Journal of Engineering Education Transformations , Volume 28 , No.2 & 3 , Oct. 2014 & Jan. 2015 , ISSN 2349-2473

An Experience of Introducing A research Experience For undergraduates (REU) course

Ashok Shettar and Uma Mudenagudiemail
BVBhoomaraddi College of Engineering and Technology, Hubli, India
ashok,uma@bvb.edu

Abstract—**In this paper we present an experience of introducing a research experience for undergraduates (REU) course to the VI semester students of B. V. B. College of Engineering and Technology (BVBCET), Hubli. We use survey data to discuss impact of the course in enhancing the attainment of learning outcomes. The course is designed to expose the students to realistic technological research experience. The student under the guidance and supervision of a faculty carries out activities like formulation of research problem, literature survey, conduct of research and reporting of results. They are encouraged write and present paper on the basis of their findings. A college wide a one-day open house is conducted where the experts interact with REU students and give their inputs. The survey results demonstrate that the perception of the students about the course is positive. The course experience also motivates the undergraduate students to pursue higher studies and research careers.**

***Index Terms*—student outcomes, a-k outcomes, curriculum design, research experience**.

I. INTRODUCTION

In this paper we discuss the experience of introducing a research experience course for undergraduate students during 2011 for VI semester undergraduate engineering students of different discipline of BVBCET Hubli. There are wide theories concerning the process of learning and development of intellectual/research skills by students during their college years and how communities of practice encourage these types of growth in the students' cognitive, epistemological, and interpersonal and intrapersonal development [1,2,3,4,5]. It is evident from the literature on education, that the percentage of students taking up the research career is more if they are exposed to research experience during undergraduate level [6]. The experience shows exposing undergraduate students to research experience enhance possibility of keeping the students into the core streams [7,8,9,10,11,12].

It is challenging in most cases how the students learn and develop the inclination towards research. The learning is characterized by a persisting change in human performance or performance potential brought about as a result of the learner's interaction with the environment [2]. Typically the learners are categorized into objectivist and constructivist. In case of

objectivist, learning happens when knowledge is transmitted to students and they store it in their mind and knowledge has aseparate, real existence of its own outside the human mind. I this case the learner learn through the cognitive learning and behavioral learning. The information is transferred from the instructor to the students. However, this method does not provide learner an experience of constructing knowledge himself. The category of the objectivist can be associated with the lower level of learning and the constructivist can be associated with the higher level of learning of Blooms taxonomy of learning [Blooms]. The research experience can help the student. This emphasizes the experiential learning gives more impact on the learner to achieve higher level of learning.

Research is the pursuit of new knowledge through the process of discovery. Research is also process of questioning, discovery, evaluation and

analysis. Studies suggest that the students learn these processes better when they experience them first-hand. Undergraduate research opportunities help the student to experience and learn how to identify and define the problems and solve them, how to find and evaluate evidence, how to consider and assess competing interpretations, how to form and test their own analysis and interpretations and how to communicate their ideas and findings. These learning enable them to take part in the research missions in their future career inside or outside academia.

This study is motivated by three research questions, viz. questions are: i) is the educational experience of undergraduates being enhanced with the exposure to research? ii) are undergraduate research programs attracting and supporting talented students interested in a career involving scientific research? iii) are undergraduate research programs motivates higher studies and becomes the "pathway" to a scientific or high profile career? Also, one of the factor which decides the face value of the institutes is the amount of input the institute is providing for the research activities or the research jobs and research jobs are regarded as high profile jobs. The experiment shows that research experience at UG level enhances the possibility of attracting students to such jobs. There efforts to improve the number of students enrolling for higher education particularly in India, since the number of students enrolling for higher studies is very less %[lit]. With these motivations we introduced research experience for undergraduate (REU) course during 2011 for VI semester students of different discipline of BVBCET Hubli.

The main contributions of the survey of REU course offered during 2011 are can be summarized as:

1. REU course, helps to strengthen the attainment of a-k outcomes
2. Retains talented students to careers in engineering
3. Enhances the opportunities for students to get high profile jobs in R & D
4. Provides motivation for higher studies

II. Research Process

The term undergraduate research and its integration into the curriculum grows out of US practice; in particular through innovations pioneered at the Massachusetts Institute of Technology (MIT) in 1969. Similar programs were started by few other research-intensive US universities in 1980's. A commission of educators sponsored by Carnegie Foundation headed by Ernest L. Boyer in its report entitled 'Reinventing Undergraduate Education (1998)' [12] strongly advocated providing research opportunities for undergraduate students to enhance their learning experience. In line with the recommendations in the last decade universities worldwide undertook integration of 'research experience for Undergraduates (REU)' in the curriculum of their programs. The results of the studies on these initiatives are encouraging and significant positive benefits for the students have been reported.

Fig. 1 shows the different levels of learning. The first method can be associated with the lower level oflearning and constructivism can be associated with the higher level of learning from Blooms taxonomy. The learning methods and blooms levelscan be summarized in Fig 1. All these analysisshow that the experiential learning gives more impact on the learner.

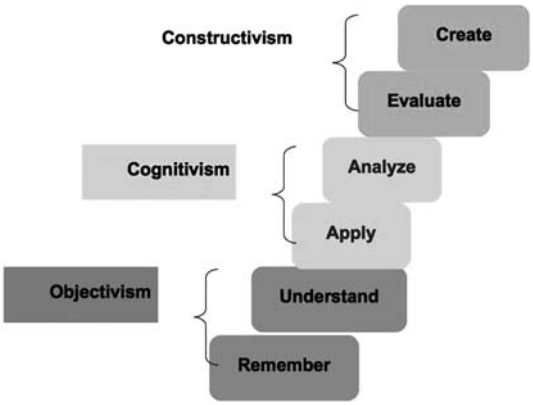

Fig. 1. Learning process with different blooms levels [2]

As discussed in the introduction providing a research experience to undergraduate students enhances the achievement of a-k outcomes. Research is an organized and systematic way of finding answers to questions. Gathering information from resources such as books or magazines is not research and also research is not the transportation of facts. Providing a research experience builds the better attainment of a-k outcomes.

The main characteristics of research and the corresponding learning of student outcomes are:

- Research initiates with a question or problem: (e)
- Requires clear articulation of a goal: (c,e)
- Follows a specific plan or procedure: (i)
- Often divides main problem into sub-problems:(c,e)
- Guided by specific problem, question, or hypothesis: (e)
- Accepts certain critical assumptions: (e)
- Requires collection and interpretation of data: (b,c,e)

Research is an extremely cyclic process. Later stages might necessitate a review of earlier work. This is not a weakness of the process but is part of the built-in error correction machinery. Because of the cyclic nature of research, it can be difficult to determine where to start and when to stop. In this process student learn the process of life long learning.

Fig. 2 (a) shows the traditional view of research where each stage starts after the completion of the previous stage. However the current scenario is the evolutionary model of the research shown in Fig. 2 (b).

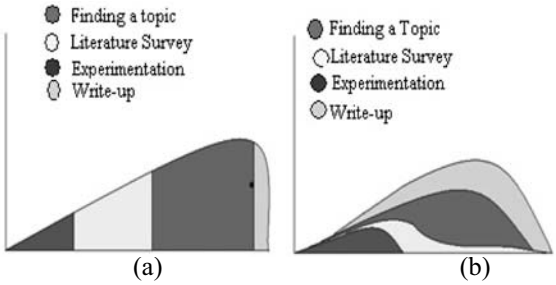

Fig. 2. Traditional and evolutionary approaches to process of research.

III. Design Of The REU Course

We introduced a 6 credit course "Research Experience for Undergrads (REU)" in place of 2 electives one each at 7th and 8th semesters respectively from the academic year 2011-12. Students of B.E. program may register for a 6 credit course "Research Experience for Undergrads (REU)" in place of 2 electives one each at 7th and 8th semesters respectively. Registration for this course shall be during the supplementary semester after the 6th semester and will be completed at the end of the 7th semester. The performance of the same will be reflected in the 7th semester grade card. The following sections explain the guidelines, course outcomes of the REU course and course outcome mapping to the program outcomes.

A Guidelines:

1. Students of B.E. program may register for a 6 credit course "Research Experience for Undergrads (REU)" in place of 2 electives one each at 7th and 8th semesters respectively. Registration for this course shall be during the supplementary semester after the 6th semester and will be completed at the end of the 7th semester. The performance of the same will be reflected in the 7th semester grade card.
2. During this course the candidate shall work on a research topic which reflects substantial understanding of the courses and capability to apply the same. At the end of the work the candidate shall submit a dissertation and will be evaluated by a committee of 3 members consisting of Head of the department, guide and an external examiner.
3. The topic of research and the guide and allotment of student shall be approved by the DUGC.
4. If the research topic is of interdisciplinary in nature the candidate may opt for a co-guide with minimum master's degree.
5. In case the student is ineligible or discontinues this course, then the student may **re-register either for the same course** or chooses 2 electives to fulfill the curriculum requirement.

6. Research group can take maximum of two/three students with defined goal of the project for each student.

Selection process is followed if more than two/ three students register with the group.

In what follows we discuss the course outcomes (CO) that we have set for REU course and the mapping of course outcomes to program outcomes.

B. Course Outcomes (CO):

At the end of the course student will be able to:

- carry out literature survey bringing out the contemporary issues in the defined area and identify the problem. (3a-M, 3e-M,3h-L, 3i-M,3j-L)
- develop competency to use the tools required to analyze/solve the defined problem. (3b-M, 3k-M)
- define process/methodology/steps towards solving the defined problem. (3c-L, 3e-H)
- establish flowchart/test bench/block diagram etc towards solving the defined problem. (3c-H, 3e-H)
- conduct/simulate, analyze and interpret the data/ input for the defined problem.(3b-H, 3e-M)
- communicate effectively in written and oral form of the research findings. (3f-L, 3g-M)
- get motivated for higher studies.

C. Course outcome and program outcomes

According to ABET, program outcomes (PO) describe what students are expected to know and be ableto do by the time of graduation. These relate to the knowledge, skills, and behaviorsthat students acquire as they progress through the program.A methodology for assessing the program outcomes is established by the accreditation committee of each programs. For each course, a set of course outcomes were defined and mappedto the POs. Table 1 summarizes the mapping of CO's and program outcomes (3a-3k) for the defined COs of REU course.

TABLE I. MAPPING OF CO WITH ABET 3A TO 3K

CO	a	b	c	d	e	f	g	h	i	j	k
1.	M				M			L	M	L	
2.		M									M
3.			L		H						
4.			H		H						
5.			H		M						
6.						L	M				

.IV. ASSESSMENT AND OUTCOMES

A method for assessing course outcomes is developed, which in turn provides the attainment of the program outcomes.Overall success in attainment of each outcome is identified by analyzingcombination of course reports of eachphases.Course outcomes are typically mapped to program outcomes and are evaluated using direct and indirect assessment methods. Direct assessment method uses course assessment reports with associated rubrics and indirect method uses the survey reports. The attainment of CO's are evaluated using both direct and indirectassessment methods. In the direct method CO's are mapped to program outcomes and survey report with a set of questionnaire are used as an indirect method.This provides us an ability to quantify the outcomes of REU.

TABLE II provides summary of direct method of evaluation of REU course using different phases, rubrics for each phase, mapping of program outcomes and student learning. Weightage given to each review stage is also provided in the scale of 0-10. The student gets maximum if he has carried out all the steps in the respective reviews. Each of the review contributes to a particular set of program outcomes and is provided with each of the review stages. The table also shows the different learnings the students can attain for each review stages.

TABLE II. Evaluation of REU Course

Sl.No	Phases	Reviews	Items to be reviewed	a-k	Learning
1	Phase-1 During summer semester (CIE)	Review-1 (15Marks) At the end of 2 week	Idea-Generation: Literature survey, different solutions, Tool learning, expt setup, requirement analysis RoadMap (In scale of 0-10)	a,c,e,h,I,j,k	How to carry out the Lit survey, summary etc
		Review-2 (15 Marks) At the end of 6 week	Procedures/Design Phase Implementation (In scale of 0-10)	b,c,e	How to find a specific solution to the problem
		Review-3(20Marks) End of the semester	Implementation continuation with the course (In scale of 0-10)	b,c,e	Implementation
2	Phase-2 During odd semester (CIE)	Review-4 (25Marks) (DuringMinor-1)	Implementation (In scale of 0-10)	b,c,e	Implementation
		Review-5 (2Marks5) (During Minor-2)	Demonstration of results, report writing, presentation, paper writing (In scale of 0-10)	f,g	Use of language, writing and presentation skills
3	Phase-3 End of the odd sem (SEE)	Dissertationreport (50 Marks)	Writing REU course thesis report (In scale of 0-10)	f,g	writing and presentation skills
		Viva-voce(50 Marks) External +guide/s	Viva-voce with the external examiner (In scale of 0-5)	e,f,g	Presentation skills

A. Direct assessment :

Direct assessment consists of two components: (i) Continuous Internal Evaluation (CIE) and (ii) Semester End Examination (SEE). REU course is assigned with 100 marks and the distribution of marks between CIE and SEE is decided as 50% for CIE and 50% for SEE and made known to the students at the time of registration. In the final grading total marks are normalized to 100: 50% (50 from 100) marks from the CIE and 50% (50 from 100) marks from SEE shall contribute. TABLE II provides the three-phase assessment of the course, which contains two phases as a part of CIE and third phase as a SEE evaluation. Rubrics are provided for each of phases and mapped to program outcomes. The table also provides the summary of student learning. TABLE III provides the summary of assessment of students using rubrics in phase-3.In direct assessment the students achieve very good grades, which shows attainment of course outcome is high.REU course is allowed to only few students across the institutes, who show the inclination for research and higher studies. Attainment of REU course outcomes with direct assessment also reinforces that the set of students who select REU courses are indeed performabove the average student of the class.

TABLE III. Different Grades Obtained By The Students

Year	N	Ns	Na	Nb
2011-12	**19**	6	12	1
2012-13	**29**	24	5	--
2013-14	**31**	27	4	--
N-# REU students, Ns- # students with S grade Na- # students with A grade, Nb- # students with B grade				

B. Indirect assessment:

As indicated indirect assessment of program outcomes and course evaluation uses the survey reports. Table IV and Table V present the set of survey questionnaire provided to students. Questionnaire in Table IV are set to assess the program outcomes. The set questions are also mapped to the program outcomes so that we can enhance the REU course in the next iteration

TABLE IV. Survey Questions Related To Pos

Qn no	*Details* (5-Excellent, 4-very good, 3-good, 2-average, 1-poor)	*Survey reports*				
		5	*4*	*3*	*2*	*1*
1	Overall experience of REU course (b,c,e,i,k)	*6*	*4*	*2*		
2	Experience encourages for Higher studies (4)	*8*	*2*	*2*		
3	Enhances confidence and independence in solving (e)	*9*	*1*	*2*		
4	Experience with other students (i)	*2*	*8*	*2*		
5	Experience helps in developing better engineers (b,c,e)	*6*	*6*			
6	Enjoy working with research problems (b,c,e)	*8*	*4*			
7	Enhancement of research experience (e)	*7*	*5*			

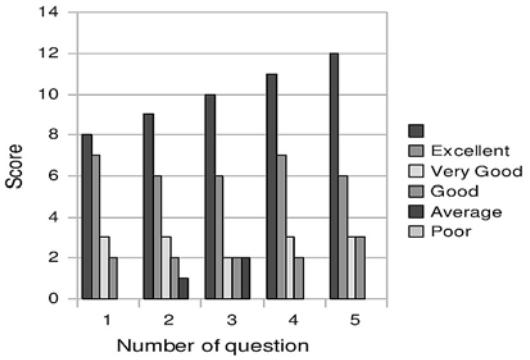

Fig. 3. Survey scores for questions shown in TABLE IV related to program outcomes.

Fig 3 shows survey scores for questions in TABLE IV related to program outcomes. The figure demonstrates the effectiveness of qualitative attainment of the program outcomes assessed by the students. The scores pertaining to motivating for higher studies (Q2) and enhancing confidence level (Q3) are very much relevant to the objectives of the course that we have defined. Q4 relates to the team interaction,attains lesser score compared to other questions, since REU is carried out by each student separately and is reflected in the score. The overall attainment of REU course by indirect method

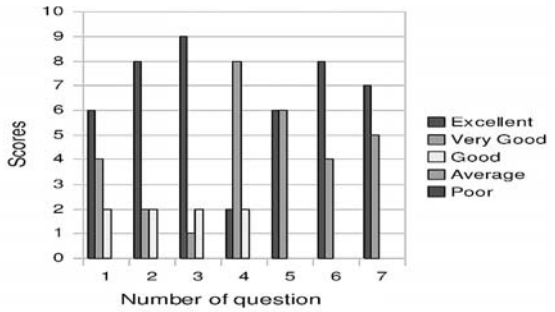

Fig.4 Survey scores for questions shown in Table 4 related to conduct of the REU course.

is excellent. These results again reinforce the good attainment of program outcomes in case of REU course.

TABLE V provide a set of Questionnaire related to overall conduct of the REU course. These set of questions are provided to the students after they are graduated from the institute. The questions were framed to get the effect of REU course at the program level as well as at the institute level. The overall Conduct of the REU course has attained 54% of excellent, 23% of very good, 18% of good and only 5% of average score.

TABLE V. Survey Questions Related To Overall Conduct Of The REU

Qn. no	***Details***	***Survey reports***				
		5	***4***	***3***	***2***	***1***
1	Amount of time spent	*7*	*3*	*2*		
2	Support from the guides	*6*	*3*	*2*	*1*	
3	Funding support from the Institute	*6*	*2*	*2*	*2*	
4	Enrich the Institutes and its face value	*7*	*3*	*2*		
5	Attract better students	*6*	*3*	*3*		

TABLE VI. Scaling Up Of REU Courses From 2011 And Outcomes Course

Year	Nr	Ng	Np	Nm
2011-12	**19**	**22**	**25**	10
2012-13	**31**	**40**	22+6	10
2013-14	**3 0**	**44**	**15+8**	5
2014-15	**46**	**51**	**--**	--
Nr - Number of REU students, Ng -Number of Guides, Np-Number of publications and Nm-Number REU students enrolled for PG in 2014.				

Fig. 4 shows survey scores for questions in TABLE V, which are related to overall conduct of the REU course. The figure demonstrates the effectiveness of qualitative attainment towards the overall conduct of the course by the graduates who have taken REU course. The questions Q1 to Q3 are related to the experience of the taking REU course and Q4 and Q5 are related to the effect of the REU course at the institute level. Scores of Q1-Q3 indicate an excellent experience nad the course. More motivating and satisfying are the score of Q4 and Q5 related to enriching the face value of the institute and also as a tool to attract good students to the institute.

I. SCALING OF REU COURSE

Initially during 2011, the REU course is offered to 19 students with the participation of 22 guides. The set 19 students from 2011 batch of REU course published more than 25 publications in refereed conferences and journals. We published institute REU journal, which contains all the publications by the students, and can act as a reference material for the institute. This journal is also a good showcasing material for the institute. We were very carefulin scaling up of the REU course to the next set of batches. During 2011-12, only 19 students registered with 22 guides across TABLE VI gives the summary of scale up of REU students from 2011 to 2014. The table clearly indicates that nearly 50% of the REU students enroll for or completed the higher studies in India or outside within 2 years of graduation.

I. CONCLUSIONS

This experimentation is first of its kind and the outcome is very much encouraging and satisfying. In this paper we have presented an experience of introducing a research experience for undergraduates (REU) course to the VI semester students of B. V. B. College of Engineering and Technology (BVBCET), Hubli. We have used direct method of assessment of course outcomes and program outcomes and also indirect method of assessing course using survey data to discuss impact of the course in enhancing the attainment of learning outcomes. The course is designed to expose the students to realistic technological research experience. The student under the guidance and supervision of a faculty carried out activities involved in the process of research like formulation of research problem, literature survey, conduct of research and reporting of results. Students have published and presented papers on the basis of their findings. Institute provided a one-day open house to showcase the findings and discuss and interact with the experts. The assessment of direct and survey results demonstrate that the perception of the students about the course is positive and encouraging. The course experience also motivates the undergraduate students to pursue higher studies and research careers.

References

[1] Anne-Barrie Hunter, Sandra L. Laursen, Elaine Seymour, “Becoming a Scientist: The Role of Undergraduate Research in Students’ Cognitive, Personal, and Professional Development”, DOI 10.1002/sce.20173 Published online 12 October 2006 in Wiley InterScience (www.interscience.wiley.com)

[2]Baker, E “Constructivism and learning”, McGaw, B. & Peterson P (Eds) (2007) International Encyclopaedia of Education 3rd Edition, Oxford: Elsevier (in print).

[3] Boghossian P. (2006). Fear of Knowledge: Against Relativism and Constructivism, Oxford: Oxford University Press.

[4]Hunter, A.-B., Laursen, S. L., & Seymour, E. (2006, February 10 – 11). Benefits of participating in undergraduate research in science: A comparative analysis of student and faculty perceptions. Paper presented at the Texas, Tech University, Lubbock, TX.

[5] Driscoll, M. P. (1994). Psychology of learning for instruction. Boston: Allyn and Bacon.

[6] http://snf.stanford.edu/education/undergraduate.htm

[7]Junge B, Quiñones C, Kakietek J, Teodorescu D, Marsteller P. “Promoting undergraduate interest, preparedness, and professional pursuit in the sciences:

An outcomes evaluation of the SURE program at Emory University.",PMC2879378

[8] Bailey Reynold, Amoussou Guy-Alain, Barnes Tiffany, Bischof Hans-Peter and Naps, Thomas, " Relevant real-world undergraduate research problems: lessons from the nsf-reu trenches", Proceedings of the 41st ACM technical symposium on Computer science education, SIGCSE '10, 62—63, Milwaukee, Wisconsin, USA.

[9] Koppelman Herman, van Dijk, Betsy and van der Hoeven, Gerrit, " Undergraduate research: a case study", Proceedings of the 16th annual joint conference on Innovation andtechnology in computer science education, 2011, pages 288-292, isbn 978-1-4503-0697-3, Darmstadt, Germany.

[10] Barker, L. "Student and Faculty Perceptions of Undergraduate Research Experiences in Computing", Trans. Comput. Education, March 2009, volume-9, number-1, March 2009, issn 1946-6226, pages 5:1 -5:28.

[11] Miguel A. Labrador1 and Rafael Pérez "Fulfilling Mentors' Expectations: An REU Site Experience", 2006 ASEE Southeast Section Conference.

[12] Labrador, M.A. and J. Wolan, G. Centeno, A. Kumar, G. Mullins, and R. Schlaf. A Research Initiative to Close the Gapbetween Undergraduate and Graduate School in Engineering. In Frontiers in Education.