Creating Learning Communities for Student Success in Gateway Discrete Linear Systems

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Cheryl B. Schrader recently retired as president and rejoined full-time professor ranks in Wright State University's Department of Electrical Engineering. Prior to Wright State she served as chancellor of Missouri University of Science and Technology and associate vice president for research and dean of engineering at Boise State University. Professor Schrader earned her BSEE degree from Valparaiso University and MSEE and Ph.D. degrees from the University of Notre Dame. Over her career she received several best paper and presentation awards; authored approximately 100 publications; and delivered more than 100 invited presentations and keynote addresses. Her grant and contract funding exceeds $11 million.

A Fellow of both the ASEE and IEEE, Professor Schrader has served ASEE in myriad technical, regional and institute-level leadership positions and committees and has been recognized for her many contributions. She was most honored to receive the Presidential Award for Excellence in Science, Mathematics and Engineering Mentoring from the White House, enhancing participation of individuals who might not otherwise have considered or had access to opportunities in STEM.

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Abstract

Wright State University is a multi-campus, public research university headquartered in Dayton, Ohio, which has one of the largest concentrations of electrical engineers and computer scientists in the United States [1]. By the early twentieth century this region was well-known as a center for innovation and entrepreneurship, becoming the top site in the country in patents per capita in 1903 when the university's namesakes Orville and Wilbur Wright flew. Wright State University was created in 1967 to meet the region's needs for research, innovation and education and is situated on land that formerly belonged to Wright-Patterson Air Force Base (WPAFB), home of the U.S. Air Force Research Laboratory (AFRL) and five directorates. Technology companies surround the university and base, creating a vibrant innovation hub. To this day, electrical engineering continues to play a large role in the workforce and in opportunity afforded the citizenry, university and prospective and current students of all ages.

In a proactive move to provide students more flexibility, electrical engineering faculty members at Wright State University conducted an in-depth review of all course pre-requisites to streamline the Bachelor of Science in Electrical Engineering (BSEE) program and make it more adaptable for students with diverse experiences to progress through their degrees. This includes high school students accessing university curricula through the state's dual enrollment opportunities; a technology workforce heavy in job opportunities, internships and co-ops for those with degrees and interest in electrical engineering at all levels; a large influx of active and retired military and civilians; and an accessible and affordable research university in the heart of it all. Among others, changes in pre-requisites occurred in both Continuous Linear Systems and Discrete Linear Systems, which had previously been offered respectively in sequence and had required higher-level mathematics.

These gateway courses were both reorganized with the same pre-requisites effective Summer 2022 – Analog Circuit Theory with accompanying laboratory and Calculus II – without any particular ordering of linear systems courses; that is, students may take continuous first, discrete first, or both courses simultaneously. This flexibility recognizes that diverse student experiences may enhance student success dependent upon the first course passed. Of note, Analog Circuit Theory now includes electrical quantities and their relationships, transform-calculus impedance models, conservation models leveraging algebraic solutions, transform-calculus-derived algebraic models of dynamic systems, and mathematical solution techniques. Calculus II remains fairly standard and includes integration techniques, applications of the definite integral, numeral integration and improper integrals, parametric equations and polar coordinates, and infinite sequences and series. The author taught both linear systems courses in addition to follow-on control courses before and after these pre-requisite changes were implemented and was successful in transitioning learning achievement to the new pre-requisite scenario.

Both courses are gateway, required courses for the BSEE, often are first courses in the major that challenge students theoretically, and either or both may become a barrier to success; as such, they have higher rates of students earning a D or an F or withdrawing from the class with a W (i.e., DFW rates). Many required courses and technical electives in the junior and senior years dictate proficiency in foundational linear systems topics. For these reasons and at the author's recommendation, the Wright State University College of Engineering and Computer Science (CECS) Undergraduate Policy and Curriculum Committee selected these two linear systems courses to include in a year-long, university-wide initiative to improve student success.

Although originally designed for online/hybrid implementation, many of the innovative strategies on creating learning communities reported here port seamlessly to in-person classes and benefit students regardless of content or modality. Such ideas were implemented in the author's Summer 2023 online/hybrid course and Fall 2023 in-person/hybrid offering of Discrete Linear Systems with promising results.

The section following provides additional motivation and novel strategies demonstrated to be particularly attuned with the current generation of students effected by COVID-19 and other disruptions in learning. With flexibility at the forefront, important factors to student success and skills gaps are addressed. Specific course enhancements and results then are highlighted and conclusions described.

Motivation and Learning Loss

Since 2020 faculty and students throughout the United States face what is described as "Learning Loss" characterized by learning that remains unfinished in some way, whether as a result of disruption of academic years such as what happened in 2020 and 2021; attrition of previously acquired knowledge; or disengaged learners. Research shows that such loss is not relegated to acquiring or retaining knowledge, but also includes skills, behaviors and mindsets [2], [3]. National indicators are troubling. First year direct from high school college students in 2023 were first year high school students when the COVID-19 pandemic began. This cohort earned average composite ACT test scores at the lowest level in 32 years, and 40 percent of graduating seniors did not reach the ACT college readiness benchmark [4]. Test optional admissions which remain in place at many colleges and universities may exacerbate data collection. Additional K-12 data show that COVID-19 eliminated years of improvement in both reading and math scores, with math taking a most precipitous drop; see, for example, [5].

The impact of this loss on the United States is widespread and has been estimated in economic terms as $128-188 billion dollars each year such learners enter the workforce due to lower college-going rates, academic achievement, and earnings as well as higher mental health challenges [2], [6]. To understand effects of COVID-19 on college students' mental health, interviews were conducted with students from a large Texas university system, 60 percent of whom were majors in a college of engineering [7]. Stressors impact on motivation, concentration and social interaction were found to be considerable across academic, health and lifestyle categories. Also female, underrepresented minority, and low-income students in science, technology, engineering and math (STEM) are at heavy disadvantage and less likely to feel

prepared, with women in particular experiencing a loss of confidence overall [8]. This widens the achievement gap and makes it even more difficult to attract historically marginalized or underserved students or to create the diverse engineering workforce companies, communities, universities, government and military need to thrive.

Engineering curricula are considered some of the most inflexible compared to other bachelor degrees. With national challenges mentioned above limiting students entering engineering programs, this is precisely the time when engineering faculty need to take widespread action. Wright State University has a history of innovations to provide just-in-time mathematics that help counter traditional curricula inflexibility; see, for example, [9]. The rigidity built into degree attainment limits diversity within the engineering student body as a whole, and the Learning Loss experienced by incoming students multiplies these effects. It is not an overstatement that an entire generation of engineering students could be lost due to a pandemic; and students traditionally underrepresented in engineering (namely women and underrepresented minorities) are leaving at an alarmingly high rate. A reflection of the urgent need is a 2022 National Science Foundation (NSF) Award to a partnership between the American Society for Engineering Education (ASEE) and the National Academy of Engineering (NAE) entitled "Engineering the Inclusive Mindset for the Future: A Blueprint for Systemic Change in Engineering Education" [10]. A planned NAE Engineering of 2050 Report describes the direction, the referenced ASEE Mindset Report sets the path, and The Blueprint for Change Award develops an actionable plan to get engineering where it needs to be.

The author also had opportunity to spend time with invited researcher Dr. Amy Salazar, Associate Vice Provost of Student Success at Sam Houston State University (SHSU), in multiple venues over several days in 2023 and 2024. Dr. Salazar conducted an in-depth study on Learning Loss influences on SHSU students, faculty and staff [3]. In addition to identifying overall impacts to her institution – such as declining performance indicators like recruitment, retention and persistence; loss of revenue; faculty and staff fatigue; and loss of community – focus groups of over 100 Sam Houston State faculty members identified student skill gaps as summarized in Table 1 on the next page.

Interestingly, the Learning Loss skill gaps summary of Table 1 connects directly to the Gallup-Purdue Index Report [11] that identifies six important factors for student success; see Table 2 on the page following.

These six factors "so strongly related to graduates' lives and careers [it] is almost hard to fathom . . . yet few college graduates achieve the winning combination [11]." The more of these factors survey respondents reported receiving in college, the greater their degree of well-being and career engagement later in life. So, what is the takeaway? Our actions as faculty, simple as some may seem, can have an outsized impact on students' lifelong success.

SKILL GAPS OF STUDENTS

Life Management

Time Management
Prioritization
Resilience
Self-Efficacy/Self-Advocacy

Academic

Critical Thinking
Writing
Self-Directed Learning
Information Fluency

Professional

Communication
Collaboration
Career Direction and Goal Setting

Table 1. Learning Loss Skill Gaps [3]

IMPORTANT FACTORS FOR STUDENT SUCCESS

Professors who made students feel excited about learning	Foster student engagement such as discussion, projects and workplace connections
Professors who cared about students as people	Demonstrate empathy and compassion rather than rigid adherence to classroom policies
A mentor who encouraged students to pursue their goals and dreams	Take a personal interest in students and verbalize belief in their potential to succeed
The opportunity to work on a long-term project	Foster collaboration and ability to work with others; communication across contexts and audiences; critical thinking and the ability to solve complex problems; and creativity and innovation
Taking part in any internship or job where students were applying what they were learning in the classroom	Build classroom connections to the workplace; provide opportunities to apply learning to real-world contexts; understand importance of professional networks; broaden understanding of career options; and introduce workplace norms and behaviors
Being extremely active in extracurricular activities and organizations in college [being engaged]	Foster retention, persistence and academic achievement; create an enhanced sense of belonging; and capacity for growth in interpersonal and intrapersonal competence

Table 2. Important Factors for Student Success [11], [12]

Flexibility

Flexibility was the key issue driving the aforementioned streamlining of the BSEE curriculum that allowed for shared pre-requisites between the two linear systems courses and the ability to choose whether to take discrete or continuous first. Such flexibility recognizes that diverse student experiences may enhance student success dependent upon the first course completed successfully. The author noted that some students who took Discrete Linear Systems first and who had experiences in the "real world" upon which to draw – whether work or interest related – were very engaged in class discussions, more confident in speaking out, eager to share with their peers and often did well in this course. Such students were particularly valuable in group discussions assignments and were often paired with more traditional students who also had gifts to share that were helpful in return. Enhanced faculty and student peer interactions brought more experienced or practical-minded students into Discrete Linear Systems first and often produced a feeling of confidence and motivation to succeed that was then helpful in Continuous Linear Systems and other follow-on courses.

To help provide just-in-time mathematics, the Analog Circuit Theory pre-requisite now highlights mathematical modeling and solution techniques tailored for success in linear systems without requiring differential equations as a pre-requisite. Calculus II continues to remain fairly standard. One particular student who was taking differential equations simultaneously with the redesigned linear systems course credited the latter course with the ability to earn an A in the former. Interesting how such ideas come full circle!

The question to consider is, "what about those students who took both linear systems courses simultaneously"? This professor has had at least five students in this category. In Summer 2022, the author taught both courses using the same textbook and planned how the courses progressed with the new change in pre-requisites. No doubt taking both linear systems courses together was a challenge, but similar topics in both courses were addressed often within a week's time, and the professor could remind students of this similarity and how concepts reinforce each other. This experience became almost a linear systems immersion. Fellow students began to look at the students taking both classes as seasoned veterans; and those who took both courses together did very well, earning A's and B's and ready to step into other required and technical electives utilizing either linear systems course as a pre-requisite. Even when not teaching both linear systems courses simultaneously, the author refers to related linear systems course concepts to reinforce learning communities and emphasize diversity of thought and lived experiences as valuable assets in both classroom and workplace.

In Summer 2023, Discrete Linear Systems was offered as a blended learning, "mostly online" course for the first time on a pilot basis. Live, synchronous class sessions were provided and recorded in case a student had an occasional need to miss class. Students also appreciated reviewing materials and examples through the recordings. Students were required to submit an email to the instructor if they had some difficulty attending a class synchronously. Generally, this was well received with work conflicts, illness, car trouble or family obligations the most cited reasons for non-attendance. Students respected this requirement, which helped the

instructor follow up with them to see how they were feeling or prompting a question in a subsequent class to share their recent work or internship experience. With this simple example bringing together academia and industry, the instructor set the stage for students to consider expectations in the workplace; that is, they should let their boss know if for some reason they would not be available that day. And, as everyone knows, life happens. Monitored class attendance and active engagement and participation in class activities measured multiple ways now contribute to the final grade. Rarely does a student miss more than an allotted number of classes specified on the course syllabus. Additionally, midterm grades were recorded and discussed with students for the first time.

As much as possible and according to Learning Loss skills gaps, the professor works to make connections between the course and what students might expect in their careers, which also helps enforce self-efficacy and self-advocacy. Stories are shared about times in industry, academia or consulting to build community and highlight aspects of that day's discussions. Students and the professor were encouraged to wear logos and apparel that exhibit pride in their accomplishments and interests. In a live, synchronous class this is a good way to keep career goals, aspirations and interests at the forefront.

Such an offering also helps accommodate students who just transferred into Wright State University from other colleges or universities, mature students with industry or military experience, or students working in summer internships or co-ops that limit their ability to attend an in-person course. In addition to a change in modality, this course was redesigned to enhance learning communities using video and group discussions in the learning management system in innovative ways as discussed below.

Over half of the students in the Summer 2023 course had been challenged in one or both linear system courses at least once before (and had not previously passed DFW thresholds) but successfully completed this course with a C or better, which allowed all students to progress through their major.

In addition to the "mostly online" summer offering of Discrete Linear Systems, the author also offered a Fall 2023 in-person class enriched through many of the same techniques originally designed for remote learning.

Course Enhancement Highlights

Several additional enhancements address the skills gaps and important factors for student success illustrated in Tables 1 and 2. As mentioned above, resiliency, self-efficacy, critical thinking, writing, communication, collaboration, and career direction are of most interest to this course redesign. These include enhancing communications, collaboration, and participation; building learning communities that develop critical thinking, self-efficacy and a professional mindset; and focusing students on their careers and aspirations. Students experiencing Learning Loss may look to technologies to help them interact initially, and then often they become more comfortable engaging in person. This is an important understanding of how to create initial

connections and engage students.

Frequent and Approachable Communications

From the first interactions with students before and throughout the course, the professor considers a culture of care that has been proven to enhance student success. Faculty should contemplate how to help students feel a sense of belonging; build community in the classroom; and model those desired behaviors for students to follow [13]. The traditional welcome email sent before the first class meets and the syllabus attached have been revised to promote belonging. Moreover, the instructor lets students know on the first day that sometimes life gets in the way and that this happens for everyone (faculty included). They are invited to send an email communicating an issue so that how best to move forward can be considered together. Weekly emails to the class and responses to students are crafted with these ideas in mind. It takes courage for a student to reach out to a faculty member and communicate. Similarly, this author has learned to share personal challenges or barriers faced so as to be more approachable to students who can identify.

Video Introductions and Discussions

Since Summer 2021 this professor posts a video introduction in Flip [14], a free video discussion application; links it directly to the learning management system and invites students to view it before the first class session. Although this first graded assignment began in a fully online course, it proved so successful that it is included regardless of modality. Students view the instructor's three- to five-minute video and respond to it with a video introduction of themselves. They also are required to review and meaningfully comment on videos posted by their peers during the first week of class. For a typical size class there are often 20 hours or more of interactions that could not happen in the classroom. And, it is not unusual for students to make a tennis date, assemble as woodworkers or crafters, or attend a basketball game together when they find others with similar interests.

This video introduction is a concept that is capturing widespread attention with other Wright State faculty as a way to create community both in-person and online and to appreciate the advantages of diverse groups learning together. It has become a platform for understanding how creative engineers are and how their creativity in other realms, such as fine arts or business or athletics, enhances classroom experiences. Because the professor learns about students in a more personal way from their videos, she can invite specific students throughout the semester to share their experiences with the class regarding current course topics; and this helps build student confidence and self-efficacy. Without this innovation, classes do not realize the amazing attributes and lived experiences others bring to the table and how this helps diverse groups reach solutions beyond what individuals alone can. The videos are also helpful when students face group assignments as they can review videos of the other students to be reminded of connections they may already have.

For example, this year some students shared that they were:

- Recently retired as a 20-year signals analyst in the military, finishing their bachelor's degree under a coveted national grant, interning at Wright-Patterson AFB, and planning to continue at Wright State University for their master's degree
- A ten-year veteran of the automotive industry, following their spouse to the Dayton region and completing a bachelor's degree while parenting
- An early high school graduate who utilized resources in the community to achieve a first in family dream
- A refugee working a full-time job to support a family and attending school as a full-time student
- A technical high school graduate with industry experience whose parents suggested attaining a bachelor's degree in electrical engineering
- Direct from high school students benefitting from dual credit college/high school programs
- Community college and other university and college transfer students
- Continuing to persist in their degree progress regardless of setbacks
- Musicians, composers, painters, farmers, athletes, gamers, band members and bandies, crafters, volunteers, pet owners, entrepreneurs …

The instructor video was made on the back porch overlooking an expansive backyard with waterfall and koi pond. Of course, hobbies are shared, including that the instructor and spouse are avid gardeners; grandchildren are discussed; and sometimes the dog makes an appearance. Leadership and participation in professional technical societies like IEEE and ASEE are highlighted along with the instructor's engineering pathway. Students have left response comments that the video assignments made them think differently about the professor as a person and that they were eager for class to begin. Students who have been in multiple courses relayed that they purposefully sought out these courses and wanted others to know just how "awesome" a professor they had.

Along with a more targeted background skills survey, this video information is used to form groups for discussions and projects throughout the semester based upon diverse skills and experiences. Students are evaluated on both group and individual work, and often go back to the introduction videos to learn more about their partners.

Groups and Discussions Learning Communities

Discrete Linear Systems and the learning management system create novel and important opportunities to use technologies in a way that attracts students, makes it easy to engage regardless of modality, and enhances learning communities.

These include creating:

- Group Discussions spaces for group work on more detailed projects that promote critical thinking and simulation and assess both group and individual work;

- Homework Help Discussions spaces with peers for every homework assignment where the professor often posts links to related material or additional resources along with hints or solutions;
- A Quiz Results Discussions space for all students to discuss concepts that may remain unclear for some after quizzes are graded and returned with feedback from the instructor; and
- A General Discussions Chill Zone ...

Each of these learning communities are discussed below.

Group Discussions and Suggested IEEE Report Format

Depending on the course and the maturity of the students in a particular class, group discussions in the past had mixed results; that is, some student loved them and others did not. Students may not have been responsible for group organization, dynamics or leadership before, and some wished to avoid collaboration altogether. It is clear in retrospect from Table 1 that skill gaps associated with Learning Loss were at issue from each of the three categories, life management, academic, and professional. Students were assigned to diverse groups that covered the set of required skills within each group as assessed by survey and personal video introductions and then took advantage of the gifts of individuals in that class. Problems were assigned that required a high level of group interactions, critical thinking, simulations, graphs and results. One .pdf file in report format was to be uploaded from each group with specific information, and format was discussed in class and described in the learning management system. Students received the same group grade based upon their group submissions and team interactions in the learning management system and an individual grade based upon their personal participation and individual contributions to group discussions.

However, some students remained anxious regarding expectations and collaborations. Some students wanted to move to other platforms that did not provide insight into individual contributions for the professor. Some students were used to submitting code but not providing results and expecting the professor to correct coding errors. Some students waited until the last minute to connect with their group. And, many students stepped forward in leadership roles and many groups produced very impressive results.

In Summer and Fall 2023 the instructor set out to address some of the challenges experienced by students previously. The instructor realized that more guidance was necessary and decided to provide a suggested IEEE conference paper format to illustrate what was expected [15]. An excerpt of the assignment instructions is included in Figure 1 on the next page.

This change met with resounding success. Groups were given the option to use the report format but were guided by the suggested format regarding content and thoughts on organization. This approach added the opportunity to discuss IEEE and its technical societies and regional activities with the class, what is considered IEEE format, and what professional expectations are held for communicating results. It also drove students to the IEEE website to explore offerings and membership in the IEEE.

Attached below is an IEEE conference template that is fairly standard and may be used to shape your group report. This format may help address key components of the report (and of journal and conference papers), including an abstract; problem statement, analyses and discussions; results, equations, images, and plots; conclusions, acknowledgments and references all integrated into a clear, concise and powerful result.

Please note that there is no expectation to use this format. However, I thought you would all appreciate suggested form or content as you craft your group discussions in this class.

IEEE Conference Template

Figure 1. Group Discussions Using Suggested IEEE Format

Homework Help Discussions with Peers

This discussions forum provides collaboration space to explore homework with classmates. Students who seek assistance and students who share knowledge and expertise all benefit from such interactions. Students are allowed to post anonymously if it makes them feel more comfortable.

Students pose questions on homework both before and after an assignment has been submitted. The professor does not monitor the space but drops in occasionally to observe participation and understand where issues might be. When students consult with the professor on homework often what is discussed in that smaller session is also posted in the Homework Help for the benefit of all. Additional hints, examples, helpful videos and references are posted there by the instructor and peers alike. And, the instructor follows up by posting comments on graded assignments and solutions for reference.

Quiz Results Discussions with Peers

This discussions forum includes the entire class. In this case, posts cannot be made anonymously. The forum's purpose is to promote constructive peer interactions and learning for all students, both those who have grasped concepts and those who are on their way to doing so. This forum allows students to pose questions and provide insight to each other on concepts that may remain 'fuzzy' after a review of individual quiz assessments and feedback.

The instructor does not moderate the forum officially but may drop in on occasion to determine active participation. This forum replaces using class time to review quiz results while providing a mechanism for all students to fully understand each quiz assessment before moving on to the next.

General Discussions Chill Zone

A Chill Zone in a learning environment is a space where students can take a break and hang out with their peers, engaging in more unstructured ways to connect personally or self-organize. The virtual General Discussions Chill Zone space in the learning management system is open to the entire class to just unwind or initiate ad hoc social events or in-person or virtual study sessions.

Interestingly, students entering Wright State University in Summer 2023 established their own face to face learning communities that continued into Fall 2023 and Spring 2024, some of which utilize specialized college and campus support resources such as the Veterans and Military Center, University Student Center, Library, and the Engineering Complex. At the students' request, the instructor added what ultimately became the Chill Zone.

Results and Conclusions

An examination of DFW rates for the redesigned 2023 Summer and Fall offerings is promising. Of the 22 students taking both the "mostly online" and the in-person class only one student earned a place in the DFW rate. This student is described as a ghost student, in that they did not respond to emails or ever log into the learning management system which as the center of all interaction among faculty, students, content and materials makes it impossible to be successful in this class regardless of modality. The new university requirements to provide participation rates and mid-term grades aided in reporting this issue to student success staff who in turn reached out to this student but with no success. The author has recently learned that an instructor in certain instances may text students if cell phone information is submitted, and this might be an additional way to reach out in the future. That being said, the overall DFW rate over these two semesters is about 5 percent, well below previous double-digit results.

It is also important to understand what students are expected to demonstrate by the end of this course; how this is assessed; and to compare results before and after the redesign. Discrete Linear Systems at Wright State University at the undergraduate level is assessed for ABET and continuous improvement purposes related to student learning outcome two, "an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors."

Three assessments for Discrete Linear Systems are gathered according to the plan shown in Table 3. The percentage recorded in the table is the percent of students in that semester who earned 70 percent or higher on these assessments. Only Fall 2023 data was collected after the redesign and it is the only semester where all three assessments exceeded the evaluation threshold of 70 percent. Fall 2022 data is after the pre-requisite changes but before the redesign that dramatically improved DFW rates. Fall 2021 is before both pre-requisite changes and the redesign. These data indicate that the pre-requisite changes and course redesign have resulted in students performing above an acceptable level according to detailed program assessment with vastly improved DFW rates.

Assessment	Fall 2021	Fall 2022	Fall 2023
(2-1) Design of an ideal anti-aliasing filter	67%	89%	77%
(2-2) Design of a finite impulse response filter	78%	67%	77%
(2-3) Design of an infinite impulse response filter	72%	78%	85%

Table 3. Assessment Statistics for Discrete Linear Systems Before and After Redesign

Finally, although originally designed for online or hybrid implementation, many of the innovative teaching and learning strategies focused on creating community for student success port seamlessly to in-person classes and benefit students regardless of content or modality.

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