# Undergraduate Research Scholar: The First Step Towards a Hybrid Lecture-Based and Inquiry/Research-Based Undergraduate Engineering Program

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## Abstract

In this paper, we describe our approach on how to integrate undergraduate research into a lecture-based curriculum through summer workshops, research-designated courses, and undergraduate research grants. This approach is the first step towards a hybrid lecture-based and inquiry/research-based undergraduate engineering program. We proposed the establishment of a series of undergraduate research workshops instructed periodically every summer to better prepare students interested in undergraduate research. We also proposed a course, UREH-4999 Undergraduate Research, that will be used to provide the undergraduate student with an opportunity to engage in supervised research. Upon completing a certain number of undergraduate research credits and presenting the findings of the research conducted, the students will be granted an "Undergraduate Research Scholar" status on their transcripts or diplomas as recognition for their participation in research. We have conducted a set of surveys to identify the learning style of our students, the students' favorable learning style, and identify the students' willingness to be involved in undergraduate research.

## Introduction

Based on the Felder and Silverman index of learning styles [1], the human natural learning style is mainly inductive. Inductive learning is learning by drawing inference of generalized conclusions from particular instances through inquiry, observation and data measurement; i.e., inquiry/research-based learning, problem-based learning, and project-based learning are considered to be inductive learning methods. Unfortunately, the traditional teaching style in the majority of engineering schools is focused on "lecture-based learning" which is mainly deductive learning. Deductive learning is learning by instruction of new concepts and explaining how it is used. Deductive learning is a teacher-centric approach. In the last decade, students' learning styles have witnessed a drastic shift towards inductive learning, especially with the advancement of interactive gadgets and applications. However, inductive learning methods alone are not sufficient to achieve a highly effective teaching model. Therefore, the co-existence of both inductive and deductive learning methods is essential.

We conducted a set of surveys to identify the students' learning style, the students' favorable teaching style, and their willingness to be involved in undergraduate research. Then we proposed an undergraduate research model to develop a hybrid lecture-based and research-based undergraduate engineering program. We integrated undergraduate research into a lecture-based curriculum through summer workshops, research-designated courses, and undergraduate research grants. We also instituted an Office of Undergraduate Research to help facilitate the undergraduate research and oversee its integration into the curriculum. Upon completing a certain number of undergraduate research credits and presenting the findings of the research conducted, the students will be granted an "Undergraduate Research Scholar" status on their transcripts or diplomas as a recognition for their participation in research.

**Understanding Student Learning Styles**

Learning styles are models that utilize different measures to define the students' preference in how they would learn the best. Over the past five decades, many models for learning styles have been developed, such as the Myers-Briggs Type Indicator, Kolb Model, Felder-Silverman Model, and others. Felder, in a later revision of his work "Learning and Teaching Styles in Engineering Education," omitted the deductive/inductive dimension from his model [1]. To understand the reason for omitting this dimension, Felder indicated that the majority of students, especially at the undergraduate level, favored the deductive learning style, while the inductive approach was proven to be the most effective. The students' preference for the deductive learning style was used as a reason for faculty to keep using traditional deductive teaching approaches and to resist applying the newer inductive teaching methods. The deductive learning style is favored by the students since it represents a well-defined recipe to succeed with the least effort, unlike the inductive learning style, where the students have to spend more effort to learn [1].

In this study, we used the Felder-Soloman index of learning styles (ILS) survey to illustrate the student learning style profile. Based on the Felder-Silverman model, there are four scales for the learning aptitude that are active/reflective learners, sensing/intuitive learners, visual/verbal learners, and sequential/global learners [2]. Since the deductive/inductive dimension was omitted from the model, we added a few questions to check the students' ability to learn using inquiry/research-based learning techniques. Our findings are in line with Felder's findings concerning the students favoring the deductive learning style. Figure 1 illustrates the student's learning styles profile.

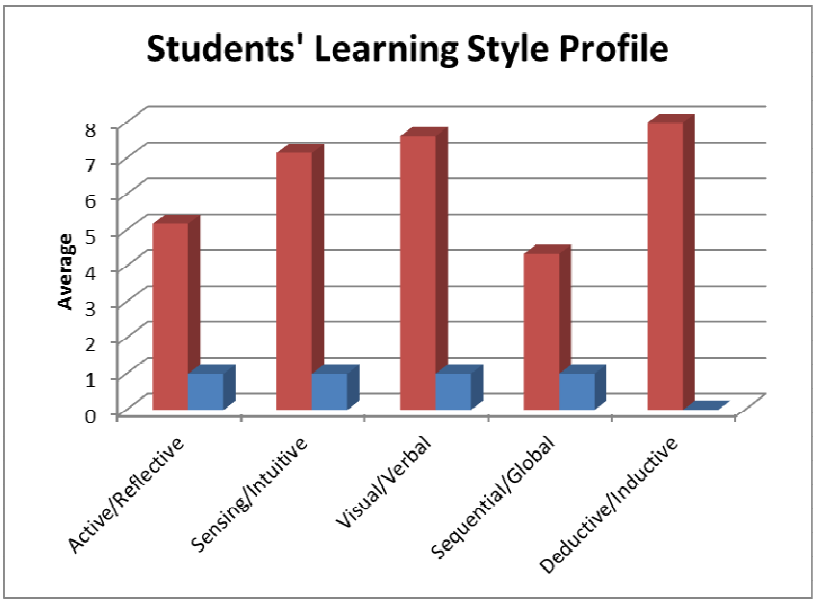


Figure 1. Student learning style profile

The students' learning style profile predominantly favors the active, sensing, visual, sequential, and deductive scales as illustrated in Figure 1.

Despite the fact that students favor deductive learning style, the inductive learning style has been proven to be the best learning style especially at the undergraduate level [1,3]. To meet the challenges of the 21st century, students research-enhanced teaching process is needed [4].

With the goal to trigger an institutional cultural change, we proposed a top-down approach that starts by instituting an Office of Undergraduate Research to help promote undergraduate research among students and faculty. This approach integrates undergraduate research within the curriculum as the first-step to achieve a hybrid lecture-based/inquiry-based engineering program.

The curriculum design with respect to research and teaching could be categorized as follows [5, 6]:

Table 1. Curriculum design

| | **Emphasis on Research Content** | **Emphasis on Research Processes** |
|---|---|---|
| **Student-Focused (Students as Participants)** | Research-Tutored (Engaging students in research discussion) | Research-Based (Engaging students in research to become researchers) |
| **Teacher-Focused (Students as Audience)** | Research-Led (Teach students about research) | Research-Oriented (Develop the students research skills and techniques) |

In the following undergraduate research model, we drafted a balanced approach to integrating undergraduate research within the curriculum as follows:

1. *Research-Led* is integrated throughout the instruction of courses and relating the topics discussed to the current trend in research.
2. *Research-Tutored* is integrated through the course projects, which involves paper reviews and presentation of the current research topics.
3. *Research-Oriented* is integrated by offering a series of workshops to help students learn research methodologies and all necessary research skills.
4. *Research-Based* is integrated through an undergraduate research course within the curriculum.

**Proposed Undergraduate Research Model**

In an effort to adopt the best practices, we visited undergraduate research offices at other higher education institutions, such as the University of Central Florida, the University of Florida, the University of North Carolina at Greensboro, and the University of South Carolina. We based our undergraduate research model on the best practices for establishing, running, and publicizing undergraduate research programs within these institutions. Figure 2 illustrates the proposed undergraduate research model.

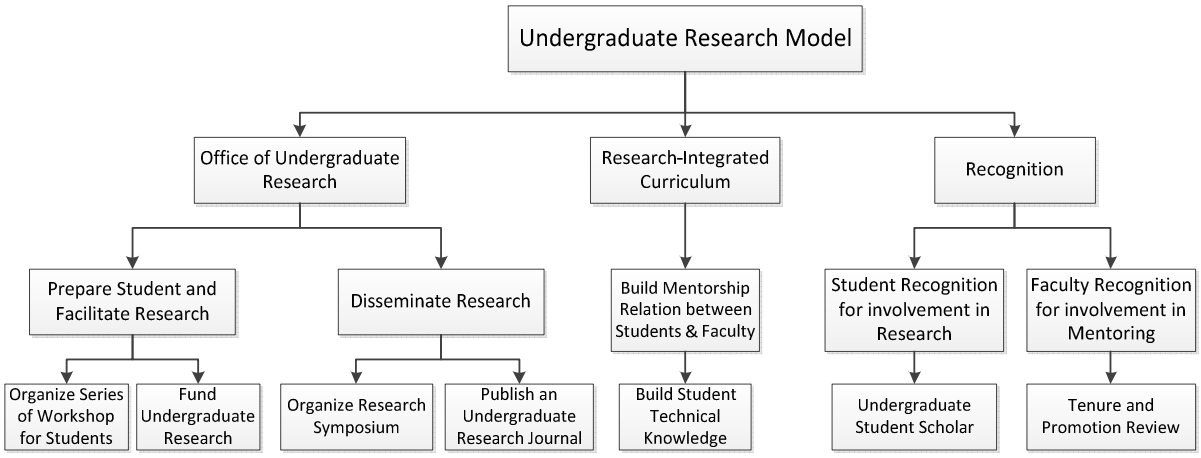


Figure 2. Proposed undergraduate research model

The following components represent the details of the framework for an effective undergraduate research engineering program.

1. Establish a brick-and-mortar Office of Undergraduate Research staffed by a full-time faculty director with an administrative assistant and support from an advisory committee. The director should report to the associate dean for Research. The primary benefits of establishing a physical Office of Undergraduate Research are to

a. Increase the awareness of undergraduate research and highlight its effectiveness in the learning process.
b. Help attract external funding to support and increase the capacity of the undergraduate research in the college and throughout the university.
c. Coordinate efforts between academic and administrative units to maximize the success of the undergraduate research program.
d. Help the university to become a leader in developing and conducting cutting-edge research.

2. Integrate undergraduate research into curriculum through research-designated courses. All undergraduate engineering students pursuing research will enroll in UREH-4999 with 0 to 3 credit hours. The primary motivations for this requirement are to

    a. Increase the likelihood that high-achieving students will look at this opportunity as an appropriate culmination of their undergraduate academic careers and elect to stay at the university for their entire undergraduate and graduate academic careers, rather than transferring to other institutions.
    b. Accurately record the number of undergraduate students who actively engage in research in order to track improvement and provide statistics to the vice president for Research and Economic Development.
    c. Establish a minimum set of expectations for faculty advisors and students (as suggested by UREH-4999 course syllabus), thus ensuring consistent research experiences.
    d. Be able to recognize participating undergraduate students by indicating "Undergraduate Research Scholar" on their transcripts or diplomas.

3. Provide funding through undergraduate research awards with a minimum of 100 awards per college at a maximum of $2,500 per award. The student stipend should not exceed $750 and the faculty stipend should not exceed $250. The remainder of the award ($1,250) will be allocated to other research-related expenses. The student stipend will be divided into two equal payments. The first payment will be received at the beginning of the project, and the second payment will be contingent upon the completion of all the requirements and deliverables. This will also include participating in the undergraduate research symposium. Funding for the undergraduate research programs should be allocated to the colleges as part of the Office of Undergraduate Research budget. While applying for funding is optional, students with financial aid can still be able to apply funds to purchase equipment and supplies. This could be indicated in the funding application budget. In such a case, funding will be mainly allocated to purchasing equipment and supplies.

4. Develop a series of undergraduate research workshops conducted periodically during summers to prepare students for research. As an incentive, each student will earn one research credit hour at no cost for completing the workshops. Workshop attendance will be required for all students receiving funding for their undergraduate research.

5. Have the undergraduate research count towards the faculty scholarly activities in reviews for tenure and/or promotion as an incentive to maximize faculty engagement in this experience. In addition, faculty will receive an honorarium stipend ($250) for any research project successfully funded. Faculty participating in undergraduate research will also help identify prospect graduate students. To recruit faculty, the Office of Undergraduate Research will regularly contact faculty to join the office as affiliate faculty. In addition, the Office of Undergraduate Research will maintain a database of all affiliate faculty and their research interests.

6. Organize an annual undergraduate research symposium and establish an undergraduate research journal to publish students' research results and findings.

7. Start an initiative to create a regional Council for Undergraduate Research in collaboration with other institutions of higher education in the region.

8. Organize and host a statewide conference for undergraduate research.

**Responsibilities and Duties of the Office of Undergraduate Research**

The Office of Undergraduate Research plays an integral role in the success of any undergraduate research program since it would help

1. Increase the number of students participating in undergraduate research.
2. Reduce the number of students transferring to other graduate Institutions.
3. Improve student retention, progression, and graduation rates.
4. Provide a platform for students to apply lessons learned in the classroom.
5. Develop mentorships between students and faculty advisors.
6. Provide experience to help students succeed in their professional careers.
7. Increase the likelihood that students will continue their graduate studies.

Based on the Office of Undergraduate Research responsibilities, the duties of the prospective director will include

1. Promoting undergraduate research among undergraduate students
2. Recruiting undergraduate students to participate in undergraduate research
3. Serving as the coordinator for the undergraduate research course
4. Developing a marketing plan for undergraduate research
5. Organizing research-related workshops, seminars, and symposia
6. Facilitating the process of pursuing research opportunities
7. Managing internal/external research funding and undergraduate research grants
8. Keeping track of all students and faculty engaged in undergraduate research and all previous and current research activities
9. Developing an assessment plan to assess the learning outcomes of students engaged in undergraduate research and report the results to the vice president for Research and Economic Development

10. Representing the Office of Undergraduate Research in university events
11. Organizing the undergraduate research symposium/conference

**Research-Integrated Curriculum (Undergraduate Research Course)**

The main objective of this course is to give students an opportunity to get involved in supervised undergraduate research. A faculty member will mentor a student or a group of students throughout the process of researching a topic of interest and assist in the dissemination of the research findings. Depending on the topics, project types may include, but not limited to, inquiry, design, investigation, scholarship, discovery, or application. A set of expectations will be agreed upon before the beginning of the research project. The student will be responsible for certain tasks within the research project, and the student will usually assist a faculty member with a research project by preparing the study and contributing in a meaningful way so as to meet the objectives of the study. The student may also work with a graduate student who is conducting research supervised by the research faculty member.

Integrating undergraduate research into a lecture-based curriculum is simple if the curriculum is new or under development. However, if the curriculum is well established, integrating undergraduate research is possible by substituting some elective courses with the research-designated courses or even adding them as research credits towards future graduate degrees.

***Course Credit***

Credit hours will be allocated to the research course based on the research level of complexity and the student involvement in this research. Credit hours may vary between 0-3 per semester.

***Enrollment Process***

Any student interested in pursuing undergraduate research must receive prior approval from a faculty advisor. The student and the faculty must agree on the topic and the set of expectations for the intended research project. The student will then submit an application signed by both the student and the faculty mentor.

All students engaged in research must enroll in UREH 4999 with the section number specific to the faculty advisor's department. If a student is pursuing research with a faculty at another department or college, s/he should obtain approval from his/her Academic Advising Office.

To increase the success rate, student participation in the undergraduate research should be optional. Based on the survey data collected from different institutions, it was indicated that student participation in undergraduate research accounts for only 2% to 5% of the total student population.

### *Pre-Requisites And Co-Requisites*

While no pre-requisites are required to enroll in this course, the student's project may have specific pre-requisites that the research advisor would identify before enrolling in this class.

### *Course Website*

The Office of Undergraduate Research will host the course website for all students enrolled in undergraduate research. This website will house information related to safety, research methodologies, ethics in research, best practices in recording and keeping data, etc.

### *Course Objectives*

After completion of this course, the student will be able to

- Conduct a literature review and perform research inquiry
- Effectively use the equipment in the laboratory
- Properly keep an accurate record of research performed
- Formulate a research problem and develop a research methodology
- Write a professional technical report
- Conduct herself/himself responsibly and ethically in research
- Present and communicate research results to technical/non-technical audience

### *Assessment*

For assessment purposes, we propose the following grading rubric:

Table 2. Grading rubric

| **Grading** | **Performance Criteria*** |
|---|---|
| 50% | Meeting the research preset expectations (**determined by the faculty**) |
| 20% | The significance of the student's contribution to the work |
| 10% | Final Report/Publication |
| 10% | Final Presentation |
| 10% | Work ethics, diligence, and collegiality |

*These grading levels are subject to changes by the faculty mentors.

The following are the minimum set of expectations for every student taking this class:

1. Perform a thorough literature review
2. Define the research statement
3. Develop a research plan
4. Perform experimental work (Simulation or applied)
5. Write and document the research finding in a technical report
6. Present the research findings at least in the university research symposium

No letter grade will be assigned in this course. The final grade will either be satisfactory (**S**) or unsatisfactory (**U**). A grade of **S** is given if the grading rubric reflects 70% of the total points or better; otherwise, it will be unsatisfactory (**U**).

Upon graduation, if the student has earned at least 6 credits of undergraduate research, s/he will be granted an "Undergraduate Research Scholar" status as a recognition for participating in research.

## Conclusion

In this paper, we proposed an undergraduate research model as a hybrid lecture-based and research-based undergraduate engineering program. The model consists of three main parts: by establishing an Office of Undergraduate Research, developing a research-integrated curriculum, and instituting a recognition system. We also described our approach about how to integrate undergraduate research into a lecture-based curriculum through summer workshops, research-designated courses, and undergraduate research grants. Furthermore, we proposed the institution of a series of undergraduate research workshops offered periodically during summers to better prepare students interested in undergraduate research. We also proposed the offering of a research course titled UREH-4999 Undergraduate Research as an integral component of this proposed research experience.

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## Biographies

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