Integrating Research into Undergraduate Courses: Experiences from a Multi-Disciplinary Faculty Learning Community

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Abstract

A Faculty Learning Community (FLC) in any university provides an excellent way for faculty to both innovate and improve teaching methods and styles. When our FLC, consisting of seven faculty members and two staff members, convened, it became apparent across academic disciplines that undergraduate research warranted emphasis. Undergraduate research integration into curriculum promises benefits: student engagement and development of employer-desired skills such as communication, teamwork, analytical reasoning, and the application of knowledge to real-world settings. This paper details the FLC's efforts to incorporate more research into seven undergraduate classes by using discovery learning pedagogies and to begin compiling a list of best practices to share with others. The fact that these efforts span different undergraduate grade levels and disciplines offers key insights for any undergraduate program. Further, discussions about the formation and collaboration of the FLC at this university presents a guide to others for starting one of their own.

Keywords

Faculty learning community, discovery learning, undergraduate research

1. Introduction

Industry expects students to conduct research, think abstractly, and work in teams. Incorporating research into undergraduate classes can enhance student learning and performance in all those areas,[15,16] but incorporating it bears two inherent challenges. Course content in most cases must give way to introducing or incorporating research. An even larger hurdle, faculty accustomed to certain teaching methods and pedagogies have to change their approach and take the risk of incorporating research into their classes. This paper presents an initial effort by an innovative Faculty Learning Community during the 2015-2016 academic year to find the best ways to overcome the challenges associated with incorporating research into undergraduate classes.

This paper presents a series of course-specific approaches with comments about their effect on student learning. Diverse experiences from six courses in five STEM disciplines and one in global security and intelligence provide ideas from previously tested methods for incorporating research. The total of seven classes included in this study had a total of 341 students ranging from the second to the fourth year. Admittedly, the small size of the university and correspondingly small class sizes (less than 30) made it easier to maintain contact with students, improving monitoring and feedback.

For those thinking about incorporating research, this paper offers insights, some course-specific and some generic, about the associated challenges and how to improve the initial experience for both professors and students. At the end of the project's first year, the FLC felt that the outcomes of incorporating research warrant the costs. By offering insights and lessons learned from this particular experience, this paper will help other faculty avoid surprises, lower initial costs, and enrich the experience of their students.

2. The Basics & Benefits of Faculty Learning Communities

A Faculty Learning Community (FLC) is a group of trans-disciplinary faculty working together in groups of 8 to 12.[1] Each FLC engages in an active, collaborative, year long program with the goal of enhancing teaching and learning. Participants in FLCs may select projects that allow for experimenting with teaching innovations and assessing resultant student learning. FLCs increase faculty interest in teaching and learning, and provide safety and support for faculty to investigate, attempt, assess, and adopt new (to them) teaching and learning methods. After participation in an FLC, faculty report using new pedagogies, while also seeing improvements in students' critical thinking and ability to synthesize and integrate information and ideas, often in an holistic manner.[1] Additionally, FLC participants in one study reported improved teaching effectiveness, confidence, and an increase in knowledge about how students learn.[2] Faculty participation in FLCs also has been shown to improve scholarly productivity, create stronger connections with colleagues and students, and foster greater collegiality across the institution.[3-5] More recent research showed by participating in an FLC, faculty development is enhanced through opportunities for professional learning and growth.[6]

As a topic-based learning community, which designs a curriculum to address a special campus or divisional teaching and learning need, issue, or opportunity, faculty from the Embry-Riddle Aeronautical University Prescott Campus' Colleges of Engineering, Global Security and Intelligence, and Aviation formed a topic-based learning community during the 2015-2016 academic year. The topic of interest and study focused on ways of integrating aspects of research into the undergraduate curriculum, which is one approach for discovery learning and is also a current university initiative. As such, each faculty member implemented one or more types of discovery learning in one or more of their courses during the 2015-2016 academic year.

3. Discovery Learning

Discovery learning is a specific type of active learning strategy that allows students to have hands-on learning opportunities, focusing on the process of learning through inquiry and the exploration of concepts. Failure and feedback are both important and necessary for learning to occur. Discovery learning is constructivist in nature; it is grounded in inquiry-based instruction where learners build new knowledge from prior knowledge and active experience. Further, discovery learning focuses on the process of learning rather than the product. Discovery learning takes the form of a variety of pedagogies, including, but not limited to: problem-based learning, case-based learning, simulation-based learning, and project-based learning. As a result, methods of discovery learning result in a greater and deeper understanding of course content.

Discovery learning is characterized by three main attributes[7], as cited by Castronova[8], all of which prove integral to the teaching and conduction of research:

1. Using exploration and problem-solving to create, integrate, and generalize knowledge.
2. Using student-driven, interest-based activities where students determine the sequence and frequency.
3. Involving activities to encourage the integration of new knowledge into the learner's existing knowledge structure.

3.1. How Research Impacts and Improves Learning

Nationwide, undergraduate research and scholarship is recognized as a high impact practice that increases student engagement and success.[9] In addition, undergraduate research has been shown to provide the skills employers are looking for: Communication, teamwork, analytical reasoning, and applying knowledge to real-world settings.[10,11] The traditional model for involving undergraduates in research is an apprenticeship model with either one-on-one interaction between a mentor and student or mentorship of a team. However, as defined in the PCAST report[12], National Academies of Sciences, Engineering, and Medicine[13], and recently highlighted by Elgin, et. al.[14], this often limits the total number of students who are involved in undergraduate research and primarily targets students during their junior and senior years. Therefore, an increasing number of institutions and individual faculty are identifying ways to integrate research into their courses and program curricula, which results in greater involvement of the student population as a whole. This relatively new approach for learning how to conduct research at the undergraduate level provides for scaffolding of research skills across a curriculum.

Given the mission of *Embry-Riddle Aeronautical University*, "…to teach the science, practice, and business of aviation and aerospace, preparing students for productive careers and leadership roles in service around the world.", it is not surprising that undergraduate research is already an important part of the university culture. The current Quality Enhancement Plan, part of the Southern Association of Colleges and Schools Commission on Colleges accrediting requirements, focuses on engagement of students in research and scholarship through both curricular and co-curricular activities.

Between the importance of this university initiative and innate interest of all FLC members to teach skills and knowledge relevant for conducting research, each FLC member selected a form of discovery learning most applicable to their discipline that fostered the development of such skills pertinent for conducting research at the undergraduate level.

In the next section, we discuss the resulting seven course-specific approaches with comments about the inherent challenges, opportunities, and effects on student learning.

4. Implementations of Discovery Learning

4.1. Engineering Fundamentals Course

In order to implement problem-based learning in an introductory engineering programming course, groups of first and second-year undergraduate students were required to design an automated mechanism for sorting Lego robot parts based on their shapes or colors. Additionally, students presented their preliminary design review and wrote a technical report. Students were asked to complete a self-report survey adapted from the rubrics of AACU Value Assessment of Learning in Undergraduate Education (https://www.aacu.org/value-rubrics), for which they evaluated their creative thinking, oral and written communication, and teamwork skills once before the project started and once at the project's completion. Pre/post tests were administered to check for significant improvement in all four skills. Students were also asked to respond to an additional questionnaire designed by the instructor to acquire further information specific to the project; see Table I. Here, blue and red cells for each row refer to the sub-skills with the smallest and the largest average differences between pre and post project data.

While the overall objectives of the design were given, selecting among alternative design solutions and details as well as the level of difficulty for the final product was left for the students to decide. Students had to apply the material taught in class to a real-life mini-industrial project and learn about software-hardware communications. Furthermore, to fulfill the requirements for one of the tasks, they had to study an advanced topic of MATLAB programming, i.e., creating Graphical User Interfaces on their own; hence, engaging in a form of self-directed learning. Lastly, the students had to learn how to effectively work in teams outside of the classroom in order to deliver a final oral presentation and written report about the project.

In this project, the students were given an opportunity to enjoy a hands-on experience in programming and learn about hardware-software communication. This is typically not included in the syllabus of a first-year introductory programming course. They could learn how to design a mini-industrial robotic project and add value to their resumes. They could also reinforce what they learned in this course as well as the material from a pre-requisite engineering fundamentals course where they worked with Lego Mindstorm robots. Finally, the students understood the benefits of active learning as opposed to traditional lectures, including self-directed learning, and obtain improvement in critical thinking, oral and written communication, and teamwork skills.

One-tailed paired *t*-test with a significance level of 0.05 tested for differences between responses on the AACU rubrics completed *before the project started* and *after the project was done*, for critical thinking, oral and written communication, and teamwork skills. It was hypothesized that conducting this project would lead to a significant increase in each measured skill, meaning that the averages of sub-skills for each skill after the project completion will be significantly bigger than what they were before the project started, i.e., probability of pre- and post-averages for each sub-skill belonging to the same population is less than 0.05. Results for each item on each of the rubrics are in Table II in Appendix A. Furthermore, the questionnaire using a response scale of 1 (Strongly Disagree), 2 (Disagree), 3 (Neutral), 4 (Agree), and 5 (Strongly Agree) showed significant results for a variety of items. Table I shows the results for the questionnaire.

4.2. Digital Circuit Design Course

Faculty in the electrical engineering program investigated the impact of research, when introduced across both class and lab sections of the same course. Students in a freshman-level digital circuits design class, which was historically biased to electrical and computer engineering (EE/CE) majors, served as study participants. Since over 85% of the students enrolled in the course were aerospace and mechanical engineers (AE/ME), we wanted to observe whether the students connected disparate EE/CE laboratory topics to real-world AE/ME applications (problem-based learning) after writing a substantial research paper on a topic of their choosing, within the broad category of aircraft control systems and design.

Table I – Average of the Responses to the Extra Questionnaire in the Introduction to Engineering Course. Scales of 1 to 5 refer to Strongly Disagree, Disagree, Neutral, Agree, and Strongly Agree, respectively.

Question	Average Response
Because of having hands-on experience and learning about hardware-software communications in this course, I think I am knowledgeable to apply what I learned in the future robotics and controls courses, which require running robots, such as Lego EV3 with MATLAB.	4.04
Because of having hands-on experience and learning about hardware-software communications in this course, I think I am knowledgeable to apply what I learned in the future real-life industrial problems, which require communication between hardware and software.	4.12
I think that fulfilling this project, which is a modified version of a graduate automation project, during a semester, might count as a worthwhile item in my resume for future employment opportunities.	4.36
I learned more from this project by working outside the class rather than inside the class.	3.32
I learned more from this project by working in a group rather than individually.	4.08
Because of working with Lego robots and webcams and having hands-on experience in this course, I enjoyed this class more than a purely-programming course.	3.84
I think the need to use programming for the final project reinforced what I learned in class about MATLAB coding.	.96
I think the need to build two different robots using the Lego EV3 kits and work with these robots for the final project reinforced what I learned in the "introduction to engineering (EGR 101)" course about the Lego robots.	3.92
Through this self-directed learning process of studying about GUI development in MATLAB on my own, I could achieve sufficient understanding of how to make a GUI in MATLAB.	3.44
I might learn more about developing standalone apps from MATLAB GUI's to earn money in the future.	3.4

Several challenges emerged in this exercise. One of the most challenging aspects was gaining student compliance. While a majority of the students were interested in the topics they were researching, several students expressed discontent at the volume of work that needed to be done for a freshman-level class. Of the 90 students enrolled, 9 failed to complete the research

assignment altogether, despite it being worth 10% of the final grade in the class. Of the 81 submissions received, 11 adhered to the standard set by the assignment requirements, while the remaining 70 submissions had major omissions in terms of content, formatting, or citations.

Another challenge is in student research techniques. Despite receiving a large number of acceptable research papers, most students could not use academic journals to support their research to the extent required by the assignment. After conducting one-on-one debriefing sessions, many students expressed either that academic journals have information irrelevant to the concepts of interest to students, or that these journals are specialized and examine scenarios that seldom happen in the real world. A large number of students could not extract meaningful information from articles to support their research even when these articles were well-written.

Yet another challenge was in laboratory implementation. The last lab of the sequence was to build a joystick-controlled model of a supersonic aircraft, designed to use all of the concepts learned in the course. Students had to apply their knowledge of how the aircraft control surfaces should react to inputs from the joystick and how the aircraft should automatically correct its orientation when faced with external forces based on an accelerometer's readings. From the instructor's standpoint, the implementation of the laboratory experiments that tie together theoretical concepts into real-world applications required a great deal of effort. As most of the concepts used in the final laboratory experiment were at the advanced level, the entire lab sequence had to be overhauled to include a scaffolded approach. Students learned the pieces to a more complex puzzle one at a time. These "stepping stone" labs introduced students to state-of-the-art technologies and industry tools.

When completed in tandem, the research paper assignment gave greater relevancy to the laboratory exercises and tied disconnected topics to real-world applications. Students were more receptive to the concepts introduced during their laboratory sequence and could envision potential applications of these concepts when designing aircraft. An end of project survey was administered to evaluate student motivation, applicability of concepts, and the relevance of digital circuits in aeronautics and avionics. Results from this survey are presented in Figure 1.
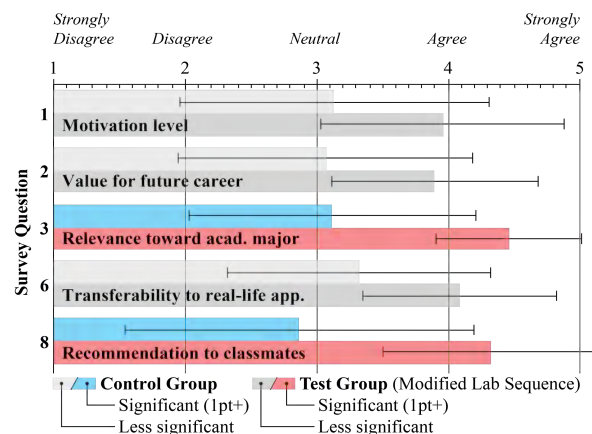

Figure 1. Student responses to survey questions in the test and control groups. The test group consists of students, which underwent the new laboratory/class implementation.

The most frequent complaint from students concerned the narrowness of the research assignment topic because it focused solely on aircraft control systems. From one-on-one student interviews, it became apparent that there were a large number of students in the space and astronautics track within AE, for whom aircraft were not a topic of interest. As an alternative to consider when moving forward, students proposed introducing additional topics, such as flight termination systems for spacecraft, rocket gimbaling (gimbaled thrust), and spacecraft attitude dynamics.

Moreover, since this is a freshman-level course, it would be beneficial to have an overview of proper research techniques and formatting guidelines early in the course. Plus, introducing the research assignment as a staggered set of assignments (i.e., scaffolding), where the instructor provides comments at each stage of the research process throughout the semester, is recommended for future implementation. In retrospect, if scaffolding for the research assignment had been used this time around, compliance may have increased, and the students would achieve greater accuracy in citing and paper formatting. It is believed that scaffolding would have allowed students to better understand and use information from journal articles more effectively.

4.3. Experimental Space Systems Engineering Course

A junior-level experimental space systems course for students in aerospace engineering implemented discovery learning through integration of new knowledge and exploration: students discovered a peer-reviewed paper about a satellite subsystem of their choice; and, students created their own lab for which another section completed a few weeks later.

A major challenge was that some of the students would collaborate on the same paper or fail to read the paper beyond the abstract. They also struggled to choose papers that were peer-reviewed and to follow citation guidelines. Furthermore, students had difficulty creating enough tasks for the entire lab section. Students were also challenged by creating the lab in one 150-minute session. Furthermore, students did not have the opportunity to test their lab before handing it off to the other section. Thus, the resulting labs produced mediocre results.

Both these exercises gave students a choice about course content. Peer-reviewed papers gave students a chance to learn about cutting-edge research, albeit engrossed in difficult terminology. Yet, by creating their own lab, students learned to create a method to test a hypothesis, which was especially challenging when the hypothesis itself was not well understood by the students.

In general, students reported that summarizing peer-reviewed articles benefited them. One section of 17 students was asked, "How do you feel about including peer reviewed articles in the discussion section? Why?" Of the 14 students who responded, 71% felt the peer reviews were useful and 29% felt they were not useful. While students disliked reading the whole article, they found value in learning about new technology. When implementing the reading of peer-reviewed papers in the future, it is important to provide enough information as to where to find acceptable articles and how to correctly cite them. Students who provided informal feedback expressed enjoying the opportunity to create their own lab but wished they had another week to test it before implementation. Alas, students who performed the labs thought that the labs were too simplistic and not worth repeating. In the future, an additional week will be added to this project

so that students have time to create a more in-depth lab and can conduct a pilot test of the lab before the other section is asked to complete it.

4.4. Object-Oriented Programming Language Course

Faculty investigated project-based learning in a sophomore-level programming language course. Students researched a software security issue of their choosing. This was a 5% extra-credit opportunity which resulted in over 80% of the class participating in the project. As part of this project, students researched C/C++ security issues: finding vulnerability, discovering how the vulnerability is exploited, and identifying how the attack can be mitigated. They orally presented their findings during class in a 10-mins. presentation and wrote a two-page research report; report template was given by the instructor and resembled a standard research publication.

A major challenge when attempting to integrate research into the course revolved around achieving a 100% student participation. Factors hindering student motivation for project engagement may be because it was made optional, timing of when the assignments were issued, cyber security topic not being of interest to some engineering students, and the heavy workload of the senior-level students in the course. Furthermore, 3 lecture periods on advanced programming language features in the week 14 of the semester had to be traded for student research presentations; on the other hand, students learned C/C++ security topics.

A majority of the students in the programming language course were cyber security majors. By integrating a software security research opportunity in the programming course helped them gain much needed insight that they can leverage to enhance their knowledge from past and future cyber security courses. They were exposed to relevant software issues that are emerging in cyber security research. Students presented their research in a rather comfortable fashion. Some students even demonstrated example code execution as part of their presentation. PowerPoint slides varied in quality from medium-to-high (80% to 100% score), but the quality of the research reports disappointedly varied from low-to-medium (60% to 80% score).

4.5. Programming Language Organization Course

We used project-based learning in a junior-level course on the comparative study of different computer programming paradigms. The majority of undergraduate software and computer engineering students learn the imperative style of programming alone. But, these students are challenged by alternate programming language designs, including functional and logic programming that have application in many interesting areas such as game theory, natural language processing, artificial intelligence. Hence, generating student interest in learning these additional types of programming and thinking more critically about fundamental computing theories, even when student experience is limited to imperative procedural programming, was the primary goal of this exercise.

Immediate student objections towards learning these additional programming languages included statements like: "I can solve any problem I care about with MATLAB or C, or FORTRAN, so why should I learn something new?" The course introduced programming languages such as

Lisp, Scheme, Haskell, Caml, Swift, and Racket, all of which focus on alternative methods of functional programming as well as Prolog, which focuses on the alternative of logic programming methods compared to procedural programming. Along with historical single paradigm alternate programming languages like Lisp and Prolog, multi-paradigm languages such as Python and C# are reviewed and may be selected by students for further study. Because the very latest multi-paradigm (imperative and functional) programming language are being more rapidly adopted in engineering programming courses along with high-level interpreted programming languages for teaching, we decided to introduce it to our students as part of this FLC endeavor.

Each student researched why an alternative programming language was created, its associated strengths and weaknesses, and then chose an algorithm to demonstrate said advantages and disadvantages by picking an algorithm and application to build of their own interest. Examples included game playing programs, optimization, numerical methods, biological classification, and test automation. Before doing so, they were asked to hypothesize which programming language would be best suited. Students devised metrics and the analysis to demonstrate value and research history as to why others use alternative programming languages and features today. This was an individual research project. The previous year the same individual projects were assigned, but without the related research aspect. The hypothesis was still assigned, but students were not asked to consider what prior researchers had determined related to their algorithm and application of interest. In the previous year only 33% of the projects had a positive hypothesis outcome (Prolog hypothesized to have advantage and shown to in fact have advantages for scheduling logic), 33% had a neutral outcome (Lisp was shown to have some advantage), and 33% had no outcome (incomplete). So in the prior year, 66% completed the project satisfactory or better overall.

This year, the majority of students hypothesized that the alternate programming language would provide some advantages (29% hypothesized the alternative would be worse than the primary). In 14% of the cases, the presentations simply failed to design a good experiment and/or to identify objective metrics. The majority of the presentations (57%) proposed objective, unbiased arguments and concluded the alternate programming language was worth more of their time to learn and use in scenarios similar to what they investigated. Overall, it appeared as if students ultimately convinced themselves that an alternate programming language, or multi-paradigm programming language, is worthy of futher investigation and study for specific classes of algorithms and problems, especially those that are semi-numerical, logical and symbolic in nature. So, while the majority of students again completed the assignment satisfactory or better, they also formed a hypothesis supported by research and experimentation and convinced themselves of the value of alternative programming methods.

4.6. Electromagnetic Fields Course

In this junior-level electrical engineering course, students were tasked with an open-ended problem involving electromagnetic waves and antennas. The problem statement asked for a design of an antenna that would work for an 802.11n router. Working in groups of 2 or 3 , decided by the type of antenna they would be designing, students were charged with producing

an antenna similar to the type expected of them upon employment post-graduation. Students kept a record of their meetings and meeting minutes, just as would be expected of them in industry. Meeting journals also included generated ideas, discoveries, and questions about assignments given. Instructor feedback was provided for the type of research performed prior to the agreed upon antenna design. This process was repeated throughout the course. Group members were each responsible for completing tasks regarding a very specific part of the antenna's design. Each group shared their designs with the entire class at the end of the semester.

Three specific challenges emerged throughout the course of the project. First, students' prior knowledge about antennas was limited, causing much confusion when the first assignment was issued. Second, students' experience working with and solving open-ended problems was lacking. Third, time demands for the instructor were high. Spending time during class explaining the properties of antennas prior to when they are typically covered, plus extensive time spent grading and providing student feedback on a regular basis, made this type of assignment unexpectedly challenging for the instructor.

Students were given many opportunities to work together on an open ended assignment much like they will do in their careers. Moreover, they were tasked with making their own meeting times, keeping adequate notes, and with the division of tasks as needed. Many individual assignments were given as necessary. One such assignment asked students to find an article related to electromagnetics and give a 3 minutes presentation on it. Each student had to research and cite a peer reviewed article for the presentation. Students also received feedback in the form of questions related to their design proposals. Such feedback allowed them to research and critique their own designs while coming to conclusions about what was good, better, or best. This is the basis of a "trade off design," where making one minor change causes something else to change.

This problem-based learning approach provided unique insight for the instructor and students. As part of the design and learning process, students were able to assess one another on their presentation skills and the feedback received allowed for self-reflection and assessment. Overall, student feedback about the assignment was positive. In general, students reported that they thought the subject was well designed for the course, but additional information at the beginning of the term about the assignment's overall goal and end-product would have been helpful.

4.7. Global Security and Intelligence Course

In this junior-level social science course with 29 students, the research process was fully scaffolded. The course design paralleled that of the three phases of the research process: finding literature, writing a review of the literature that compares alternative explanations, and then taking a position and defending it using logic and evidence based on the literature. In order to understand the research process, students were given a broad question to answer--Why will Russia stay in Syria? Proposing this particular question gave the students a problem to solve (problem-based learning approach): how do I explain this predicted phenomenon? Eight classes were specifically devoted to introducing, teaching, and developing the skills needed to accomplish assigned tasks assigned in each phase; five of which forced students to bring ideas or

drafts of their work to class, collaborate with other students, and then present one individual's work from the group.

The intent of using a scaffolded research process in a social science course (Introduction to International Relations) was to increase each student's ability to examine a situation, frame an associated problem, consider potential causes for a particular behavior, and then analyze and evaluate the possibility and plausibility of different causes. Providing students experience with the research process was an effort to give them an opportunity to engage in discovery for themselves—from taking an unstructured question and guiding them through framing the problem to posing potential explanations or causes. Additionally, students were encouraged to embrace the idea of imperfect information and find ways to use research to argue for potential causality knowing they did not have all the facts.

Four primary challenges emerged during the completion of the research project. First, was time or the lack of. Incorporating this fully scaffolded research process into an undergraduate class reduced the opportunity to present new course topics due to time spent otherwise. Plus, asking students to conduct research outside of class led them spending less time preparing for class. In addition, the time required to provide adequate feedback for each assignment was exorbitant and very time consuming for the instructor. Second, all four skills introduced in this class (annotated bibliography, literature review, position paper outline, and position paper) were new for the students. Only about 25 percent of the students were able to incorporate the skills presented in the class fully into most of their assignments. Roughly 50 percent of the students were able to incorporate some of the skills, and the remaining 25 percent incorporated only a few. Third, the students struggled to incorporate instructor's timely feedback into their revised and future assignments. For example, detailed comments provided in one assignment rarely manifested into the next. Fourth, students struggled with citing and formatting credible sources -- a challenge noted by many FLC members. Only five of the 29 submitted outlines were acceptable without further revisions; the sources provided for the arguments were poorly sourced.

Students, nevertheless, had the opportunity to learn and practice basic research skills. Students learned some of the benefits of collaboration, such as the value of presenting their work to each other in every phase and how discussing other's work and ideas improve self-understanding. Across the board, students grew in their knowledge and capacity. Despite the general lack of mastery for sourcing, the final position paper showed a connection (in varying degrees of proficiency) between theory and evidence--one of the main objectives of the course.

The overall results of the scaffolded approach to teaching research in this course suggest four conclusions. First, the feedback from the students overwhelmingly indicated that peer-group work contributed significantly to their ability to understand the purpose of the different phases and exercises. Second, the course required students to learn and apply too many new skills at one time--students generally understood the purpose of each phase, but could not adequately perform the desired skill. Third, students need additional exposure and practice with sourcing; the final position paper showed significant improvement in terms of finding relevant sources to make a particular claim compared to previous students, but students as a whole still struggled with finding appropriate and credible sources that provide substantive support for a particular point or

claim. Fourth, the only exercise that required two iterations (submission-feedback-revise and resubmit) showed the greatest and most consistent improvement. Thus, it is suggested that classes incorporating the teaching and learning of research skills provide students with at least two opportunities to perform the targeted skill.

5. Conclusions

Seven faculty from different disciplines and two staff members came together to form a Faculty Learning Community (FLC). The FLC spent two months debating several topics of interest to its members and settled on the integration of undergraduate research into courses. Another two months were used by each FLC instructor to develop a suitable plan for one of their upcoming courses and meeting the Institutional Review Board (IRB) requirements. The individually developed plans were shared with the FLC for feedback and common discovery learning pedagogies for the development of student skills and knowledge pertinent to conducting research were also identified. The first year focus of the FLC project was on lessons learned, leaving the collection of data on the impact on student skills and course outcomes to future work.

The FLC instructors adopted their chosen discovery learning technique into their courses in the following semester. A total of seven courses were impacted, incorporating new activities that gave students opportunities to use exploration and problem-solving to create, integrate, and generalize knowledge, develop their own interest-based course exercises, and, integrate new knowledge into existing knowledge structures. By using active learning, students honed their critical thinking, oral and written communication skills, and teamwork skills.

Overall, despite the demands placed on instructors and students as a result of the chosen strategies employed to integrate research organically into the course content, students, on the whole, greatly benefited. In most cases, hands-on experience coupled with active learning was positively received by students. Projects requiring the finding of solutions to real-life inspired problems, the creation of laboratory exercises, and programming with fringe languages, provided students with opportunities to engage in novel topics on their own.

In spite of the successes noted above, challenges were still present. One such challenge for instructors involved the open-ended structure of the activities. If other instructors plan to adopt the strategies discussed herein, note that an adequate amount of lead time needs to be allocated to design the majority of the learning activities prior to the course's beginning. In addition, instructors must prepare for logistical matters in advance of implementation, such as purchasing and checking out equipment to students, reserving 24/7 labs with necessary software and hardware support packages, providing more frequent timely feedback to students, and understanding IRB training and compliance needs. And, as with most active learning implementations, especially when lecture had previously served as the primary delivery method, instructors faced student complaints about the course, and students were initially disinterested in actively participating in learning.

Like instructors, students faced their own challenges. When structuring a course using discovery learning methods, students typically learn the course material at a greater depth, but in order to

do so, they need to dedicate out-of-class time and apply material to real-world problems. Plus, if students had not had much prior experience working in teams or presenting work orally, these two additional expectations may have proved challenging for them as well. Finally, students also appeared to struggle reading journal articles in their entirety and providing feedback for their peers.

6. Next Steps

Taking what was learned from this FLC project, we believe we can improve the effectiveness of the FLC and more easily integrate research into our upcoming engineering and social science courses. One improvement is to identify end goals for the FLC, set realistic milestones for the group, establish individual member responsibilities based on these end goals, and better communication of logistical requirements such as IRB compliance and data collection rules. In our future courses we plan to make enhancements, such as scaffolding the learning of research components throughout the semester to make students show greater learning for searching, citing, and summarizing research articles. Understanding the most basic components for conducting research, i.e., searching, citing, and summarizing peer reviewed journal articles, will be our collective primary focus for future work when it comes to teaching and learning undergraduates about the importance and process of conducting research.

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Appendix A:

Results of paired t-test on the data collected using the rubrics of AACU Value Assessment of Learning in Undergraduate Education from before and after the project.

Table II – Results of Paired t-test for Sub-skills of Critical Thinking, Oral and Written Communications, and Teamwork between the "before the project started" and "after the project was done" Data. Blue and red cells for each row refer to the sub-skills with the smallest and the largest average differences between pre and post project data.

t_{stat} for Critical Thinking Sub-Skills, df=22, $t_{critical}$ = 1.717144					
Acquiring Competencies	Taking Risks	Solving Problems	Embracing Contradictions	Innovative Thinking	Connecting, Synthesizing, Transforming
0.000177	0.001166	0.000101	0.00054	0.0000397	0.00054
t_{stat} for Oral Communications Sub-Skills, df=22, $t_{critical}$ = 1.717144					
Organization	Language	Delivery	Supporting Material	Central Message	
0.000228	0.000417	0.0000064	0.000228	0.000177	
t_{stat} for Written Communications Sub-Skills, df=22, $t_{critical}$ = 1.717144					
Context and Purpose of Writing	Content Development	Genre and Disciplinary Conventions	Sources and Evidence	Control of Syntax and Mechanics	
0.000241	0.000034	0.00054	0.000929	0.00121	
t_{stat} for Teamwork Sub-Skills, df=22, $t_{critical}$ = 1.717144					
Contributes to Team Meeting	Facilitates the Contributions of Team Meetings	Individual Contributions Outside of Team Meetings	Fosters Constructive Team Climate	Responds to Conflict	
0.001977	0.000101	0.002379	0.001977	0.000177	