurred over time, including curriculum mapping to improve sequencing, and redistribution of projects to align with student readiness. Utilizing input from students on course loads, sequences in the curriculum were adjusted to account for difficulty and project intensity. This included debates on required credits for the degree which were initially set at 136 but subsequently reduced to 132 after much discussion, curriculum mapping, and baseline studies looking at similar programs (see Appendix A for overall curriculum maps). Course hours, institutional requirements, pre-requisite and co-requisite courses all had to be carefully balanced.

Particular attention was given to the Thermodynamics–Fluids–Heat Transport sequence. Faculty observed students often struggled to transfer core ideas related to control volumes, energy balances, and transport mechanisms across courses. In response, learning objectives and project timing were revisited to emphasize conceptual continuity. Foundational concepts (i.e. energy balance) were mapped and reinforced throughout the sequence to improve outcomes and were connected to external sources such as Learn ChemE [13] and Concept Warehouse [14]. Low-cost desktop learning modules and short, targeted hands-on activities were introduced to reinforce connections without increasing overall project load, allowing students to build confidence before encountering more open-ended design challenges [15-16].

Community of Practice

A faculty Community of Practice (CoP) serves as an ongoing mechanism for reflective improvement in the curriculum. The group meets regularly to examine teaching through a shared, practitioner-focused lens rather than a formal assessment structure. Meetings include discussion of selected pedagogical literature, rotating facilitation of topics of interest, and peer observations of teaching followed by structured feedback conversations. Faculty also present areas of disciplinary expertise when challenging situations arise in coursework (e.g. difficult concepts, engagement barriers, or unexpected student misconceptions), allowing the group to collaboratively generate instructional responses. The CoP additionally functions as a space for testing course modifications before implementation; instructors present planned changes and receive formative feedback grounded in both experience and educational research. Participation is further reinforced through engagement with KEEN-related professional development, including on-campus workshops and small internal mini-grants that support experimentation with entrepreneurial-mindset activities. Collectively, the CoP shifts improvement efforts from isolated individual refinement to a shared, iterative design process, embedding reflection and pedagogical risk-taking into routine departmental practice.

ABET and Course Assessments

ABET assessment processes were systematically integrated into curricular oversight through formal mapping of ABET student outcomes to course-level learning objectives, assignments, and performance indicators [5]. Prior to each semester, faculty conducted a structured pre-semester review of the previous course assessment report, including documented recommendations from both the course instructor and an independent faculty evaluator. Identified gaps, target thresholds, and areas of concern were addressed through planned instructional adjustments. At the conclusion of the semester, outcome data were analyzed to determine whether performance benchmarks were achieved, and findings were documented within the continuous improvement record. This closed-loop assessment cycle ensured alignment with ABET accreditation requirements while supporting evidence-based curricular refinement. Additional ABET sessions were conducted at faculty retreats if structural issues were encountered.

Curricular Philosophy and Design Intent

From its inception, the CHPH concentration was designed as a living curriculum rather than a fixed sequence of courses. Faculty intentionally viewed curricular decisions as provisional, expecting that early implementations would require revision as students, institutional realities, and external forces revealed misalignments. This reflective posture shaped decisions about project density, scaffolding, and the balance between conceptual rigor and experiential depth, and connecting to relevant industry in the local economy.

Hands-on learning was never intended to be additive; instead, projects were meant to replace traditional homework, lectures, or laboratory exercises. Early iterations revealed that this replacement model required careful calibration to avoid cognitive overload, particularly for students still developing mathematical fluency and engineering identity. This became evident from interviewing students who changed disciplines, which is partly seen in Table 2 and the reduction in percent of CHPH students graduating in the department.

Reflection on Project Density and Scaffolding

Faculty reflections indicate that early enthusiasm for experiential learning led to an overabundance of open-ended projects within individual courses and across semesters. Students frequently reported feeling overwhelmed, describing difficulty in discerning which skills or concepts were most essential. These responses prompted faculty to step back and engage in curriculum mapping exercises to intentionally distribute project complexity across the four-year experience. It also allowed faculty to map the growth of students in professional skills like tolerance of ambiguity, able to solve open-ended problems, question generation in light of incomplete information, and teaming.

One recurring lesson was the necessity of scaffolding—not only within individual projects but across courses. Projects that assumed prior tacit knowledge often disadvantaged students encountering engineering ways of thinking for the first time. Subsequent iterations incorporated explicit modeling, intermediate checkpoints, and reflective prompts to support student sense-making.

Course-Level Case Examples as Reflective Evidence

Rather than cataloging all hands-on activities, this paper highlights several signature projects that served as reflective anchors for curricular improvement. Starting with two reflective case studies, the narrative describes how the learnings from these experiences translated to other courses and improved outcomes across the curriculum. These projects functioned as diagnostic tools, revealing both student learning gains and structural weaknesses in the curriculum.

The following course-level cases are presented as reflective evidence rather than exhaustive descriptions. Each example highlights how hands-on learning surfaced misalignments between instructional intent, student readiness, and curricular sequencing, and how those observations informed subsequent design decisions.

Case 1: Heat Transport

Heat Transport provides a prime example of the genesis of integrating hands-on projects. From early experiences, faculty members observed that students had difficulty grasping certain concepts such as radiation. An initial project required students to quantify the amount of heat transferred through the three mechanisms of conduction, convection and radiation. To improve student engagement, the project was modified to include a 'hook' to get students more engaged by providing a scenario and to focus on value creation through testing protypes based on value creation. Prototype testing and modification was required, as was documenting and modeling the heat transfer. Teams were directed to brainstorm for specific values based on identified stakeholders, for which they then gave a pitch to a group of actual entrepreneurs and business owners. The faculty observed anecdotal evidence of improved student engagement and improvement in scores. However, project time constraints required curriculum content realignment. A major issue was initial project implementation did not provide sufficient scaffolding to direct students on effective time management and prototype testing. Scaffolding requirements were modified to provide more specific deliverables to help teams progress in a more timely manner in subsequent years. The project replaced textbook assignments on radiation, but students were provided with examples of radiation calculations to help guide them in their self-directed learning and model development for the summary paper. Greater detail and results are provided in [18]. It became apparent from student feedback, though, that the demands of a second project with heat exchangers created too many time constraints. Initially, the heat exchanger project was modified and simplified. However, in consulting with alumni, industry and other faculty, ultimately the hands-on radiation project was removed from the two-credit course due to the need to emphasize heat exchangers.

Case 2: Thermal-Fluids Sequence

The Thermodynamics–Fluids–Heat Transport sequence became a focal point for reflective curricular refinement within the concentration. Prior to eligibility for ABET accreditation, students were strongly encouraged to take the discipline-specific FE exam, supported by a one-credit senior FE preparation course. Early FE performance data identified thermal–fluids topics as a relative weakness for CHPH students, prompting faculty reflection on conceptual continuity, disciplinary emphasis, and course sequencing. This was paired with anecdotal student evidence that the shared thermodynamics course was a repeat of content from Material and Energy Balances (MEB).

Faculty analysis revealed several structural misalignments related to the shared nature of core engineering courses across concentrations. See Table 3 for course sequencing. While overlap between MEB and Thermodynamics provided reinforcement for most CHPH students, it also contributed to redundancy while leaving gaps in areas such as equilibrium, mixing, and chemically contextualized thermodynamics and fluids concepts. These gaps were particularly salient given that Thermodynamics and Fluids were taught from predominantly mechanical engineering perspectives, and the mechanical and electrical students had no preparation for Thermodynamics from a course like MEB as seen in Appendix A. The result was a thermodynamics course that did not fully overlap with the energy balance portion of MEB and omitted important course content on multi-component mixing and gaseous systems necessary for chemical engineers. After some casual discussions between faculty, it was recognized that while MEB was not a prerequisite for thermodynamics, the CHPH faculty identified that course as an important part of the CHPH thermal-fluids sequence while the EE and ME faculty did not.

Table 3: Curriculum Table for the Thermo-Fluids Sequence for the CHPH concentration

Course	Typical CHPH Sequencing	Pre-Requisite Course
CHPH 215: Material and Energy Balance	First semester sophomore year	MATH 122, CHEM 113, ENGR 121
ENGR 310: Thermodynamics	First semester junior year	PHYS251, CALC II or III, CHEM 111
ENGR 320: Fluids	Second semester junior year	MATH 310, PHYS251, ENGR 220, ENGR 310,
CHPH 325: Heat Transfer	Second semester junior year	ENGR 310, Co-req ENGR 320, MATH 337

In response, relevant thermal-fluids faculty engaged in a stakeholder-informed review of learning objectives and benchmarks from comparable programs of nearby engineering schools, while maintaining a unique emphasis on a chemical/pharmaceutical concentration. Supported by professional development through the KEEN Leadership Unleashed workshop [17], modest but targeted adjustments were implemented, most notably the intentional integration of equilibrium and mixing concepts into the thermodynamics course. Constrained by the general engineering degree structure which required a shared thermodynamics course for students with different levels of energy balance preparation from the various concentrations (chemical vs. electrical and mechanical) as well as the number of credit hours the CHPH concentration gives to the pharmaceutical emphasis, this refinement improved conceptual continuity across the thermal–fluids sequence. While incremental in scope, the inclusion of content specific to chemical engineering was viewed as a meaningful gain that strengthened coherence without increasing overall curricular load. [17-21]

Course Development Cases

In addition to these two case studies, improvements have been made in other CHPH concentration specific courses. Hands-on learning across the curriculum did not emerge through a linear increase in project complexity, but rather through iterative cycles of implementation, observation, and adjustment. Instructors reflected on student performance, cognitive overload, ambiguity tolerance, and skill gaps, leading to course-specific refinements. Some courses reduced project scope in response to content density, while others increased scaffolding to support experimental design and open-ended problem solving. Across the curriculum, these adjustments reveal a shift from adding projects to intentionally designing structured progression in student readiness for ambiguity, experimentation, and ownership. Major lessons and revisions are documented in Table 4 and described briefly below. These changes (not reflective case studies) are provided to document changes in the curriculum over time. These may inform other new or developing programs seeking to balance rigor, access, and experiential depth.

Table 4. Evolution of Hands-On Learning Across the Curriculum

Course	Year	Hands-On Focus	Observed Challenge	Reflective Adjustment
Material & Energy Balances	Sophomore	Structured group work	Content load	More assessment; no projects
Thermodynamics	Sophomore / Junior	Mini-Adventures	Concept transfer	Added reflection prompts
Mass Transport	Junior	Stripping column	Problem Ambiguity; concept transfer	Added planning scaffolds
Reaction Engineering	Junior	Reaction characterization of reaction order and activation energy	Experimental design, data analysis	Mastery-based exp designs, training on Excel in a different course
Heat Transport	Junior	Radiative design challenge	Time management / concept transfer	Milestone deliverables
Process Control	Senior	Theory integration to control output project	Content load, theory integration	Added small Arduino control units for curriculum content and added project
Unit Operations	Senior	Experimental development for data collection and verification	Fragmented theory integration and uneven accountability	Transition to hypothesis driven experimentation

Course 1: Material and Energy Balance

This course started out using Felder and Rousseau's text Elementary Principles of Chemical Processes and the notes with gaps [22]. Over time, hands-on projects on large units were added and removed, as were team paper projects. Now using Libertore's zyBook (chapters 1-7) [23], this class focuses on completing deadlines (homework is due every class day), regular assessments (9 quizzes and 3 tests and a final are given each semester), and no projects. The course has also shifted from 3 contact hours to 4 contacts hours (maintaining 3 credit hours) to give students more time to work together on problems.

Course 2: Thermodynamics

Thermodynamics, serving both Mechanical and CHPH concentrations, originally relied heavily on Moran and Shapiro's Fundamentals of Engineering Thermodynamics and textbook problem solving. To promote conceptual transfer, the instructor introduced applied laboratory experiences. Students collect temperature and pressure data and perform regressions to estimate absolute temperature. Additional labs focus on thermodynamic cycles, with Stirling engines used for demonstration. Entrepreneurial mindset assignments, such as "Endless Matches- The Thermodynamics of Reusable Matches, [20]" and "Bee-pocalypse In the Tundra: Help Save The Bees [21]," introduced open-ended application contexts. Reflection revealed that students struggled to articulate connections between theory and application. In response, structured reflection prompts were added to explicitly guide conceptual integration. The course now balances applied experience with intentional metacognitive framing.

Course 3: Mass Transport

The hands-on project in this course is designing, building, and testing a stripping column to remove CO_2 from seltzer water. Over time, the instructor has purchased packing (not requiring students to make it) and added intense scaffolding. The project starts with both in-class design of absorption columns on paper, making flowcharts to understand the design process, and shifting textbook problems to Excel. When the project is introduced, little additional scaffolding is needed because students have the background and the electronic Excel sheet to design the column. They need to figure out how to modify their existing resources for design. One day in class is dedicated to going to Lowe's for students to purchase materials for building (and modifying calculated values to match the constraints of pipe diameters and length available). They are also given a budget for parts which requires planning before purchase. Students build and test their columns, culminating in a demo and oral exam where the two CHPH instructors pepper the students with questions about why their experimental results do or do not match theory.

Course 4: Reaction Engineering

A fundamental part of this class has been a project where students must identify the reaction order and activation energy by developing an experimental design, performing experiments, and analyzing data. Within the class, the instructor now has clear deadlines and gives feedback on experimental designs (students are not cleared to go into the lab until they have successfully completed – mastery-based completion). The project requires all individual experimental designs, group experiments, individual data analysis, and group posters. After observing student difficulty with data analysis in Microsoft Excel, the instructor has added extensive Excel training in the ENGR 300: Engineering Economics course which is required for all students.

Course 5: Process Control

Process Control initially included a hands-on bioreactor PID project. However, student feedback and performance indicated that insufficient scaffolding and modeling foundation made the project overly ambitious. The curriculum was revised to include temperature control laboratories and structured Simulink modeling prior to engaging in more complex PID design. This staged progression improved conceptual readiness while preserving experiential objectives. The course now reflects intentional sequencing rather than immediate immersion in complexity.

Course 6: Unit Operations

Unit Operations was developed to address curricular gaps arising from heavy pharmaceutical emphasis in other courses. Initially structured as a laboratory experience, the course revealed fragmentation between theory and application and teaming. In response, oral examinations were introduced to strengthen individual accountability within teams. Subsequently, the course transitioned from a traditional lab to a design-focused format. Students formulate a hypothesis, design a procedure to test it, and present an oral validation of their experience. This evolution reflects the broader curricular shift toward hypothesis-driven engineering design, structured ambiguity, and accountability.

External Influences and Unique Circumstances

The COVID-19 pandemic significantly disrupted hands-on instruction, requiring rapid adaptation to remote simulations, videos, and modular learning tools. While suboptimal, these adaptations reinforced the importance of flexibility and community. For such a new program to experience the challenges of COVID on the program, from academically underprepared students, to re-engaging students, to learning and adapting to students coming in with significant gaps, changes had to be made. Ideas were often processed prior to implementation through the Community of Practice, as were post assessments of new techniques and sequences introduced into the curriculum. The COVID-19 pandemic served as an unplanned stress test for the program's hands-on pedagogical model. Courses reliant on physical experimentation were forced to pivot to simulations, videos, and modular learning objects. While faculty widely agreed these substitutions were inferior to in-person experiences, the transition surfaced previously unexamined assumptions about what students truly needed from hands-on work. Notably, the disruption highlighted the value of community that had been built across the different grades and concentrations. Students who remained engaged often cited instructor presence, flexibility, and reflective assignments as critical supports, reinforcing the importance of affective dimensions of learning alongside technical skill development.

The KEEN Entrepreneurial Mindset (EM) framework influenced the integration of reflection, value creation, and open-ended problem solving utilizing best practice hand-on and project-based pedagogy. Course engagement utilizing techniques such as reflective questions, small reaction art projects, and open-ended questions/problems have been peppered throughout the curriculum. For example, in courses such as Thermodynamics and Heat Transport, faculty-developed "Mini-Adventures" and projects emphasized curiosity, connections, and societal impact. Mini-Adventures are designed so that the activity can be implemented into a curriculum to engage specific learning objectives and subject matter. Mini-Adventures range from trying to save honeybees in Alaska through heat transfer, to implementing matchless (infinite) fire starters using the ideal gas law, to trying to freeze water using radiation when temperatures are above freezing. Student engagement varied, from obnoxiously engaged to uncertain on how to proceed with a problem that doesn't have any clear or singular solution. Overall, instructors observed greater involvement in discussions and class participation. Greater detail can be found in Engineering Unleashed cards [18-21, 24].

Consistent with observations from other small, agile engineering programs, the rapid pivot highlighted the value of established faculty trust, informal communication channels, and a shared commitment to compassionate flexibility. Faculty relied on frequent, low-barrier collaboration to redesign activities within new constraints while intentionally minimizing students' cognitive and technological overload. These practices not only supported continuity during emergency remote instruction but also informed longer-term instructional norms related to communication, flexibility, and inclusive engagement. Taken together, these course-level cases illustrate how hands-on projects functioned as diagnostic tools, revealing where conceptual continuity, scaffolding, or workload calibration required adjustment across the curriculum.

Findings and Reflections

Hands-on projects enhanced student engagement and preparedness but required careful calibration. Faculty reflections highlight the importance of scaffolding, alignment with learning objectives, and responsiveness to student feedback. Not all aspirational integrations—such as full lecture-lab synchronization—were fully realized.

Implications for New and Developing Programs

The experiences documented in this case study suggest that hands-on curricula should be approached as iterative design problems rather than static solutions. New and developing programs may benefit from intentionally building reflection, feedback, and revision cycles into curricular governance structures.

Importantly, this work acknowledges areas where aspirations remain unmet, such as fully integrated lecture-laboratory experiences across all courses. Recognizing these gaps has proven productive, guiding future experimentation rather than signaling failure.

Conclusions

This narrative reflects the evolution of a small, hands-on, project-based engineering program in the Southeast US, specific to the chemical/pharmaceutical concentration where students earn a BS in engineering. Starting in 2016, this program has made many adjustments, particularly in light of COVID-19, the influence of the KEEN network, and evolving curricular needs and addressing perceived gaps. Bedrock elements of the program include a regular teaching community of practice, ABET course assessments, and initial vision of the program to include best practices of undergraduate engineering education. Reflective case studies showcase detailed changes in both the second-semester junior level heat transfer course and the first-semester junior level thermodynamics course. Heat transfer adjusted to improve student interest and include more elements of entrepreneurial mindset. The shared thermodynamics course with the mechanical and electrical concentrations has also adjusted content to better serve the CHPH concentration. Certainly, the constraints of the concentration with shared core engineering courses taught by faculty not trained as chemical engineers has created challenges for the curricular elements of the program. Primary lessons learned include shared understanding between faculty of expected outcomes (of which alignment is challenging) and lack of scaffolding on open-ended projects. Over time, adjustments have been made to most chemical concentration courses. This narrative does show that high-quality hands-on engineering education must evolve continuously. Small, teaching-focused institutions can successfully implement experiential curricula when supported by intentional design, assessment, and reflection. Lessons from this program may inform other new or developing engineering programs.

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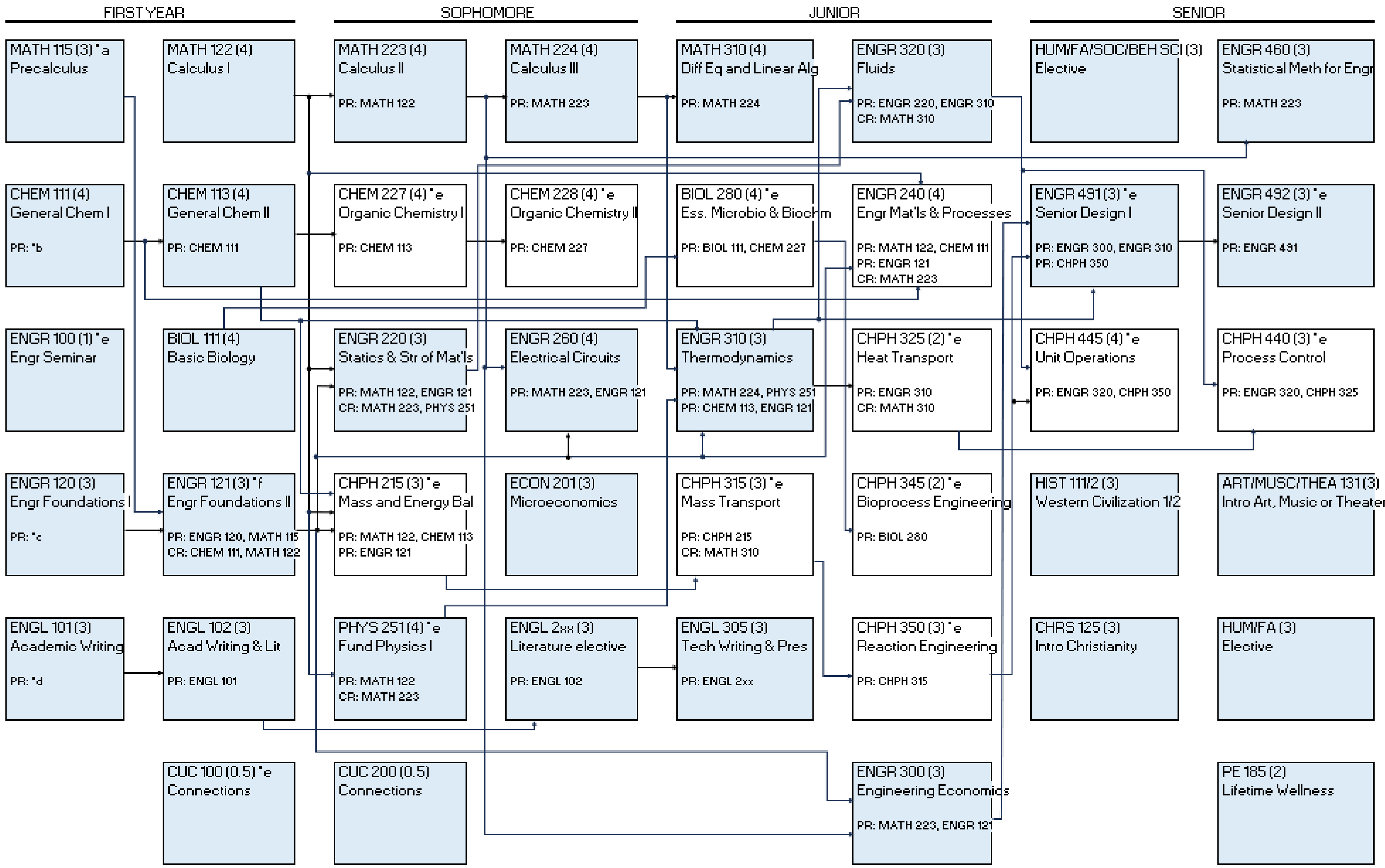
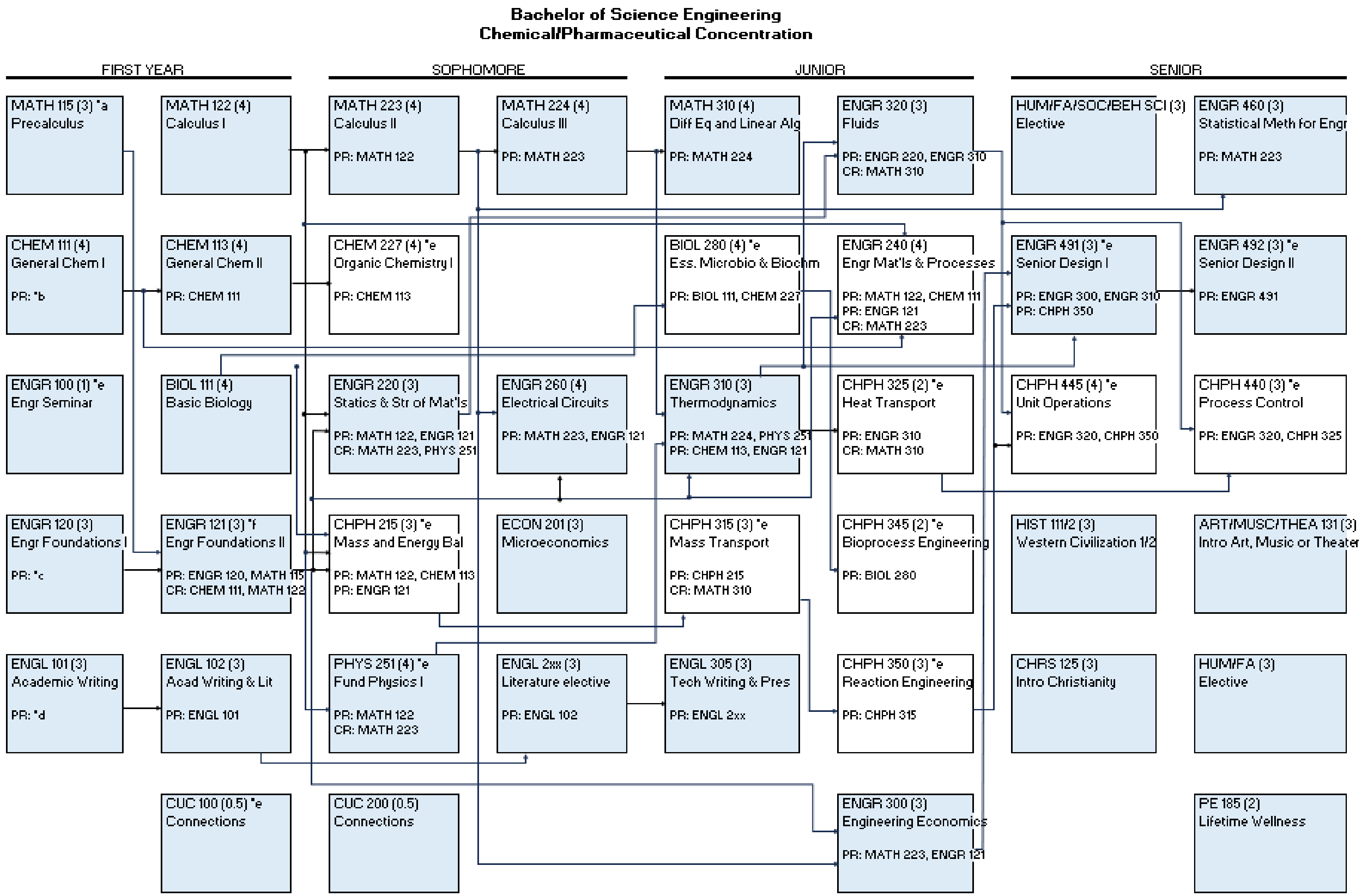
Appendix A

A1.1 Old Degree Flowchart

Bachelor of Science Engineering
Chemical/Pharmaceutical Concentration



A1.2 Revised Degree Flowchart



A2.1

Freshman Fall Semester			**Freshman Spring Semester**		
MATH 115	Precalculus	3	MATH 122	Calculus I	4
ENGR 100	**Freshman Seminar**	**1**	BIOL 111	Basic Biology & Lab	4
ENGR 120	**Foundations of Engineering Design I**	**3**	**ENGR 121**	**Foundations of Engineering Design II**	**3**
ENGL 101	Academic Writing	3	ENGL 102	Academic Writing & Literature	3
CHEM 111	General Chemistry I	4	CHEM 113	General Chemistry II	4
			CUC 100	Connections	0.5
	Semester Total:	**14.0**		**Semester Total:**	**18.5**

Sophomore Fall Semester			**Sophomore Spring Semester**		
MATH 223	Calculus II	4	MATH 224	Calculus III	4
PHYS 251	Fundamentals of Physics I	4	**ENGR 260**	**Electrical Circuits**	**4**
ENGR 220	**Statics & Strength of Materials**	**3**	CHEM 228	Organic Chemistry II	4
CHPH 215	**Mass and Energy Balances**	**3**	ECON 201	Microeconomics	3
CHEM 227	Organic Chemistry I	4	ENGL 2xx	Literature	3
CUC 200	Connections	0.5			
	Semester Total:	**18.5**		**Semester Total:**	**18.0**

Junior Fall Semester			**Junior Spring Semester**		
MATH 310	Differential Equations and Linear Algebra	4	**ENGR 320**	**Fluids**	**3**
BIOL 280	Essentials of Microbiology and Biochemistry	4	**ENGR 240**	**Engineering Materials & Processes**	**4**
ENGR 310	**Thermodynamics**	**3**	**CHPH 325**	**Heat Transport**	**2**
ENGL 305	Technical Writing and Presentations	3	**CHPH 345**	**Bioprocess Engineering**	**2**
CHPH 315	**Mass Transport**	**3**	**CHPH 350**	**Reaction Engineering**	**3**
			ENGR 300	**Engineering Economics**	**3**
	Semester Total:	**17.0**		**Semester Total:**	**17.0**

Senior Fall Semester			**Senior Spring Semester**		
CHPH 440	**Process Control**	**3**	**ENGR 492**	**Senior Design II**	**3**
HIST 111 or 112	Western Civilization I or II	3	**ENGR 460**	**Statistical Methods for Engineers**	**3**
ENGR 491	**Senior Design I**	**3**	HUM/FINE ARTS or SOC/BEH SCI	Elective	3
CHPH 445	**Unit Operations**	**4**	ART 131, MUSIC 131 or THEA 131	Fine Arts	3
CHRS 125	Introduction to Christianity	3	PE 185	Lifetime Wellness	2
			HUM/FINE ARTS	Elective	3
	Semester Total:	**16.0**		**Semester Total:**	**17.0**
				Degree Total	**136**

A2.2

Freshman Fall Semester			Freshman Spring Semester		
MATH 115	Precalculus (f,sp)	3	MATH 122	Calculus I (any)	4
ENGR 100	**Freshman Seminar* (f)**	**1**			
ENGR 120	**Foundations of Engineering Design I* (f,sp)**	**3**	**ENGR 121**	**Foundations of Engineering Design II* (sp,su)**	**3**
ENGL 101	Academic Writing (all)	3	ENGL 102	Academic Writing & Lit. (any)	3
CHEM 111	General Chemistry I (any)	4	CHEM 113	General Chemistry II (any)	4
			CUC 100	Connections (sp)	0.5
	Semester Total:	**14.0**		**Semester Total:**	**14.5**

Sophomore Fall Semester			Sophomore Spring Semester		
MATH 223	Calculus II (f,sp)	4	MATH 224	Calculus III (f,sp)	4
PHYS 251	Fundamentals of Physics I (f)	4	**ENGR 260**	**Electrical Circuits* (f,sp)**	**4**
ENGR 220	**Statics & Strength of Materials (f,sp)**	**3**	BIOL 111	Basic Biology & Lab (any)	4
CHPH 215	**Mass and Energy Bal. (f)**	**3**	ECON 201	Microeconomics (any)	3
CHEM 227	Organic Chemistry I (f)	4	ENGL 2xx	Literature (any)	3
CUC 200	Connections (f)	0.5			
	Semester Total:	**18.5**		**Semester Total:**	**18.0**

Junior Fall Semester			Junior Spring Semester		
MATH 310	Differential Equations and Linear Algebra (f,sp)	4	**ENGR 320**	**Fluids* (f,sp)**	**3**
BIOL 280	Essentials of Microbiology and Biochemistry* (f)	4	**ENGR 240**	**Engineering Materials & Processes* (f,sp)**	**4**
ENGR 310	**Thermodynamics* (f,sp)**	**3**	**CHPH 325**	**Heat Transport* (sp)**	**2**
ENGL 305	Technical Writing and Presentations (f,sp)	3	**CHPH 345**	**Bioprocess Engineering* (sp)**	**2**
CHPH 315	**Mass Transport* (f)**	**3**	**CHPH 350**	**Reaction Engineering* (sp)**	**3**
			ENGR 300	**Engineering Economics (f,sp)**	**3**
	Semester Total:	**17.0**		**Semester Total:**	**17.0**

Senior Fall Semester			Senior Spring Semester		
ENGR 491	**Senior Design I (f)**	**3**	**ENGR 492**	**Senior Design II (sp)**	**3**
CHPH 445	**Unit Operations* (f)**	**4**	**ENGR 460**	**Statistical Methods for Engineers (f,sp)**	**3**
HIST 111 or 112	Western Civilization I or II (any)	3	**CHPH 440**	**Process Control (sp)**	**3**
HUM/FINE ARTS or SOC/BEH SCI	Elective (any)	3	ART 131, MUSIC 131 or THEA 131	Fine Arts (any)	3
CHRS 125	Intro. to Christianity (any)	3	PE 185	Lifetime Wellness (any)	2
			HUM/FINE ARTS	Elective (any)	3
	Semester Total:	**16.0**		**Semester Total:**	**17.0**
				Degree Total	**132**