Undergraduate Research Experience (URE): A New Dimension in Curricular Redesign

Sanjay R. Kumbhar[1], A. C. Attar[2], M. T. Telsang[3]
[1]Automobile Engg. Dept., [2]Dean – Quality Assurance, [3]Dean – Academics,
Rajarambapu Institute of Technology, Rajaramnagar, Dist. Sangli (Maharashtra State) India – 415414.
[1]sanjay.kumbhar@ritindia.edu,
[2]abdulrashid.attar@ritindia.edu,
[3]martand.telsang@ritindia.edu

Abstract: Research experience for undergraduates is of great importance not only for conducting research on a topic that has impact on a current research activity, but also as a tool to enhance undergraduate education. For the engineering technology students, research experiences allow them to carry out in-depth study of engineering concepts, while emphasizing hands-on experiences and practical applications. Participating in funded research projects strengthens the student's resume, and fulfills the requirements of present day employers, who demand sound engineering skills in their employees. This paper highlights the importance of undergraduate research experience with its curriculum design, expected outcomes, methodologies to be followed and implementation plan. Also barriers and strategies to overcome have also been discussed. Finally model of this at RIT has been presented.

Keywords: undergraduate research experience, curriculum development.

1. Introduction:

In recent years, there has been interest in broadening the participation of students in undergraduate research experiences in engineering disciplines. While there has been considerable study and analysis of the benefits achieved by high-achieving undergraduate students engaged in research activities, relatively little consideration has been given to the impact and benefits of research experiences on engineering students.

Yet, these are the students to whom undergraduate research opportunities need to be provided in order to achieve broader participation.

Sanjay R. Kumbhar
Automobile Engg. Dept., Rajarambapu Institute of Technology, Rajaramnagar, Dist. Sangli – 415 414. (Maharashtra State) India.
sanjay.kumbhar@ritindia.edu

Therefore, it is beneficial to understand how these experiences impact average students so that programs are not designed that will not meet the students' expectations or needs.

Undergraduate research has a rich history, and many practicing researchers point to undergraduate research experiences (UREs) as crucial to their own career success. Until recently, the empirical bases of the literature on Undergraduate Research (UR) claiming benefits were largely lacking [1,5]. Most commonly, descriptive articles have detailed particular faculty - developed, institutional, or multi - institution programs in which accounts of evaluation methods were missing, incomplete, or problematic. Promotional and discussion pieces described the perceived merits of undergraduate research, either in general or for particular models of activity, but offered no supporting evidence. Reviews and histories of UR often contained limited or no reference to evaluation. Of the few available program evaluations, some used methods that were incompletely documented, problematic, or lacking comparison groups [6].

2. Types of UREs:

Many different names have been used to describe types of UREs. These names vary across disciplines and are not used in practice. UREs can be grouped into the consistently following types [2]:

a) Individual faculty research group (apprentice-style):

A common pathway to research is for students to begin working on a part-time basis in a faculty research lab. or team and to work for a semester or more to "learn the ropes" before taking ownership of advanced responsibilities. Faculty may pair inexperienced students with an intermediary supervisor, such as a graduate student or lab. technician, for day-to-day training. Although some students develop their research skills and independence over an extended period of time, other students may enter a research environment with previous experience and have a shorter and steeper learning curve.

b) Capstone experiences and senior theses:

Capstone experiences not only can be a requirement for graduation but also are part of the accreditation of particular programs like ABET, NBA accreditation for engineering programs. These experiences have been defined as "a culminating experience in which students are expected to integrate special studies in the specialized courses".

c) Internships and co-ops:

Internships and co-ops are professional experiences that often involve doing research, typically take place in the industry or private sector. The internship or co-op experience can be for a summer, a semester, or an academic year. Co-op programs are primarily based on partnerships between academic institutions and industries. Students who participate in a co- op program or internship often alternate between academic theory-based classroom learning and off-campus hands-on research experiences. Students apply classroom knowledge to work situations, gain knowledge, and develop skills that further clarify their academic focus and career interests.

d) Course-Based Undergraduate Research Experiences (CUREs):

In CUREs, students investigate novel research questions and therefore contribute new knowledge to the field. These courses can provide students with opportunities to engage in research in a more controlled fashion and are designed for cohorts of students, allowing faculty to engage large numbers of students in research projects at one time. They can also be scaled and adapted to fit the needs and resources across a variety of institutions.

e) Wrap-around experiences:

UREs have been integrated into programs that span multiple semesters or multiple academic years and include academic support services such as tutoring. These comprehensive programs frequently target students who enter college less prepared and students who are members of under-represented groups in the discipline and may be more likely to face challenges as they navigate the majority culture of their discipline.

f) Bridge programs:

Bridge programs are usually UREs incorporated into an extended orientation program that serves to support student transitions. These programs can serve to introduce research early in a student's career, when they not only provide the opportunity to begin making connections between classroom and learning within the research environment, but also can provide access to research faculty with whom undergraduate students would not otherwise interact until they took more advanced courses.

g) Consortium/project-based programs:

Consortiums allow for collaboration with faculty and students from different colleges and universities, which serves to create a multidisciplinary context for the work. The scale of the research and the questions that can be addressed are beyond what could be accomplished through more traditional apprentice-style models because teams of researchers can work on specific themes of research. Consortiums can provide opportunities for a pooling of resources across institutions to allow more students an opportunity to participate in research.

h) Community-based research programs:

Often linked to service-learning courses, community-based research experiences are a unique type of URE that includes services to the community as an outcome of the research. In this, students interact with a community partner who contributes to the design of the research project and provides the venue in which the research takes place. Ultimately, the goal of this type of research is to provide results and understanding that advance the work of the community partner in using evidence-based approaches.

3. Learning Outcomes of URE:

At the end of the course, the successful student will know and be able to:

- Conduct literature searches and effectively communicate the information orally and in writing.
- Identify and address scientific research questions using appropriate methodologies.
- Effectively communicate research results related to the field of study.
- Work collaboratively as a member of research teams to produce research output.
- Reflect constructively and critically on their research experience, identifying what they learned about the discipline, their personal strengths, their opportunities for growth, and their educational and career goals.

4. Barriers in implementing UREs:

Barriers in implementing UREs can be categorized in following groups –

a) Student-Centered Barriers
b) Institutional/Faculty Culture Barriers
c) Fiscal Barriers
d) Temporal Barriers

According to J. Ellis Bell [4], the barriers and strategies are given below in Table 1.

Table 1. Classes of barriers and strategies

Classes of Barrier	Barriers	Strategies
Student centered	• Evaluations • Resistance to pedagogy • Heterogeneity of preparation	Communicate benefits of URE approach from student perspective
Institutional/Faculty Culture	• Tradition • Accreditation • UREs in a sequences of courses • Difficult to document impact • How will an administration	• Link to promotion & tenure • Build network of mentor and mentees • Raise profile by linking programs • Incorporate

	recognize a positive outcome?	assessment tool that would provide documentation to administration on pedagogical efficacy
Fiscal	• Budget/lack of transparency in budgeting • Cost of scale-up • Space/facilities • Support to train faculty & staff	• Networking or partnerships to reduce cost • Tie investment to institutional mission • Repurpose space and document needs • Video-based training for implementing labs • Publishing and grant writing
Temporal	• Teaching load • Productivity / use of time • Inventing from scratch • Limited off-the-shelf options • Sustainability & continuity of reform	• Institutional buy-in • Mentorship • Rotation of faculty

5. Key Challenges in Implementing UREs:

Following are some of the key challenges [3] in implementing UREs -

- Identifying the "ideal" students for research project.
- Successfully planning and managing (Proposal-writing phase, Interview phase, Research phase etc.) an undergraduate research project.
- Overcoming lack of knowledge

6. URE Module at R.I.T., Rajaramnagar:

URE, a new module under choice based credit system curriculum has been introduced in seventh semester of B. Tech. programme having total credits of 25 at Rajarambapu Institute of Technology (R.I.T.), Rajaramnagar, Dist. Sangli (Maharashtra). This module is spread over two semesters (VIIth and VIIIth semester), in last year of the graduation.

URE is designed to provide students with the opportunity to develop and practice advanced discipline-specific projects in collaboration with faculty members.

Expectations from URE Module:

Minimum expectations for every student enrolled in URE module are:

- Perform a background literature search and review
- Develop a project plan
- Perform experimental work or applied experimental work
- Write and present a research report

Along-with above cited minimum expectations, additional expectations like attendance at department and/or college, research seminars, participation in research group meetings, etc. are to be clearly established and articulated to the student by the research advisor prior to commencement of the research project.

Screening of the students for URE:

As research basically requires strong academics and desire to learn new thinks, screening of the students for this URE is done based on cumulative performance index (CPI) in academics. Students opting URE module should have CPI>=7.0. If numbers of students are more, for screening, interviews should be taken to test the research aptitude of the student.

Assigning Research Advisor to Students:

Selected students under URE are assigned research advisor, especially the faculty member who has either completed his doctoral research or doing his doctoral research. This strategy will help student for getting insight into research component.

Curriculum Structure:

The curriculum structure (Teaching scheme) for this URE module is shown in Table 2.

Table 2. Curriculum Structure of URE Module

Sr. No.	Course Title	Teaching scheme		
		L	P	C
B. Tech. VIIth Semester				
1	Undergraduate Research Experience – I	--	2	1
B. Tech. VIIIth Semester				
1	Research Methodology	3	2	4
2	Research Elective - I	3	--	3
3	Research Elective - II	3	--	3
4	Research Elective – I Laboratory	--	2	1
5	Research Project	--	12	12
			Total Credits	25

(L-Lecture, P-Practical, C-Credit)

Brief outline of each course in URE Module:

Undergraduate Research Experience – I:

In this course, students are expected to search for the topic for his proposed research project. In this regard, in consultation with assigned supervisor, student should select a topic and should search the related literature from various sources like reputed journals, reference books, etc.

At the end of the semester, student should complete literature review and write synopsis work along with work plan.

For this, students may visit to the industries or research organizations for getting various avenues to start his research work. For example, Automobile Engineering students may visit research organizations like Automotive Research Association of India (ARAI), Central Institute of Road Transport (CIRT), etc. to hunt for research study.

Research Methodology:

Students are expected to have theoretical and practical skills to conduct, analyze and present in written an experimental task in the area of data communication and to give insight and understanding of research methodology. This course provides coverage of various research methodologies and main concepts of experimental design and the associated analysis of variance models.

This course is common to all departments. If this course is offered for PG students then students in URE module will opt this course and evaluation scheme will be as per rules and regulations (RR) of the institute.

In case, if this course is not offered for PG students, then entire course will be taught in first two weeks of VIIIth semester. In this case it will have in semester evaluation (ISE) and end semester examination (ESE). Weightage of ISE will be 20% and weightage of ESE will be 80%.

Research Elective – I:

Students enrolled in URE Module must select a course at UG or PG level which is relevant to his/her research project. The selected course preferably should have lab course associated with it. Examination scheme of the course and evaluation will be done as per RR of the institute, if the selected course is offered in the institute. If course in line with area of research is not offered in the institute then research advisor is responsible for setting the syllabus of Research Elective-I. In this case research advisor can devise appropriate evaluation scheme for assessment of student performance in this course. Research Elective-I course selected by students must be related to area of research project.

Research Elective – II:

This course will not be floated by any department. This course can be Self Study/Online/Certification/NPTEL course approved by board of studies (BOS). If it is self-study type course, then research advisor is responsible for defining syllabus and assessment of the course.

Students can also opt Online/Certification/NPTEL course offered by reputed institute in consultation with research advisor as a Research Elective-II. Research advisor must see that there is proper assessment scheme adopted and grades are awarded on completion of course. Research advisor must monitor progress of the student in the Research Elective-II and take corrective action if required.

Research Elective – I Laboratory:

This course is related to Research Elective-I. Examination scheme of the course and evaluation will be done as per RR of the institute, if corresponding Research Elective-I is offered in the institute and it has lab. course. Student must opt Research Elective–I course which has laboratory course associated with it. In case, if relevant lab. course is not available to the Research Elective-I, then research advisor shall assign practical work in the domain area and devise appropriate evaluation scheme for the lab course.

If course in line with area of research is not offered in the institute, then research advisor is responsible for setting the syllabus of Research Elective-I and list of experiment for corresponding Research Elective –I Laboratory. In this case, research advisor can devise appropriate evaluation scheme for assessment of student performance in this course.

Research Project:

This course aims to develop research skills in UG students. The acquired skills shall be useful to pursue higher level research at M.Tech./M.S./Ph.D. level. This course may also help students to get admission in reputed foreign universities for M.S. program, as research project completed at UG is one of the selection criterions.

Students are expected to work 12 hours a week for the research project. Students can enroll in a total of 12 credit hours of this course. Students should carefully discuss with their research advisor about expectations for completion of the requirements research project.

The research advisor will provide clear expectations of the desired format, content, and deadlines of the final report. The research advisors will grade the final report.

In order to provide the student a measure of performance, the research advisor is expected to complete a mid-term evaluation of the student accompanied by recommendations for improvement for the remainder of the term. The mid-term evaluation of the student should be accompanied by a one-on-one meeting between the research advisor and the student.

7. Conclusion:

Research experiences have a major effect on persistence in science and results in positive outcomes in conceptual understanding and skills development, which are essential for effective workforce development. URE can provide invaluable opportunities for undergraduates interested in science and engineering to experience research for an extended period of time. URE is widely recognized as having a positive impact on not only the educational experiences of undergraduates, but also in providing research opportunities for faculty at undergraduate institutions. The design and implementation of UREs can be varied to serve both early-matriculation and more senior undergraduate student populations. An attempt addressing URE as a new dimension in curriculum development is presented here. With such an approach, value addition in academics is possible through curriculum development of an engineering program.

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