

# THE DESIGN AND ANATOMY OF A FIRST-YEAR CONNECTION COURSE FOR CHEMICAL ENGINEERING STUDENTS

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## INTRODUCTION AND PEDAGOGICAL THEORY

It is imperative for us as chemical engineering educators to ensure that our students develop a thorough understanding of the profession, i.e. the breakdown of the profession, from the very start of their educational endeavor. Studies have shown that first-year students become more successful “when they perceive relevant connections between what they’re learning in college and their current life or future goals.”<sup>[1-2]</sup> In general, student success in terms of retention, progression, and graduation is a major point of concern for educators, and engineering disciplines, including chemical engineering, are not excepted. Salim, Wagner, and Finley<sup>[3]</sup> submit that retention is a critical issue for their chemical engineering program and present the case of a two-course introductory sequence for chemical engineering students and its dramatic effect on retention at Tri-State University. The authors report that first-year retention in their program “jumped from 44 percent three years ago to approximately 80 percent the past two years.”<sup>[3]</sup>

In that regard, numerous studies have shown the importance of the first-year experience and its impact on student success and completion. In fact, Noel et al.<sup>[2]</sup> have identified the critical period for establishing one-to-one contact between students and their professors and advisors to be the first few weeks of the freshman year.<sup>[2]</sup> The authors submit that students will be more likely to persist to graduation when the instruction is individualized and cultivates relevant knowledge.<sup>[2]</sup> Upcraft et al.<sup>[4]</sup> stress the importance of connecting students to institutions in order to enhance retention and student success and make the argument that an institution’s people can make that happen. They submit that those who come in contact with first-year students have the ability to create a positive environment conducive to learning.

For engineering students who often do not begin their curriculum until the second semester of their sophomore year,

such connections can be made with the very first semester of their college experience by placing them within the department of their major discipline. This association with the home department provides them with a stronger sense of belonging as they get to know their faculty, staff, and peers and learn about many opportunities that are available to them for engagement in campus life beyond just attending their classes.

Other studies have shown that social integration in the form of “connections between the student and members of the college community peers, faculty, staff and administrators”<sup>[1, 5-8]</sup> also contribute to student retention and success. Conversely, isolation or estrangement may result in student attrition. In fact, Astin<sup>[5]</sup> suggests that students who frequently interact with faculty are more likely to be satisfied with their college experience compared to other students. Bruffee<sup>[6]</sup> presents an entire chapter on the subject of peer tutoring and institutional change. Johnson et al.<sup>[7]</sup> argue that a cooperative college structure begins in the classroom: they advocate teaching students the leadership, decision-making, communication, trust-building, and conflict-resolution skills needed in order to perform effectively within cooperative learning groups. Tinto<sup>[8]</sup> asserts that student persistence and learning are shaped

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by all aspects of the first-year experience. As such, the student's first encounter with the institution is an important and influential factor in the student's persistence.

Recognizing the importance of such early connection to the discipline and home-department faculty, Tennessee Tech's Chemical Engineering Department created a first-year "connection" course that combines the elements of the university's common course for all first-year students with additional knowledge about the discipline itself while providing information about the services that the department and the college can offer to make them more successful. Arce and Visco have described the genesis of the course.<sup>[9]</sup>

## METHODOLOGY

Drawing on decades of teaching and interactions with students that have culminated in the belief that students should develop a thorough understanding of the scope of the profession before becoming immersed deeply in the technical aspects of its knowledge, the author has made changes to an already successful course to further enhance its impact. The changes were based on extensive available literature emphasizing the importance of the first-year experience and its impact on student success. The course objectives are to help students:

- develop a better understanding of their chosen profession
- become more successful in terms of retention, progression to degree, and graduation
- become more engaged in campus life
- take advantage of high impact practices and programs that are available to them, such as undergraduate research, service learning, study abroad, and internship programs
- learn "soft skills," such as teamwork, presentations and technical writing
- exercise their creativity to formulate solutions to some of the technical challenges that the chemical industry is facing.

In this paper, we assess the success of the course based upon chemical engineering student progression from the freshman year to the sophomore year. The retention data is provided through the university's Office of Institutional Research.

## ABOUT THE COURSE

The course is one-credit hour that meets twice per week and is offered during the first semester of the freshman year. It is a mandatory requirement for all first-year chemical engineering majors. As of late, approximately seventy students register

for the available sections of the course.

The class instruction begins with a continuation of the university's orientation program and further clarifies the functions of the various university offices, student success centers, chemical engineering curriculum, registration process, accessibility issues, library services, and career preparedness opportunities. Students learn about the educational value of high-impact practices, such as study abroad, undergraduate research, service learning, co-op and internship, and participation in learning villages. Also, chemical engineering faculty members are invited to give short presentations about the courses they teach and their research interests.

This course has a mandatory attendance requirement and, in addition to class attendance, students are required to attend several fine arts and cultural events that they can choose from a menu of approved campus events. They also have to complete online training programs, such as Title IX training, and are asked to do small projects as teams, present the results, and submit reports with the objectives of helping them to get to know their peers through teamwork, polish their technical writing abilities, and improve their oral presentation skills.

During the first meeting, students are asked about the reasons and motivations that enticed them to select chemical engineering as a major. The answers are not surprising: being good/interested in chemistry and math, recommendation of a parent or relative, or advice from a teacher or high school counselor. Many of them state they like the high degree of versatility that the chemical engineering discipline offers them after graduation in the sense that they can continue their education in many areas or work within a very wide variety of businesses and organizations.

The next question posed to the class is, "Based on your interest and knowledge of the field, describe what chemical engineers do on a day-to-day basis." The responses to this question become most interesting and surprising in a very positive way. In fact, some of the answers are informed, intelligent, and impressive, which is a credit to the contemporary generation of youth. While students are mostly aware of the general responsibilities of a chemical engineer, they are also eager to learn about the vast horizon of possibilities that they might face and the choices that they might have once they graduate.

To assist them with that understanding, a three-phase project is constructed that requires coordinated teamwork as well as research and creativity. The class is divided into several teams, and each team has to choose a particular segment of chemical industry or a relevant chemical technology, e.g. applications of blockchain technology in the chemical industry, as the subject of their research work. To aid with the selection process, a rather comprehensive list is provided to them with some background information about each industry or technology, but they can also choose other

relevant industries or technologies not included on the list. Each team selects a team leader who identifies a timeline for completion of tasks and assigns responsibilities to team members. The leadership responsibility rotates every two weeks among the team members.

**Phase I** - During the first phase of this project, students spend much of their time researching the particular industry/technology that they have selected. During the special designated sessions of the class, the instructor joins each team and listens to their discussions, coaches and guides them when they need help, and answers their questions. The students are also provided a minimum number of questions that they must answer, to the best of their ability, regarding the industry sector that they have selected. Table 1 illustrates the type of information that is shared with the students in the course syllabus.

Once the first phase of the project is completed, around the fifth week of the semester, each team has to give a presentation to the entire class and share with their classmates what they have learned about that particular segment of the chemical industry. The presentations are brief, about 20 minutes, and should be supported with accurate data. After each presentation, the class is invited and encouraged to ask questions and engage in a relevant discussion/debate to further enhance their learning. The presenting teams are also required to submit a report on their findings. The presentations and the reports are then graded according to the criteria shown in Table 2.

By the end of phase 1, depending upon the number of teams in class, they have some general knowledge about six or seven major chemical industry sectors and/or technologies. Often, students' findings are very impressive, reflecting their abilities to research a topic on their own and extract critical data and information to support their conclusions. In addition to periodicals, journals, government data and statistics, their resources include company quarterly reports and in some cases interviews with alumni or other practicing chemical engineers.

The class presentations and the reports might include, but are not limited to, the following:

- approximate share of the U.S. economy
- approximate number of workers in that industry
- prospects for future growth
- potential for new innovations
- national and global demand

**Phase II** – During the second phase of the project, each team has to identify some of the major problems and challenges/opportunities faced by their chosen industry or technology, e.g. availability of raw materials, logistics and transportation, global demand, etc., and select one to further research its root

**TABLE 1**  
**Project handout (Phase I)**

Select an industry sector or technology from the list below and conduct an “overview” research on your selected industry sector or technology

- Clean energy (solar and wind)
- Petrochemical industry (shale oil included)
- Traditional chemical industry
- Specialty gases
- Water purification and desalination
- Food industry
- Agricultural products
- Health and cosmetics
- Biomedical industry (including medical devices)
- Blockchain technology as applied to chemical industry

**TABLE 2**  
**Presentations and reports grading criteria**

Slide Presentation

- Content \_\_\_\_\_
- Adequacy of Details \_\_\_\_\_
- Relevance to Project Scope \_\_\_\_\_
- Q&A \_\_\_\_\_
- Quality of Slides \_\_\_\_\_
- Format of Slides \_\_\_\_\_

Slide Presentation Grade \_\_\_\_\_

Written Progress Report

- Content \_\_\_\_\_
- Adequacy of Details \_\_\_\_\_
- Relevance to Project Scope \_\_\_\_\_
- Report Format \_\_\_\_\_
- Technical Writing \_\_\_\_\_
- References \_\_\_\_\_

Written Report Grade \_\_\_\_\_

causes and how the problem has been created and currently addressed. They will then share that information with the class in the form of a second presentation and report. Table 3 illustrates the type of information shared with the students in the course.

This phase is envisioned to be completed by about the tenth week of the semester. During this second phase, they are encouraged to interview chemical engineering faculty members as well as other experts on campus and provide as much technical information as possible for a first-year student. By the end of this phase, students have some knowledge of certain major chemical industry sectors or technologies as well as challenges and opportunities that lie ahead.

**TABLE 3**  
**Project handout (Phase II)**

Substantially narrow the scope of the research to identify a problem within that segment of industry/technology that needs to be addressed. The selected problem should be investigated by each team through any one or combination of the following tasks:

- Research (library literature search)
- Surveys
- Interviews with engineering faculty, experts in the field, practicing engineers, etc.

The teams will then present the identified problems and challenges to the entire class. The presentation and the report might include, but is not limited to, the following information:

- the nature of the problem
- the root causes of the problem
- how the problem has been handled thus far

**Phase III** – This phase of the project is the most interesting part as it requires a great deal of brainstorming, creative inquiry and out-of-the-box thinking. Students are encouraged to think differently, question the existing technical methodologies, and formulate new solutions even if they might be completely unconventional. Table 4 illustrates the type of information that is shared with students in the syllabus.

Each team will then present the identified potential solutions to the entire class. The presentations and reports might include, but are not limited to, the following information:

- different approaches that were used in problem solving
- what possible solutions emerged
- how the final solution was formulated
- is the final solution a permanent one or simply a temporary fix?
- is it possible that the proposed solution might cause other unintended problems?

## THE OUTCOME

This course is designed to make first-year students more successful and engaged in their discipline starting with their first semester in college. It accomplishes that by welcoming and bringing first-year chemical engineering students to the department from day one and engaging them in departmental activities, such as the student chapter of the American Institute of Chemical Engineers, Engineering Council, design competitions, innovation and entrepreneurship activities and competitions, as well as some of the social and cultural activities across the campus. They are required to complete certain training programs, such as Title IX training. Included in the lectures are discussions on the importance of engineering ethics and safety as well as information about some of the engineering traditions, such as the Order of the Engineer<sup>[10]</sup> and the history of the chemical engineering discipline and how it has evolved through the years.

One of the important aspects of this course is that the students get to meet the chemical engineering faculty and learn about their teaching and research interests. Students also learn from the experiences of the department's alumni, particularly recent graduates who are closer to their age group, who meet with them to share their professional experiences. Additionally, they meet the staff from various university offices who aim to make the students successful in terms of retention, progression, and graduation. Students learn

**TABLE 4**  
**Project handout (Phase III)**

Find a solution to address the identified problem. This task requires the traits that engineers use in performing their daily tasks, namely:

- Critical thinking
- Creativity
- The ability to make observations and analyze and examine the problem from different angles
- Teamwork
- The ability to listen to/or read about those who are directly involved with or affected by the problem
- The ability to work with others outside the discipline
- The ability to think differently and not be bound by conventional methodologies

about high-impact practices, such as study abroad, service learning, co-op and internship, and undergraduate research opportunities. They also learn about disability and accessibility issues, career planning and interview techniques, library services, free tutorial services, and facilities, such as 3-D printing spaces, that are available to them to construct their design ideas. Some learning activities are also offered by guest faculty, such as hands-on experiments with fuel cell cars and the evaluation of the power to the car through an electrochemical reaction. Students also learn about “soft skills,” such as the ability to make oral presentations, work in teams, and improve their technical writing as they prepare their reports and slide presentations.

Most importantly, they learn what chemical engineers do and what professional opportunities might await them when they graduate as well as the challenges and opportunities that lie ahead for the chemical and biomedical industries and, frankly, whether what they expected and envisioned when they selected their major matches with the realities of what they have now learned through their own research of the field as well as the research and findings as reported by their peers.

## RESULTS

The fall semester of 2019 was the author’s second time teaching this class with a new methodology to help students better understand the profession by researching the various aspects, identifying the current technical challenges faced by the industry, offering potential solutions, and developing a vision of their future within the chemical engineering profession. The experience of being able to help first-year students, answer their questions, and provide guidance when they needed it has been immensely rewarding.

During fall 2018, this project was introduced in two sections of the course taught by the author, but the project was done all in one phase as opposed to three separate phases. The other two sections of the course were taught by the author’s colleague, with whom a somewhat similar agenda was jointly coordinated. This year, the author divided the project into three distinct phases in order to be able to bring focus to different tasks, add to the students’ report-writing experience and presentation skills, and improve the coaching function.

The assessment of the efficacy of the course is based on two factors: the quantitative student evaluations and Fall-to-Fall retention rates for first-time chemical engineering freshmen. In terms of student evaluation results, the author’s student evaluations for the past two years of teaching a total of four sections of the course are 4.0 and above out of 5.0, indicating the

students’ satisfaction with the instruction. The qualitative student feedback, while not a direct assessment factor, has also been very favorable. Additionally, the Fall-to-Fall retention rate of the entire 2018 chemical engineering cohort (all four sections), Figure 1, is among the highest at the university and, in fact, the highest among all university units/programs with more than eight students. Of course, many other factors contribute to such results, among them advising, front-office staff assistance, department faculty support and the various university support services.

Also, this course has been taught by other chemical engineering faculty colleagues in the past with a similar general format using different projects, and the results have been very positive as well, as shown in Figure 1. Nonetheless, the results thus far with this new methodology of letting first-year students immerse themselves in researching the discipline and framing a vision of their own future profiles within the profession are very encouraging. Although more data are needed to make a firm conclusion, the trend is very positive (Figure 1).

As a comparison, Figure 2 illustrates the percentage of all first-year students at four-year colleges who return for the second year.<sup>[11]</sup>

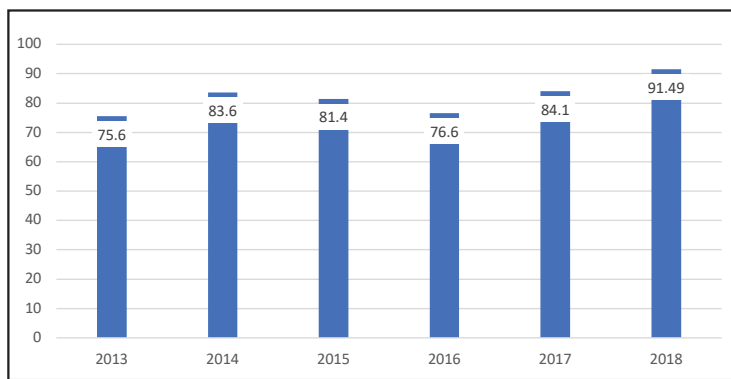


Figure 1. TTU Chemical Engineering Fall-to-Fall Retention Rates (%) for First-Time Freshmen.

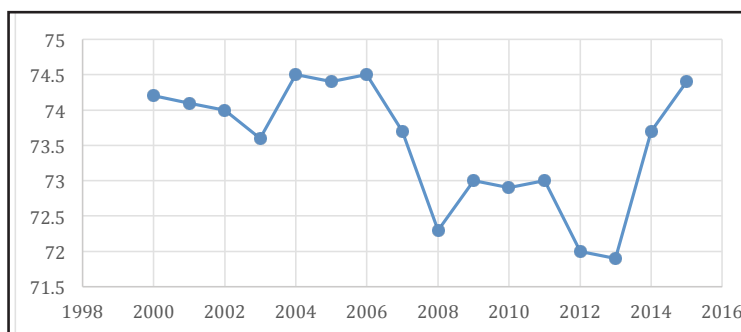


Figure 2. Percentage of first-year students at four-year colleges who return for second year.<sup>[11]</sup> (ACT Institution Data)

## CONCLUSIONS

The following paragraph is from a paper that the author presented at the World Future Forum in the spring of 2019: “Over the last decade, we have seen an intense focus placed upon enhancing the retention rate and graduation rate of college students. Numerous programs have been established and a deluge of funds have been unleashed to support various innovative programs supported through the latest data analytics platforms and statistical models. Many states have restructured their funding formula for higher education in order to tie them to performance metrics that value student progression, retention and graduation rates. National programs and various state-supported programs have allocated substantial sums of money to reward those efforts, and the institutions that have not complied have seen cutbacks in funding. However, thus far, the results have been less than remarkable.”<sup>[12]</sup>

In that same paper, the author also recognized that the subjects of student retention, progression, and graduation are rather complex and multi-dimensional. There is not one universal solution or model that could be used to address the problem. Rather, many different approaches should be employed simultaneously to respond to the unique needs of different groups of students.

As stated at the beginning of this article, studies have shown that first-year students become more successful if they are immediately placed in direct contact with their home departments as this association provides them with a better sense of belonging. Based on that premise, this first-year connection course is designed to offer students a more holistic approach by helping them to:

- develop a more comprehensive understanding of their selected profession
- explore some of the current challenges faced by the industry and exercise their creativity and imagination to offer potential solutions
- get to know their chemical engineering faculty, their research interests, and the courses they teach
- become more engaged in campus life and participate in high-impact programs that are offered to them by the university
- develop the “soft skills” of technical writing, oral presentation, and teamwork

Again, it should be noted that the assessment of the efficacy of the course is based upon the quantitative student evaluations and Fall-to-Fall retention rates for first-time chemical engineering freshmen. Additional assessment criteria for evaluating the various components of the course could be added. However, it is envisioned that those who wish to

implement such a project would choose their own assessment criteria based on their program requirements and institutional assessment methodologies.

Through this course, students connect with their future profession and better appreciate their curriculum when they have a clearer understanding of their major field of study and develop a preliminary vision of their own future within the profession. It is hypothesized that such a holistic experience contributes to their success and progression from the freshman year to the sophomore year. In that sense, the results obtained, thus far, are very promising.

On the subject of developing a vision of their future within the profession, we, as chemical engineers and educators, have to ask ourselves, do our first-year students really know what chemical engineers do, or as the WorldWideLearn<sup>[13]</sup> puts it: “What doesn’t a chemical engineer do?”

## REFERENCES

1. Cuseo J. Student success: Definition, outcomes, principles and practices from *The Big Picture. eSource for College Transitions*. National Resource Center for the First-Year Experience and Students in Transition, University of South Carolina. <https://www2.indstate.edu/studentsuccess/pdf/Defining%20Student%20Success.pdf>, accessed March 15, 2020
2. Noel L, Levitz R and Saluri D (1985) *Increasing Student Retention*. Jossey-Bass Publishers. San Francisco, CA.
3. Salim M, Wagner JE and Finley DR (2000) The introductory sequence for chemical engineering students and retention at Tri-State University. *Proceedings ASEE Annual Conference*. <https://peer.asee.org/8517>.
4. Upcraft ML, Gardner JN and Associates (1989) *The Freshman Year Experience*. Jossey-Bass Publishers. San Francisco, CA.
5. Astin AW (1999) Student involvement: A developmental theory for higher education. *Journal of College Student Development*. 40(5), 518–529
6. Bruffee KA (1993) Ch 5: *Collaborative Learning: Higher Education, Interdependence, and the Authority of Knowledge*. The Johns Hopkins University Press. Baltimore, MD.
7. Johnson WD, Johnson RT and Smith KA (1991) Section 9:3: *Active Learning: Cooperation in the College Classroom*. Interaction Book Company. Edina, MN.
8. Tinto V (1993) *Leaving College: Rethinking the Causes and Cures of Student Attrition*. 2nd edition. University of Chicago Press. Chicago, IL
9. Arce P and Visco DP, Jr. (2006) A freshman course in chemical engineering: Meeting first year experiences with discipline specific needs. *Proceedings ASEE Annual Conference*. <https://peer.asee.org/623>.
10. Wedel KA (2012) *The Obligation: A History of the Order of Engineers*. AuthorHouse.
11. ACT Institutional Data Files (2015) 2015 Retention/completion summary tables. <http://www.act.org/content/dam/act/unsecured/documents/2015-Summary-Tables.pdf> accessed June 30, 2016.
12. Ghorashi B (2019) Student success as measured by retention and graduation rates. *World Future Forum Conference*.
13. WorldWideLearn (2019) What does it mean to study chemical engineering? <https://www.worldwidelearn.com/online-education-guide/engineering/chemical-engineering-major.htm> accessed July 25, 2019. □