Engineering Learning Strategies Course Supports Student Retention

Elizabeth A. Stephan, Abigail T. Stephan, Laurel Whisler, Matthew K. Miller, and Andrew I. Neptune
Clemson University

Abstract

This paper describes an innovative learning strategies course that is one aspect of the holistic approach of the General Engineering Learning Community at Clemson University. The program's goal is to boost retention for entering first-year engineering students with low math achievement scores.

The course equips students with skills for personal and professional success using a self-directed, iterative approach to learning. The underlying pedagogical framework, Entangled Learning[1], prompts students to choose activities they believe will improve their effectiveness, document what they learn, evaluate their applied practices, and synthesize new knowledge.

Previous research[2] suggests the course adds value to the students' learning experience and contributes to the overall mission of the program by increasing retention for this population. Students demonstrate greater metacognitive awareness related to their behaviors and the strategies they utilize as a result of the course assignments.

Keywords

first-year programs, learning strategies course, Entangled Learning, retention, general engineering

Introduction

With the overall goal of increasing student retention in engineering, the General Engineering Learning Community (GELC) was designed to integrate existing coursework and resources at Clemson University to improve the engineering graduation rate and enhance the educational experiences of students who begin their first-year underprepared for calculus. As indicated by a study of six-year engineering graduation rates at Clemson University[3], initial math course placement carries significant implications for graduation, with a 25% gap in graduation rates existing between students placed into Calculus I and those placed into an extended, "Year-Long" Calculus I, and a 45% gap between students placed into Calculus I and those placed into traditional Precalculus.

Starting in Fall 2017, a program was designed to surround "not calculus ready" engineering students at Clemson University with intentional, targeted support within a community of learners. The program combines social and academic changes. Social changes include an early move-in program prior to the start of the fall semester and sponsored evening hours with undergraduate academic coaches to establish and sustain development of community. Academic

changes include cohorting the students in STEM courses and enrolling them in a learning strategies course, which is the focus of this paper.

The purpose of the two-credit learning strategies course co-developed by engineering faculty and Clemson University's Academic Success Center (ASC) personnel is three-fold. The first goal is to equip students with effective personal and professional skills related to behaviors, learning strategies, and habits of mind[2]. The second goal is for students to develop metacognitive awareness in the domain of becoming successful STEM students. The course has adopted aspects of the Entangled Learning model[1] and the Skillful Learning video series[4] to teach metacognition with demonstrated success[2]. The third goal is to encourage students to utilize existing academic support resources housed within the ASC. The ASC provides programs such as Peer-Assisted Learning and content tutoring services, both of which have been shown to be effective in enhancing retention, scholarship maintenance, and graduation rates[5,6].

The broad theme of the learning strategies course is gaining professional skills; course activities and assignments are intentionally crafted to ensure students see the value in their current practice as students as it relates to their future practice as engineering professionals. For example, students are expected to continuously evaluate their performance and track their progress towards their academic goals through journals and after-action reviews.

The 120 students enrolled in the learning strategies course are divided into four sections, with the number of students in each section ranging from twenty-one to thirty-nine. Each section is taught by a member of the General Engineering faculty.

Pedagogical Framework

Due to its self-directed nature, Entangled Learning (EL, see Figure 1) permits participants to engage in learning activities of personal significance within the boundaries of the course outcomes. As a pedagogy, *design* is the shape the instructor develops for the learning experience through identifying learning outcomes, curriculum, and assessments. As a structure for learners, *design* prompts students to identify their own goals, activities, and evaluation aligned with the course outcomes and curriculum. Activities are identified to empower students to *learn*, *apply*, and *know*. Movement through the model is initiated in the *know* sector and cycles both clockwise through *design* and the other sectors, and from the inner ring of personal activity to the outer ring of collaboration.

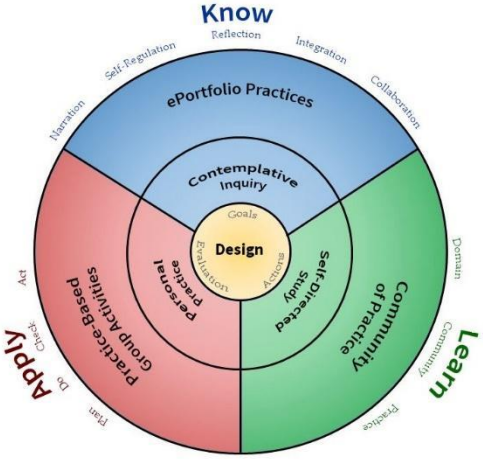

Figure 1. Entangled Learning Model

Individuals *learn* by engaging in personalized study using a variety of resources of their choice, which are aligned with their learning preferences and the requirements of the domain[7,8]. Personalized study is enhanced by a community of practice[9] through mutual support, mentorship, and learning while engaged in the practice.

Applying - making use of what one has learned - is a way to deepen learning[10]. Integrating new information or skills into personal practices, with reflection and experimentation, reinforces the learning[11]. Deming's[12] quality enhancement model of plan, do, check, act/adjust brings rigor to application through metacognitive cycles of planning, monitoring, controlling, and evaluating how one is learning[13].

Reflective practice also deepens learning[10]. *Knowing* is fostered as individuals engage in contemplative inquiry[14] to access the imagination and reflect to synthesize learning. ePortfolio practices[15,16,17] further synthesize knowledge as individuals document and narrate their learning, self-regulation, critical reflection, integration, and collaboration.

Course Activities

Course activities and assignments are correlated with broad areas of the EL model, which serves as the underlying pedagogy of the course.

Design

A learning journal activity extends throughout the semester. Students design their learning by identifying a personal or professional development strategy and write a SMART goal (specific, measurable, action-oriented, relevant, and timely) for engaging with the strategy. After a few weeks of engagement, students complete a reflection considering whether continuing with their chosen strategy will address their identified goals or whether they have a new area of development to address.

Learn

Peer sharing presentations and required participation in academic preparation sessions are two primary activities which engage students in the *learn* sector. The peer sharing presentations (Appendix A) allow students to explore an evidence-based practice for personal or professional development, craft an engaging, efficient presentation, and share their findings with their classmates. In this way, the peer sharing presentations are an innovative way for course content to be delivered quickly and effectively to and from students. In the exploration and research stages of the peer sharing presentations, students are engaging in self-directed study. Alternatively, the act of sharing presentations and offering feedback to peers allows students to engage as active learners in the collaborative construction of new knowledge within their community.

The academic preparation sessions include support resources provided through the ASC, such as Peer-Assisted Learning, tutoring, and a writing center, as well as targeted sessions led by undergraduate learning coaches for the GELC. In these sessions, students build knowledge collaboratively by engaging in the metacognitive practices of organization and elaboration[4].

Apply

As the course is focused on personal and professional development, activities and assignments encourage students to attempt and adjust evidence-based practices. With the iterative nature of

these activities, many assignments fall within the area of *apply*. Included are time trackers, exam wrappers, and project-based group activity time.

The time tracker assignments prompt students to consider how they are spending their time. At the outset of the semester, students create an "ideal week" schedule[18] with pockets of time dedicated to personal needs (i.e. sleep and meal times), class, study sessions, and recreation. At two checkpoints within the semester, students track their time for a week in thirty-minute increments, including time spent in each of the areas outlined above and evaluate their behaviors through an after-action review[19]. Often used as evaluations of a team's performance and originating from the military, after-action reviews are framed as an opportunity for growth[20]. In industry, these reviews are sometimes referred to as "post mortems" or "lessons learned," with the main idea being to provide a systematic way to capture process improvement[20]. As a personal practice, the time tracker assignments engage students in planning, controlling, monitoring, and evaluating[13] their time management.

The exam wrapper assignments are also framed as after-action reviews. In the four stages of the exam wrapper, students are asked to complete (1) a reflection detailing what they want to happen prior to their first round of exams, (2) a traditional exam wrapper activity[21] recounting their preparatory behaviors and learning strategies and the results of their exams, (3) a reflection on the strategies used, and (4) a plan for increased effectiveness.

Nine class sessions within the course, which meets biweekly during a 15-week semester, are dedicated to practice-based group activities (PBGA). Engaging in PBGA time allows students to apply and deepen their learning through collaboration with peers as students work in teams to address challenging topics in their co-enrolled STEM courses. Prior to PBGA time, each team of three to four students creates a meeting agenda with content, activities, and roles for each team member to facilitate effective collaboration[22] (Appendix B). To mirror teamwork in industry, the roles, including team leader and timekeeper, shift between students for each meeting. Crafting an agenda gives structure to the students' planning and integrates concepts from metacognition, such as whether their intended study activity represents rehearsal, elaboration, or organization[4]. During class, the team leader organizes the group and the timekeeper ensures everyone remains on task as the team executes their plan.

Know

An underlying theme of the course is the importance of self-reflection. The assignments that fall within the category of *know*, specifically a series of reflections and a final portfolio, focus on giving students the opportunity to reflect regularly on their progress and growth as students and emerging engineers.

Students begin and end the semester by reflecting on their values and purpose for matriculating in engineering. The "big picture" reflections, entitled "It Matters to Me" (Appendix C), instruct students to consider their purpose, their most important aspects of life, and their professional decision to pursue engineering.

Ten in-class reflections are built into the course. The reflections, linked to course content and experiences happening at certain points during the term, prompt students to think more deeply about what they are learning about themselves throughout the semester.

The final portfolio is more limited in application than is intended with the EL model in that our application consists of three synthesis assignments: writing a new "It Matters to Me" reflection with a discussion of what changed since the first writing, a "Letter to Myself" to offer mentoring to oneself as if starting the semester anew, and a narrative of one's learning journey through description of two challenging experiences. In this specific application students craft a compelling, evidence-based narrative with documentation of their learning at the conclusion of the semester. The assignments ask students to review how they regulated their own learning behaviors, reflect critically on what they learned and on their experiences during the semester, document skills or concepts they integrated into their habits or mindset, and explain what collaborative skills they gained. Unlike the ideal EL portfolio, our application is not a single unified document, nor is it shared collaboratively for feedback from peers.

Discussion and Implications for Practice

Previous research[2] suggests the learning strategies course is a critical component of the GELC. Based on qualitative data from written reflections and interviews, students report numerous benefits as a result of the course, including enhanced metacognitive awareness, confidence in their abilities as students and emerging engineers, sense of belonging within the engineering community, and integration of content and skills across STEM courses[2,23]. Though long-term retention data do not yet exist as the program is in its third year, preliminary quantitative data suggest co-enrollment in the learning strategies course and membership within the GELC are linked to higher final grades in STEM courses in the first semester[24], as well as improved retention from first to second year in engineering[25].

From three semesters of implementation (Fall 2017, Fall 2018, and Fall 2019) we offer a number of lessons learned that may be helpful to others considering a similar approach. A learner-centered approach to a course filled with scaffolded active, self-directed learning experiences requires a significant investment in advance. The course we described has learning activities that are sequential and iterative, so spacing and preparing scaffolding that aligns with assessment rubrics requires comprehensive planning before the semester begins. To plan a culminating portfolio assignment requires thinking at the beginning of the semester about writing prompts and planning the types of assignments and formative feedback along the way to facilitate the students' learning development so that they can be successful with the final portfolio by the time they reach the end of the semester.

A learner-centered approach also presumes the instructors will shape the course in progress to respond to the overall needs of the students. Since the course integrates learning strategies with students' co-enrolled STEM courses, the assignment schedule and activities must consider other courses' examination and major assignment schedules. Changing the schedule for class content mid-semester is a possibility and should be constantly evaluated to determine if alterations are needed.

While having the support of a learning strategies expert is important, it is also important to have the support of engineering faculty. The value of the course may be more credibly communicated when engineering faculty teach the learning strategies. Adding this course to faculty loads requires buy-in from the faculty and department leadership. Gathering the faculty and learning strategies staff for professional development before the semester begins is essential so all involved understand the goals, methods, practices, and language that will be used. Designating a single person to coordinate the course eases the load and maintains the organization of a multi-section course. It is essential the coordinator be involved in teaching the course.

Conclusion

This paper provided an overview of the learning strategies course associated with the General Engineering Learning Community (GELC) at Clemson University. In sharing information related to the framework, specific course activities and assignments, preliminary results, and implications for implementation, the goal of this paper is to inspire other educators to consider how to incorporate principles from the GELC's learning strategies course into their own course design. Promoting self-directed learning activities individually and collaboratively, applying practices to seek improvement and metacognitive awareness, and synthesizing knowing through reflection, combined with practices used in industry, creates a rich environment for emerging engineers to develop personal and professional skills for success.

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Elizabeth A. Stephan

Dr. Elizabeth Stephan is the Director of Academics for the General Engineering Program at Clemson University. She holds a B.S. and a Ph.D. in Chemical Engineering from the University of Akron. Since 2002, she has taught, developed, and and now coordinates the first-year curriculum. As the lead author of the "Thinking Like an Engineer" textbook, currently in its 4th edition, she has been the primary author team–member in charge of the development of the MyEngineeringLab system.

Abigail T. Stephan

Abby Stephan is a doctoral candidate in the Learning Sciences program at Clemson University. Broadly, her research interests include intergenerational learning in informal settings, self-directed learning, and cultural influences on the learning process. Abby currently works as a graduate assistant for the General Engineering Learning Community (GELC), a program that supports first-year engineering students in their development of self-regulation and time management skills, effective learning strategies, and positive habits of mind.

Laurel Whisler

Laurel Whisler is Assistant Director and Coordinator of Course Support Programs in Clemson University’s Westmoreland Academic Success Program. In this capacity, she provides vision and direction for the Tutoring and Peer-Assisted Learning (PAL) programs and provides support to the General Engineering Learning Community. She is also co-developer of Entangled Learning, a framework of rigorously-documented, self-directed collaborative learning. She has an M.A. in Music from The Pennsylvania State University and an M.L.S. from Indiana University.

Matthew K. Miller

Matt Miller is a Senior Lecturer in the General Engineering Program at Clemson University. His background in industrial engineering and engineering education have helped him develop innovative ways to deliver engineering curriculum for freshman engineers and talented high school students interested in engineering.

Andrew I. Neptune

Andrew Neptune is a lecturer with the General Engineering department at Clemson University. He teaches courses that introduces the engineering disciples, develops problem solving skills, and instructs in computer programming, mainly to first-year engineering students. Andrew has had the opportunity to support the General Engineering Learning Community (GELC) and the Boyd Scholar program in University Success Skills course. His doctoral degree is in Civil Engineering with research interests in Optimization of Porous Pavements based on Aggregate Structure.

Appendix A: Sample Peer Sharing Presentation Topics

Round 1: Life Management Strategies	Balanced diet and importance of nutrition	Effective communication	Health and wellness (i.e. exercise, meditation)	Organization (i.e. using a planner)
Round 2: Learning Strategies	Concept maps Spacing effect	Peer Assisted Learning	Feynman Technique Studying with quizzes	Doodling Interleaving
Round 3: Time Management Strategies	Managing energy	Balancing academic and social life	Creating an effective to-do list	Mindfulness
Round 4: Best Success Strategies	Exercise Taking practice exams	Using a planner Using ASC services	Reviewing notes Attending Office Hours	Interleaving Sleep

Appendix B: Sample PBGA Agenda

Team Leader (TL): Tayshia Lewis*
Timekeeper/Secretary (T/S): Grace Phillips*
Team Members: Tayshia Lewis*, Grace Phillips*, Jada Barnes*, Isla Kellison*

** Take group attendance, determine what materials each person brought, and discuss what changes, if any, should be made to the agenda.
- Time: 5 minutes
- Purpose: [PLAN] Check-In; Record the group attendance, materials list, and any changes to the agenda in this discussion thread.
- Lead [*sic*.] by: Grace

**** Agenda Topic: Engineering 1900**
- Time: 30 minutes
- Purpose: Our group intends to review sinusoids and vectors . We intend to specifically review chapters 4 and chapters 6. We will work out practice problems in the book and review homework questions. It is expected that everyone will have questions to ask during the review session to better understand what needs to be reviewed.
- Metacognition Category: This activity is more rehearsal and organization. We intend to review notes and organize notes to best comprehend what was taught. This activity is also, rehearsal because we intend to review several homework problems.
- Materials needed & who is responsible (if any are needed):
- Engineering 1900 Textbook, notes, and review problems
Responsible: Jada
- Pre-Meeting actions necessary & who is responsible (if any are needed):
Jada should be prepared to answer questions on vectors and co terminal angles. She should be prepared to review vector addition and finding the magnitude & theta by using law of sines and cosines. Jada should bring her textbook, notes, and review problems.
- Lead by: Jada Barnes

**** Agenda Topic: Chemistry 1010**
- Time: 35 minutes

- Purpose: The group intends to review polarity and non polar compounds. More specifically reviewing intermolecular forces such as dipole-dipole, hydrogen bonding, and London Dispersion forces. The group should discuss which bonds hold these such forces.
- Metacognition Category: This activity is mostly elaboration and rehearsal. The group will review old exam 2 problems for chemistry and review the powerpoint if needed. The group will also elaborate the topics learned and explain how electronegativity correlates to the strength of a compound.
- Materials needed & who is responsible (if any are needed):
Isla should be prepared to have old exam questions to review. She should bring her notes to class/ powerpoint worksheet. Isla should have answers prepared for the questions she may receive.
- Pre-Meeting actions necessary & who is responsible (if any are needed):
Isla needs to review and understand recent topics previously learned in chemistry class.
- Lead by: Isla Kellison

Agenda: Post meeting discussion.
- Time: 5 minutes
Purpose: Determine the Leader and Secretary for the next meeting. Decide topics to discuss and needed materials. Determine what we can do to improve the next meeting.
Lead by Group Leader: Tayshia Lewis

*Student names have been replaced with pseudonyms

Appendix C: "It Matters to Me" Reflection Prompt

Purpose: Having a clear idea of what matters to you supports motivation. This assignment asks you to document what matters to you as you start the semester and is something you can refer to as a reminder of why you are here.

Expectations: Create a written document, saved as a PDF file, or make a video, discussing the three areas listed below. Include and identify your three biggest rocks, which may fit into any category. Go into the amount of depth and write/speak with the quality that you would include if someone were interviewing you for a job.

Purpose Reflection:
Discuss your purpose for attending Clemson and studying engineering, including: What is your choice of engineering major, if you had to choose one today? Why are you interested in this major? Why is pursuing engineering important to you?

Personal Reflection:
List the top three areas on the Wheel of Life that you feel are most important to your personal success. Explain why you chose each area.

Professional Reflection:
In the Engineering Creed, the first two affirmations are:

I pledge:
To give the utmost of performance;
To participate in none but honest enterprise;

What does this mean to you when you think about the details of your approach to being a student and preparing for your career? Give examples that show how you aspire to incorporate these affirmations in your day-to-day work of being a student.