Using Experiential Learning in Course Curriculum: The Case of a Core Engineering Graphics Course

Dr. Martha M. Snyder, Nova Southeastern University

Martha (Marti) Snyder, Ph.D., PMP, SPHR teaches undergraduate and graduate courses in learning design and technology, design thinking, project management, and computing privacy and ethics. She also chairs doctoral student dissertations. Marti researches effective designs for teaching and learning in face-to-face, blended, online, mobile, and virtual learning environments; and issues relating to technology use among older adults. Her work crosses multiple disciplines including education, engineering, information systems, and health professions. Marti has published articles in national and international journals and is an active reviewer for journals and conferences in her field. Her current research focuses on use of remote monitoring technologies by informal caregivers as well as effective instructional designs for face-to-face, blended learning, simulations, and mixed-reality.

Dr. Manuel Salinas, Nova Southeastern University

Dr. Manuel Salinas received his Bachelor of Science (2009), Master of Science (2011) and Ph.D. (2014) in Biomedical Engineering from Florida International University.. He was a post-doctoral fellow at Harvard Medical School before joining Nova Southeastern University. He is a founding assistant professor of the Department of Engineering and Technology at the new NSU's College of Engineering and Computing where he designs classes and program objectives in addition to teaching. He has published several papers in academic journals relating to heart valve tissue engineering studies. His research areas include vascular tissue engineering, artificial organs, and cardiovascular biomechanics. In addition, He enjoys collaborating in projects related to computational fluid dynamics, fluid structure interactions; algorithm optimization; finite element/volume analysis, computer aided design; steady and transient data visualization among others. In his free time he practices soccer and tennis.

Dr. Molly J. Scanlon, Nova Southeastern University

Molly J. Scanlon, Ph.D., is an Associate Professor in the Department of Writing and Communication in the College of Arts, Humanities, and Social Sciences (CAHSS) at Nova Southeastern University. She teaches graduate and undergraduate courses in first year experience, composition, writing studies, and visual rhetoric. Research interests include visual rhetoric, identity construction, and experiential learning pedagogy, with publications in Composition Studies, Reflections, and ImageText; and presentations at Frontiers in Education, Conference on College Composition and Communication, National Council of Teachers of English, Florida Distance Learning Association, and the National Society for Experiential Education.

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Introduction

In Fall 2017, Nova Southeastern University (NSU) launched an experiential education and learning program (ExEL) for all undergraduate students. In this paper, we describe a work-in-progress (WIP) that focuses on the establishment of this university-wide program and the re-design of an engineering graphics course that embeds experiential and active learning pedagogies. The paper is organized as follows. First, a brief overview of experiential education and relevant theories, principles, and guidelines will be discussed. Second, an overview of the experiential education program at NSU and the role of faculty champions will be presented. Third, a case involving the re-design of an engineering graphics course will be shared including how an experiential education course qualification form and rubric were used to guide course design and formative evaluation. Finally, next steps will discuss plans for continuous improvement and refinement of the course design and formative evaluation process.

Experiential Theories, Guidelines, and Principles

Grounded in the early works of Dewey, Lewin, and Piaget, experiential learning theory has become increasingly popular in higher education. "In its simplest form, experiential learning means learning from experience or learning by doing. Experiential education first immerses learners in an experience and then encourages reflection about the experience to develop new skills, new attitudes, or new ways of thinking [1]." Experiential learning serves as a foundation for lifelong learning and the development of the whole self as a citizen, family member and human being [2]. Various theories, guidelines, and principles have been identified in the research literature that can be used to guide the instructional design of experiential learning in course curriculum.

Kolb's experiential learning theory (ELT) provides a process framework that can be used in a variety of different learning settings. There are four modes in the ELT learning cycle including experiencing, thinking, acting, and reflecting. Through a recursive engagement with experiencing and thinking coupled with reflection and active experimentation, learners experience an ideal and balanced learning process [3]. Application of Kolb's ELT and learning cycle is not uncommon in engineering, especially in the design of capstone courses. For example, Jassim [4] used Kolb's experiential learning cycle to guide the design of capstone design projects in mechanical engineering. Potisuk [5] also used Kolb's guidance to design a two-semester capstone sequence in electrical and computer engineering.

Informed by the work of Kolb and many others, the National Society of Experiential Education (NSEE) proposes eight principles of good practice for all experiential learning activities. These principles include intention, preparedness and planning, authenticity, reflection, orientation and training, monitoring and continuous improvement, assessment and evaluation, and acknowledgement. NSEE emphasizes the equal importance of both the experience and the learning and the shared responsibility between the learner and the facilitator(s). However, it is expected that the facilitator(s) are responsible for ensuring quality in both the learning experience and the work that is produced [6].

Clark's [7] Guided Experiential Learning (GEL) is a course development process model that provides specific design guidance for the development of learning experiences that "guide the cognitive (mental) processing that supports learning." Clark recommends the following course structure:

- Course Goal: Begin each course by introducing the course goal.
- Reason for the Course: To gain the learner's attention, explain the reason for the course in terms of why it is important for them to master the content.
- Course Overview: Provide a visual model of the course overview as an advance organizer for the learners. This overview should include the sequence of the course along with instructional strategies that will be used.
- Lesson Structure: The lesson structure is consistent throughout the course. Each lesson should include the following elements: present learning objectives; explain reason for course; provide course overview; review pre-requisite skills; demonstrate procedures; allow practice; give and feedback on practice. Lessons should be presented in the order in which the learner will practice them in the field and if there is no order, lessons should be presented from easy to more difficult.

Clark's [7] GEL model echoes many of the principles of best practice (e.g. orienting students to the course goals, authentic simulation of field-based concepts, moments of reflection through review of pre-requisite skills, etc.). And, application of GEL has shown positive results when applied to simulation-based instruction. For example, Craft, Feldon, and Brown [8] conducted a quasi-experimental randomized block design to compare Kolb's ELT with Clark's GEL to determine which instructional design was more effective in training nurse anesthetists on the central venous catheritization procedure. They found participants who receive training using GEL, performed significantly better than those in the ELT condition. This study implies that in simulation-based learning environments, GEL can be more effective.

Because experiential education is a pedagogical framework, it can be combined with the best practices in any discipline to inform learner-centered course design and delivery that aim to meet accreditation standards and outcomes. The Accreditation Board of Engineering and Technology (ABET) Engineering Accreditation Commission's (EAC) Criteria for Accrediting Engineering Programs [9] states the following student outcomes. (Note effective with the 2019-2020 accreditation cycle, the new ABET EAC Criterion 3 Student Outcomes will replace the a-k outcomes.)

(a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to analyze and interpret data
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
(d) an ability to function on multidisciplinary teams
(e) an ability to identify, formulate, and solve engineering problems
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and social context
(i) a recognition of the need for, and ability to engage in life-long learning

(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Experiential education and active learning methods have proven not only to help students achieve these outcomes but also improve student retention and graduation rates [10]. ELT, NSEE's *Eight Principles,* and GEL provide frameworks from which instructional methods that emphasize authentic, hands-on activities can be developed within course curriculum. This case study shares the institutional factors that inspired and supported such an effort as well as the specifics of how these best practices in experiential learning pedagogy were used to strengthen the design of an undergraduate engineering graphics course.

Experiential Learning Program

In 2015 NSU's president authorized the creation of an experiential education program for all undergraduates with the belief that students who engage in experiential education opportunities will be more likely to persist, graduate and become lifelong, self-directed learners [2]. In fall 2017, the university launched its experiential education and learning program (ExEL). First time in college (FTIC) students in the class of 2021 will complete six credit- or non credit-bearing units of experiential education prior to graduation. Students earn ExEL credits through curricular and co-curricular experiences including internships, study abroad, community service, faculty-led research, and ExEL-designated courses (i.e., first year seminar, capstones, and discipline-specific courses). With senior administration's commitment and guided by a grassroots, faculty-led Experiential Education and Learning Advisory Council (EELAC), a plan for experiential education was underway. Comprised of ten faculty from undergraduate-serving colleges and five professional staff from student affairs, the purpose of EELAC was to create a structure within which ExEL would be standardized at the university. Over twelve months, EELAC developed the mission and goals of the program, decentralized ExEL to 18 colleges and 18 operational units, identified existing co-curricular and curricular experiential opportunities, established an ExEL qualification process based in the *Eight Principles,* created an ExEL website and marketing plan, and oriented the incoming class of 2021.

Faculty Champions

Sustainable organizational change is largely dependent upon developing and investing in people, and research into higher education organizational change emphasized the importance of faculty buy-in [11]. Seventeen faculty members from nine of its eighteen undergraduate-serving colleges and four professional staff attended NSEE's Experiential Education Academy, which consisted of six workshops – three offered in December 2016 and three in May 2017. Once these courses were completed, faculty earned their national certification from NSEE and became experiential learning fellows. These fellows served as faculty champions of experiential education for the university, another best practice in institutional change [11] and were asked by administration to share information about experiential learning with their colleagues, identify other faculty who were interested in experiential and active learning teaching methods, and assist faculty who were interested in submitting their course to the EELAC curriculum committee for review, evaluation, and designation as an ExEL course. Taking an ExEL discipline-specific course is one way students could earn a unit toward their six-unit ExEL requirement.

Experiential Coursework

Experiential coursework is coursework that encourages students to engage in active learning by presenting them with situational and real-world context. To be considered an ExEL qualified course, the faculty member who teaches the course must complete an ExEL qualification form, have it approved by their department chair and dean and submit it for review by the EELAC curriculum committee. The ExEL qualification form was developed by EELAC and is based on the National Society of Experiential Education's (NSEE) *Eight Principles of Good Practice for All Experiential Learning Activities* [6].

The Case of GENG1012: Engineering Graphics

The first author is a faculty champion who worked with the second author, an early-career faculty member in the engineering and computer science department to qualify his course using the ExEL qualification process. The third author is the faculty coordinator for the ExEL program. In this section, an overview of the bachelor of science in engineering program will be described followed by a description of how the ExEL qualification form and rubric were used to design and formatively evaluate the course. This course was selected because 1) the professor expressed interest in developing his teaching skills, 2) the course already included experiential components such as an authentic project, and 3) the course is part of the core an is usually taken during a student's freshman year.

The university offers a bachelor of science in engineering with two concentrations available including biomedical engineering and industrial and systems engineering. Students must complete a total of 126 credit hours to earn the degree including 33 general education requirements; 6 open electives; 37 major prerequisites; and 50 major core requirements. In addition, each concentration is 15 credits. GENG1012: Engineering Graphics is a three credit-hour core course. GENG1012 covers the foundation of computer aided graphics; setting up engineering drawings, annotation and implementation; and an introduction to computer-aided design (CAD) software.

Students who complete the course are able to:

1. Describe principles of engineering design.
2. Demonstrate computer literacy.
3. Describe the major components associated with multi-dimensional visualization, modeling and graphics in engineering.
4. Use computer-aided design (CAD) software to create multi-dimensional parts and assemblies used in engineering components and systems.
5. Design a simple engineering device, create a report, and present it using engineering graphics language.

Students are assessed as follows:

- Midterm Exam – 20%
- Final Exam – 25%
- Quizzes – 25%
- Project – 25%
- Attendance and Participation – 5%

ExEL (Experiential Education & Learning) Qualification Form

The ExEL qualification form is used to review both credit- and non-credit bearing experiential opportunities. In this instance the qualification form was used to qualify GENG1012: Engineering Graphics as an ExEL course. The ExEL faculty champion worked with the engineering professor to identify and clarify experiential course activities. Following are the criteria along with a brief description of how the course meets the criteria.

1. **The experience is structured, intentional, and authentic:** Describe the experiences and explain how experiences become the primary means through which students achieve learning/activity outcome(s). How will students be informed of the experiential nature of the course?

Students use both free-hand and computer aided design tools to design a simple engineering device and write a report to accompany the design. This project and accompanying report demonstrate their ability to formulate and justify a solution to a modern engineering problem. Students will be informed of the experiential nature of the course during their first week of class.

2. **The experience requires preparation, orientation, and training:** How are students prepared for the experience? How does the faculty member prepare for the experience?

Students are introduced to foundational knowledge and skills required to design engineering solutions. For example, students will learn professional aspects of drawing including terms, symbols, and conventional practices. They will learn methods used for free-hand sketching. They will also develop knowledge and skills in pictorial methods of representation including isometric and oblique axis systems. They will explore methods and uses of auxiliary views and the theory behind the technique. These knowledge and skills include acquisition of a common vocabulary and engineering principles that enable them to read and create drawings from classic 2D drawings to 3D drawings. Students will practice sketching, visualization, and solid and assembly modeling techniques. Using CAD software such as Solidworks and ANSYS, students will create a virtual geometry of a 3D device such as a vehicle engine, medical device, etc. The professor will facilitate active learning strategies such as retrieval practice of important facts, concepts, and principles will help students develop foundational vocabulary that is needed to design their engineering device. The professor will also be prepared to guide students in class, model expected behaviors, and demonstrate key competencies.

3. **The experience must include monitoring and continuous improvement:** What strategies will be used for observing learner's progress? Describe the established feedback loop and how it allows for flexibility to change in response to what feedback suggests.

During the design process, students will have the opportunity to share their work in progress with the professor and receive formative feedback. Students will be able to modify their design based on the feedback they receive from the professor.

4. **The experience requires structured reflection and acknowledgement:** Recognition of learning and impact occur throughout the experience. All parties to the experience should be included in the recognition and celebration of progress and accomplishment. How are students encouraged to recall past learning prior to the experience? How are students encouraged to test assumptions and hypotheses, and consider the outcomes of decisions and actions taken? How are students encouraged to weigh the outcomes against past learning and future implications?

At the beginning of the course, students will be asked to reflect on their past experience when they have drawn something and used drawing and measuring tools such as rulers, compasses, and triangles. This activity is important because it emphasizes the importance of communicating visually. Throughout the course, students will be able to practice what they have learned by using ANSYS and Solidworks software. Students prepare a final project that includes a paper and presentation. As part of the student's final assignment they will write a reflection about their design with regard to how the hands on activity helped them to understand the importance of computer graphics in today's industry and the value of communicating effectively using engineering graphics language. Students are assessed on the relevance and complexity of their device, the content of the paper and oral report, and responses provided in a Q&A following the presentation.

5. The experience must be assessed and evaluated: Describe how the faculty member communicates the methods of assessing achievement of learning objectives to students including assessment criteria. Identify moments and methods for students to evaluate the experience.

Assessment methods for course learning objectives are described in the syllabus. Methods include objective examinations, quizzes, homework, projects, and research reports. Students are able to evaluate the experience through their reflection paper as well as the university's course evaluation system.

ExEL (Experiential Education & Learning) Rubric

Once the qualification form, syllabus, and supporting documents (i.e. instructions for the design project) are submitted to EELAC, the materials are reviewed by three faculty representatives using the ExEL rubric. The rubric aligns with the qualification forms five criteria and asks the reviewers to rate each criterion with regard to strength of evidence as strong, medium, and low. In addition, there is a section for reviewer comments. The reviewer can approve the course with no revisions, reject the form, or accept with revisions. The course was accepted with minor revisions to the syllabus that would reflect the experiential nature of the course.

Formative Evaluation

During the process of instructional design, formative evaluation is used to identify whether the instruction, such as a course, is meeting the intended objectives. It serves as the "quality control of the development process" [12]. While summative evaluation is conducted once a course has been established and taught a few times, formative evaluation is most effective when it is used during the development of a new course or revision of an existing one. That way, if weaknesses are identified, they can be addressed and eliminated early on [12]. Gooler [as cited 12] recommends an eight-step formative evaluation approach including the following:

1. Purpose (Why is the evaluation being conducted?)
2. Audience (Who are the target recipients of the evaluation results?)
3. Issues (What are the major questions/objectives of the evaluation?)
4. Resources (What resources will be needed to conduct the evaluation?)
5. Evidence (What type of data or information will be needed to answer the evaluation questions?)
6. Data-gathering Techniques (What methods are needed to collect the evidence needed?)
7. Analysis (How will the evidence collected be analyzed?)
8. Reporting (How, to whom, and when with the results of the evaluation be reported?)

Student and Professor Reflections

The engineering graphics course was delivered in its ExEL format for the first time in fall 2017. The first round of formative feedback from the course professor and the students has been positive. Some students mentioned that at the beginning of the course they were anxious about the project and worried that they might not finish on time, but as the class progressed they began to gain confidence in their ability to use graphics language and CAD tools.

Student reflections on the project revealed their feelings of confidence in building CAD devices. For example with regard to, one student commented, "I really enjoyed working on this project because I was able to explore the many features of CAD software and I was able to show people a bit about myself and how I think. I definitely feel more confident in my ability to produce 3D models after doing this project." Another student noted, "This project helped me grow as an engineering student because it really opened my eyes as to how things work and are put together. It also made me realize how useful the computer-aided designs are. We are capable of putting together any assembly without exhausting our resources!" Students also felt more confident about their decision to choose engineering as a field of study. For example, one student commented, "After completing my chair, I felt very proud and happy of what I had accomplished. Working with these programs and working on this project has helped me see my future in engineering and has made me more excited than ever."

The faculty member reflected on his experience as well noting that students performed better after giving them ample time to work on their projects in class where the professor could guide their work. He hopes to create a better balance between homework and in-class project time next semester. He also noted the need for students to gain a more solid foundation of the facts, concepts, principles, rules, procedures associated with engineering graphics and requested assistance on strategies for creating a more active learning atmosphere when teaching these foundational knowledge and skills.

Conclusions and Next Steps

The ExEL program at our university is in its infancy. The first round of ExEL qualified courses were delivered in fall 2017. The establishment of an EELAC, training of faculty champions, and development of a structure to design and review experiential coursework offers a framework through which faculty can mentor other faculty in the development of experiential learning competencies and evaluate experiential course curriculum. As a work-in-progress (WIP) paper, the purpose of this paper was to present a theoretical foundation supporting the value of experiential education in higher education, discuss how ExEL was launched at our university, and describe how faculty worked together to deliver courses in an active and experiential way specific to engineering education course design.

The formative evaluation process is not complete. Only preliminary feedback through student and faculty reflections has been captured to date. Further development and refinement of the qualification form and rubric may be needed in addition to the establishment of a more formal formative evaluation process such as the eight-step process described. By creating a formal formative evaluation process, a feedback loop can be established for continuous improvement of ExEL qualified courses.

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