Research culture in Engineering Faculty: Its effect on the attainment of Graduate attributes

Divya Nalla
Nalla Malla Reddy Engineering College
Divyanagar, Rangareddy District
Telangana, India 500088
divyanalla@nmrec.edu.in

Sneha Nalla
Nalla Malla Reddy Engineering College
Divyanagar, Rangareddy District
Telangana, India 500088
snehanalla@nmrec.edu.in

***Abstract*— Outcome based education as required by the accrediting agencies, is an important process that helps in quality improvement. It has been observed that faculty research is an important aspect in most of the accreditation processes. The Research-teaching nexus has been a topic of research since decades.**

The current scenario in our institute is such that most of the faculty are products from teacher centered education system and rote learning; Majority of faculty do not hold PhD or engage in any research activity; Majority of students do not have enough prerequisite knowledge and skills, have limited intellectual development, used to rote learning, weak in analytical writing, lack good communication skills, and not aware of research methodology.

This makes it more interesting to study the effect of faculty research on the student learning outcomes and hence the graduate attributes.

This paper studies these aspects in our institution which is a private self financed institute affiliated to a state run university. The paper studies the impact of one of the strategies proposed in the literature for strengthening the research-teaching nexus i.e., student projects. The paper studies the impact of faculty research on student learning outcomes through student projects.

Keywords—OBE; Research-Teaching nexus; Student Projects; Faculty Research; Learning Outcomes

I. INTRODUCTION

Engineering Education plays a major part in the development of the society. One of the most important outcome expected out of an engineer is to be able to identify problems and design and develop feasible and efficient solutions to those problems. The process of identifying problems and providing solutions itself is research. Orienting students towards research is hence a requirement in engineering education.

The National Board of Accreditation (NBA) which is the accrediting body for technical courses in India, lists out the graduate attributes and the list of outcomes that need to be attained by the graduates. Improvement in the quality of the graduates being produced is dependent on the level of attainment of these outcomes. Hence the study of these outcomes and comparing the level of attainment of these outcomes can demonstrate the improvement in quality.

The impact of faculty research on graduate attributes has been a debated topic for decades. There have been many studies on the research-teaching nexus.

This paper presents a study of this nexus and how faculty research has influenced student outcomes at our institute.

The paper has been organized broadly as follows. Section II presents the present Engineering Education scenario in India, and the current scenario of our institute being presented for the study. The next section (Section III) covers the background study and the existing research on the research-teaching nexus. Survey plan is presented in Section IV. The analysis and observations/results of the survey are presented in Sections V and VI. Section VII concludes the paper.

II. ENGINEERING EDUCATION IN INDIA AND CURRENT SCENARIO

In India, Engineering colleges are of various categories. They can be classified into state funded University colleges, partly state funded private colleges, and self-financed private colleges based on the administrative setup. Self-financed private colleges are of two categories based on the academic setup. There are autonomous colleges and colleges affiliated to a University that regulates the syllabus, and exams.

Engineering Curriculum involves theory courses, laboratories related to the theory courses, and projects. Embedding research component into each one of them may help the students achieve higher level learning outcomes.

Projects are the most important means through which the students can be oriented towards research. Students get practical insight into identifying a problem, analyzing, designing, and developing a solution. The required Graduate Attributes can thus be attained through student projects.

A. Current Scenario

We present the scenario of our institute which is a private self-financed institute running engineering programs affiliated to a state-run university. The students are admitted through a state level entrance examination which tests the students in basic mathematics, physics, and chemistry. Being an affiliated college, the curriculum and exam schedule is decided and the

end semester exams are conducted by the university. Students are expected to do a major project during the final semester of their four year undergraduate engineering program.

The National Board of Accreditation in India provides a list of Graduate Attributes (Appendix A) to be attained in order to obtain accreditation of any program. The accrediting bodies prescribe evaluation criteria that carry quite a good amount of weightage to faculty research. Apart from these regulatory authorities, university, and accrediting bodies, other surveys like the national Institutional ranking framework introduced by the Government of India, and other surveys give credit to faculty research. An institute which has faculty involved in research has advantage with most of these bodies that regulate, accredit, and rank the institute.

Faculty and the institutes are hence motivated and interested in faculty research. This makes it more appropriate to really study the effect of faculty research on teaching and hence student learning outcomes.

The problems that are identified at our institute have been observed to be at both student and faculty levels.

According to the regulatory authority which prescribes the norms for engineering institutions in the country, and the university that provides the affiliation, the institute needs to maintain a faculty-student ratio of 1:15, and at least 15% of the teachers should be holding a doctorate degree.

It may also be noted that there are other issues concerned with the students that affect the outcomes: not enough prerequisite knowledge and skills, limited intellectual development, used to rote learning, weak in analytical writing, lack good communication skills, and not aware of research methodology. The quality of student projects is also not quite encouraging.

As per the curricular requirement of our affiliating university, Undergraduate Students are required to take up a project in their final semester. As part of the project, the students are expected to identify a problem, propose a solution for that problem, and develop a prototype or a model solution.

The first step in the process is to identify a problem. Though the undergraduate students are not expected to take up a research problem, identifying a problem is still a big task for most of the students. There are only a few students who enthusiastically come out with problems they would like to work on. Faculty involved in research definitely have an advantage in this step of the project. They have a few problems already identified, and the students are selected to work on those problems.

There are usually an elite few students who are in a position to identify a problem, propose a design, and develop a solution for the identified problem. But the number of such students is very limited. Majority of the students are not able to identify a problem and solve it. Instead, they expect the faculty to give them a problem and expect them to guide through the entire process of solving that. The faculty also prefer to select better students for their projects.

The current scenario is such that most of the faculty are products from teacher centered education system and rote learning, and Majority of faculty do not hold PhD or engage in any research activity. But many of them are motivated to do their PhDs due to the requirement by accrediting agencies.

In this present context, it would be appropriate to study the effect of faculty research on student project quality and the learning outcomes attained by the students through their project, to ascertain if faculty research is necessary for improvement in the attainment of student learning outcomes.

III. RESEARCH-TEACHING NEXUS – BACKGROUND STUDY

The transfer of the advantages of research into teaching can be achieved by using research to inform teaching, and, less frequently, by engaging students in research. The influence of research in student Learning outcomes has been the subject of study since many years. There have been many studies on the research-teaching nexus.

The paper by Chen, Helen, Lisa, and Eric [2] explores the faculty as institutional agents who play a major role in developing, facilitating, and sustaining high levels of student engagement. The completion of the Engineering Change project [4] establishes a baseline for the preparation of engineers and provides a model for future assessments of the state of undergraduate engineering education and student learning. Implications of involving undergraduates in research are discussed in the paper [3]. An alternative realization of the teaching-research nexus was reported in [7]. It presents a case study of teaching that was informed by research and engaged both first year and final year undergraduate students in research, using problem-based learning.

There have been numerous studies on the impact of faculty research on undergraduate education. An extensive three year study [6] establishes benefits of research experiences for undergraduate students. The following list gives some indication of benefits for students described across the literature summarized in [6].

- Increased student interest in the discipline
- Increased persistence
- Enhanced career preparation: greater readiness for more demanding research and for professional careers in the sciences
- Increased skills: research and lab techniques
- Working collaboratively
- Communication (writing, presentation, and argument) and leadership
- Gains in: critical thinking and understanding how to approach research problems
- Knowledge Gain
- Increased understanding of the research process
- Increased self-confidence in ability to do research
- Improved approach to learning: shift from passive to active learning

Achieving these outcomes practically is the task. As mentioned in the paper by Prince, Felder, and Brent [5], the three commonly proposed strategies for strengthening the nexus of teaching-research are: (1) bringing research into the

classroom; (2) involving students in projects, and (3) broadening the model for academic scholarship.

We, in this work, study the impact of faculty research on undergraduate education through student projects. The benefits for the students as proposed in earlier literature (some being listed above), are analyzed and assessed to find out if faculty research really has any effect on student learning outcomes.

The paper in turn studies the effect of faculty research on the student learning outcomes – and which of these outcomes are effected the most.

IV. Survey Plan

A survey was conducted to study the effect of faculty research on the student learning outcomes. In this survey, the learning outcomes expected from an engineering graduate are studied in the context of student projects. The survey compares the outcomes achieved by the students who have done projects under the guidance of faculty who are involved in research, and those faculty who are not involved in any research. The outcomes have been framed by considering the list mentioned in section III, and the NBA Graduate Attributes.

The students pursuing their undergraduate degree in engineering were surveyed to check the level of outcomes attained by them through their academic project during the final semester of their course. These were again cross checked with the project review committee.

The various components involved in the survey include the '*type of project*', '*faculty* grouping', and the '*questionnaire*' created to test the attainment of the learning outcomes.

The students' abilities and skills which are the outcomes being assessed, are mapped to the Graduate Attributes (GAs as in Appendix A), and presented as questions in the survey questionnaire (Table III). A rubric is presented for the questionnaire.

The students have done different kinds of projects under faculty of various categories. The projects the students have done were classified into 7 types as shown in Table I. These 7 types are a detailed classification of two classes of projects: Research oriented and non-research oriented projects. Among the seven types listed, the first three types are research oriented projects whereas the next four are not.

The faculty have been classified mainly into two categories: those who are involved in research, and those who are not involved in research. Within these two categories, there are other classifications dividing the faculty into five groups. Table II depicts the grouping. The first three groups in the table consists of faculty involved in research, and the last two are the groups of faculty not involved in any research.

The final year students of the undergraduate program in core engineering branches (computer science, electronics and communication, Electrical, Mechanical) were asked to take the survey. About 220 students were part of the survey. Apart from the students, the project review committee also took part in the survey by giving feedback about the projects done under each faculty, and reviewed the student survey.

V. Analysis of the Survey

In the survey, each student outcome has been presented as a question for which three choices were provided (Table III) for each level of attainment (level 1, level 2, and level 3), of which level 1 stands to be the best one or implies high level of attainment. It can be deduced from the rubric that the attainment levels are categorized into level 1: high, level 2: medium, level 3: low. Obtaining level 1 for an outcome is 'high level' of attainment for that particular outcome.

Two different kinds of analyses are done on the survey results. The first study is on the attainment levels of the faculty groups i.e., comparing the levels of attainment of the different faculty groups categorized in the previous section. The second study is on the attainment levels of the project types. That is, the projects as classified in the previous section into groups are considered and each type is analyzed for the level of attainment of the learning outcomes for the students who have done projects of these types.

We analyze the survey by considering the number of students under a particular faculty who have reached level 1 of a particular outcome to calculate the value of the outcome attained. We call it the ***score*** of a particular outcome $\mathbf{V}(x,f)$ where x depicts the outcome (each outcome is given a number from 1 to 14 from Table III), and f depicts the faculty group (group 1 to 5 from Table II).

TABLE I. Types of Projects

Project type category	Description of the type pf project
a	Solved a Research Problem and ready for publication
b	Solved a research problem but not publishing
c	Proposed a new/ novel idea and proved that the new idea is better than the existing ones by comparing
d	Implemented an innovative idea proposed in existing literature (but has not been implemented so far) and studied its impact
e	Implemented an idea proposed earlier and studied the results
f	Took an idea from an existing project and implemented the same
g	Taken an existing idea and implementation and only presented that

TABLE II. Faculty Grouping

Faculty Group	Faculty Type
1	Faculty well experienced in Research / Teaching
2	Faculty pursuing research and is good in teaching
3	Faculty pursuing research but is not so good in teaching
4	Faculty not involved in Research but good in teaching
5	Faculty not involved in research and not very good in teaching (some of fresh graduates recruited as faculty may be in this category)

TABLE III. RUBRIC FOR SURVEY QUESTIONNAIRE ALONG WITH THE GRADUATE ATTRIBUTES MAPPING TO EACH OUTCOME

	Questions	1	2	3
1	**Ability to defend or express, present, discuss, and defend their work to peers, guide, and other faculty (GA10)**	Presented the work very confidently to everyone and able to answer all the questions posed	Presented the work very confidently but could not answer all the questions posed by them	Presented the work but not confident about the work.
2	**Writing Skills (Documentation) (GA10)**	Could Clearly document myself the entire project with proper introduction, background, project details, and conclusion	Could prepare the documentation on my own but lacking a few details	Documentation partly was written by me and it also included a few downloaded material.
3	**Lab Skills (measurement taking, modern tools usage, and other technical skills) (GA5)**	• Learnt a new tool • Improved my lab skills • Learnt new skills in implementation	• Learnt new skills in implementation • Improved my lab skills	• Tried to learn new skills but not thorough in those
4	**Time management (GA11)**	Improved time management skills in the process of doing the project. Could manage the given time properly for the project without missing deadlines.	Could barely manage the time given. Missed a few deadlines.	Could not manage the given time properly. Missed the deadlines often.
5	**Reading Comprehension Skills (GA2)**	I am able to understand research papers and able to find out the issues to be addressed	I am able to understand research papers and comprehend.	Cannot fully understand Research papers
6	**Collaborative working skills (GA9)**	Fully collaborated with my team mates in doing the project.	Did my part of the project and faced some problems in collaborating with my team members	Did my part of the project assigned and do not know what the others in my team have done.
7	**Confidence levels (GA12)**	Highly confident about the work I have done	Not fully confident as I could not complete the work fully	Not confident at all
8	**Increased Patience and perseverance (GA12)**	My patience and perseverance levels have improved a lot in the process of doing this project	My patience and perseverance levels have improved in the process of doing this project	No improvement in my patience and perseverance levels
9	**Increased tolerance for frustration, setbacks, and failures (GA12)**	I can now withstand any failures and keep trying for the results till I achieve	I can withstand failures but give up after a few trials.	Failures frustrate me.
10	**Greater understanding of theory/concepts in depth (GA1)**	The concepts in the subjects I studied during my course work are much clearer to me now with the applications for those concepts	I understand the subjects I studied during my course work in a better way but can't relate those to the project I have done.	My project does not relate to any of the subjects I studied
11	**Increased appreciation for the relevance of the course work to understand the essence of the subject. (GA1)**	The theory I leant in class sounds relevant to me now as I used the concepts in my project	The theory I learnt in class sounds relevant but can't relate that to the project done by me.	The theory that I studied and the project I did are totally unrelated
12	**Ability to analyze data within theoretical or conceptual framework (GA2)**	Collected data that was analyzed to prove the concepts implemented in the project	Collected data and analyzed for the project but not able to correlate that to the concepts	There was no analysis involved in my project
13	**Understanding how to frame research questions, develop, and refine a research design. (GA4)**	Can now frame research problems, develop and refine a solution for the problem	Can frame a research problem but not in a position to develop a solution	Cannot frame a research problem.
14	**Increase in interest in learning / motivation to learn (GA12)**	My interest in the subject has improved and I wish to learn more in this subject	I could learn a lot in the subject form the project but not interested to learn more about this	Have not learnt anything new by doing the project.

Suppose the number of students guided by a faculty in a faculty group ***f*** is **St(*f*)**, if the number of students of faculty group ***f*** who reach level 1 of an outcome ***x*** is ***O1(x),*** then the score of the outcome ***x*** for a faculty group ***f*** is ***V(x,f)*** where ***V(x,f) =O1(x)/St(f).***

These *score*s for a particular outcome ***"x"*** are compared across all the faculty groups (from 1 to 5). i.e., ***V(x,1), V(x,2), V(x,3), V(x,4),*** and ***V(x,5)*** are compared. It can be understood that the faculty group with the highest score is supposed to have reached the maximum level of attainment for that particular outcome.

Similar analysis is done to calculate *score* of a project category for a particular outcome. The *score* of each category of projects is calculated for each outcome in the same way as was done for the faculty groups. For a project category, the number of responses at level 1 for a particular outcome are taken and divided by the total number of students who have done the project under that category to get the *score* of that project category for that particular outcome. These scores obtained are the attainment levels of the project group for a specific outcome. The attainment score of all the outcomes together is calculated by taking the sum of the scores of each outcome for a specific category of project. These scores when compared show that the overall attainment levels for a particular kind of a project are higher than those of others.

The *score* of a project category ***p*** for a particular outcome ***"x"*** is denoted by ***W(x,p)*** which is equal to ***R1(x)/St(p)*** where ***R1(x)*** is the number of responses that are at level 1 under the project category ***p*** , and ***St(p)*** is the total number of students under the project category ***p***. The scores **W*(x,a), W(x,b), W(x,c), W(x,d), W(x,e), W(x,f), W(x,g)*** are compared.

VI. Results and Observations

The results of the survey are presented in the form of *score*s for the attainment of each outcome at the highest level that is level 1.

A. Classification of Faculty Groups

The first analysis is presented in Table IV that shows the *score*s of each faculty group for each of the 14 outcomes being assessed.

In the Table IV, each row depicts the scores of each faculty group according to the group number in the column i.e., ***V(x,f)*** where ***x*** is the outcome number and ***f*** is the faculty group number. The two rows below the group numbers show the number of faculty considered from each group, and the total number of responses considered under each faculty group.

The number of students who have attained level 1 in an outcome divided by the total responses in a particular group has resulted in the *score* for each outcome depicted by each cell in the table. Each cell gives the information about the attainment value for a particular outcome corresponding to a particular group in the faculty. The top *score* for each outcome have been highlighted. The following observations are noted:

- A general observation is that the *score*s ***V(x,2)***, or ***V(x,3)*** are the highest for ***x*** from the set {1,2,….,14}, and ***V(x,1), V(x,2), V(x,3)*** are greater than ***V(x,4)*** and ***V(x,5)*** for all x in the set {1,2,….14}. i.e., the scores obtained by the first three groups of faculty (Groups 1,2,3) are higher than the last two groups (Groups 4,5).
- The highest score has been obtained by one of the first three groups for almost all the outcomes except one.
- Another observation is that the faculty group 2 has scored the highest in the overall score of all the outcomes.

B. Classification of Project types

The second study is the scores calculated for each project group.

Fig.1 depicts the number of projects done under each category of projects as classified in Table I. It can be observed that the type of projects done are not all research oriented projects.

TABLE IV. Faculty Groupwise *Score*s

Outcomes ↓	Faculty Group Number →	Group 1	Group 2	Group 3	Group 4	Group 5
	Number of faculty in each group →	8	3	2	28	12
	No. of responses →	37	19	11	108	45
1		0.78	0.79	0.91	0.43	0.62
2		0.54	0.84	0.55	0.53	0.73
3		0.65	0.63	0.73	0.40	0.47
4		0.62	0.84	0.73	0.66	0.60
5		0.54	0.32	0.55	0.34	0.56
6		0.68	0.84	0.91	0.86	0.80
7		0.89	1.00	0.91	0.81	0.84
8		0.54	0.84	0.91	0.56	0.51
9		0.73	0.89	0.91	0.75	0.78
10		0.57	0.74	0.55	0.55	0.60
11		0.70	0.68	0.91	0.53	0.67
12		0.89	1.00	0.73	0.57	0.76
13		0.38	0.68	0.55	0.33	0.56
14		0.81	0.95	0.82	0.75	0.84
Total		9.32	11.05	10.64	8.06	9.33

The results of the attainment levels are hereby presented in Table V.

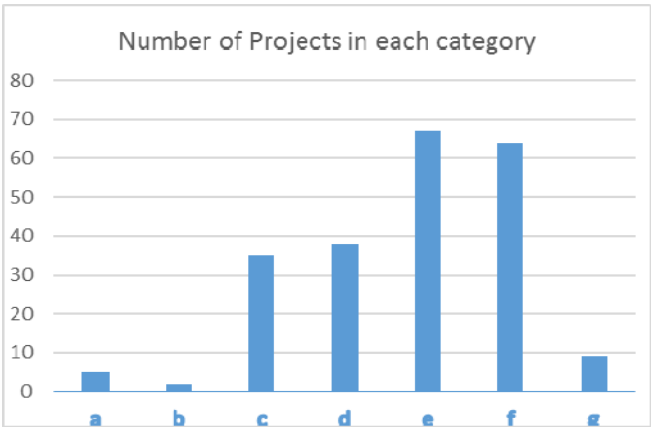

Fig. 1. Number of Projects in each category

TABLE V. PROJECT CATEGORYWISE *SCORE*S

Project Category (Number of projects done in this category) →	**a (5)**	**b (2)**	**c (35)**	**d(38)**	**e (64)**	**f (58)**	**g(15)**
Outcome Number ↓	**1**	**1**	**1**	**1**	**1**	**1**	**1**
1	0.60	0.50	0.63	0.55	0.58	0.62	0.53
2	0.80	0.00	0.60	0.50	0.63	0.62	0.73
3	0.40	0.00	0.54	0.58	0.52	0.52	0.73
4	0.80	0.50	0.74	0.53	0.67	0.76	0.73
5	0.60	0.00	0.49	0.45	0.17	0.53	0.40
6	0.40	0.50	0.97	0.76	0.80	0.84	0.73
7	0.40	0.00	0.80	0.79	0.84	0.88	1.00
8	1.00	0.50	0.63	0.55	0.59	0.62	0.60
9	1.00	0.00	0.83	0.34	0.83	0.67	0.47
10	1.00	0.50	0.74	0.53	0.45	0.47	0.73
11	1.00	0.00	0.74	0.66	0.64	0.47	0.67
12	1.00	0.50	0.86	0.61	0.67	0.72	0.60
13	0.80	0.00	0.43	0.58	0.36	0.38	0.27
14	0.80	0.50	0.77	0.82	0.86	0.79	0.80
Total Score	10.60	3.50	9.77	8.24	8.61	8.90	9.00

The following observations are made:

- The *score* ***W(x,p)*** for most of the values of ***x*** between 1 and 14, is the highest when ***p*** is either ***a*** or ***c*** except for the values ***x*** = 3, 7, and 14. That is, the highest score of outcome attainment for most of the outcomes is in the project categories ***a***, and ***c*** which are the research oriented project groups. (It may be noted that the number of projects in the category ***b*** are very less and considering the scores in that category may not result in correct analysis)

- The overall attainment level when compared for each project group is found to be the highest for the project group of category ***c*** i.e., the category "Proposing a new/ novel idea and proving that the new idea is better the existing ones by comparing"

VII. CONCLUSIONS AND FUTURE WORK

The observations in *Subsection A* in Section VI, have demonstrated that the Faculty research has a positive effect on the attainment levels of the student learning outcomes.

The observations in *Subsection B* in Section VI can be a basis for claiming that the kind of project selected also effects the outcomes attainment, and higher levels of outcomes are attained with research oriented projects.

We thus conclude from our study that faculty research plays an important role in enhancing the attainment levels of student learning outcomes and hence improves the scope for Outcome based Education.

The significance of this survey lies in the fact that the faculty of the institute who were the participants in the survey could practically realize the positive effect of their involvement in research. Though there have been many such studies to prove that faculty research effects student learning outcomes, this study is a motivating factor for our faculty to pursue research.

In future, we would like to further incorporate research component in teaching as proposed in [5] by bringing research into the classroom. This is possible by implementing active learning techniques in the classroom and involving the students in research practice indirectly. Further, with the results obtained in this paper, we would like to encourage more of our faculty to pursue research and thus would like to improve the outcomes.

APPENDIX A: GRADUATE ATTRIBUTES

GA1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization for the solution of complex engineering problems.

GA2. Problem analysis: Identify, formulate, research literature, and analyze complex engineering

problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

GA3. Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for public health and safety, and cultural, societal, and environmental considerations.

GA4. Conduct investigations of complex problems: The problems that cannot be solved by straightforward application of knowledge, theories and techniques applicable to the engineering discipline.

GA5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modelling to complex engineering activities, with an understanding of the limitations.

GA6. The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

GA7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

GA8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

GA9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

GA10. Communication: Communicate effectively on complex engineering activities with the engineering community and with t h e society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

GA11. Project management and finance: Demonstrate knowledge and understanding of t h e engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

GA12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

REFERENCES

[1] R.A.Calvo, L.Markauskaite, & K.Trigwell. Factors Affecting Students' Experiences and Satisfaction about Teaching Quality in Engineering. Australasian Journal of Engineering Education, Volume 16, Issue 2, 2010

[2] Chen, Helen, Lisa R. Lattuca, and Eric Hamilton "Conceptualizing engagement: Contributions of faculty to student engagement in engineering".Journal of Engineering Education 97(3): 2008, 339–354.

[3] M. Kevin Eagan Jr. • Jessica Sharkness • Sylvia Hurtado • Cynthia M. Mosqueda • Mitchell J. Chang, "Engaging Undergraduates in Science esearch: Not Just About Faculty Willingness". Research in Higher Education, March 2011, Volume 52, Issue 2, pp 151-177

[4] Lattuca, L. R., Terenzini, P. T., Volkwein, J. F., "Engineering change: A study of the impact of EC2000". Baltimore, Md: ABET, Inc. Accreditation Board for Engineering & Technology (U.S.), & Pennsylvania State University. (2006).

[5] Michael J. Prince, R. Felder and R. Brent. "Does Faculty Research Improve Undergraduate Teaching: An Analysis of Existing and Potential Synergies" *International Journal of Engineering Education* (2007)

[6] Seymour E., Hunter A.-B., Laursen S., DeAntoni T. Establishing the benefits of research experiences for undergraduates: first findings from a three-year study. Sci. Educ. 2004;88:493–594.

[7] Willcoxson, Lesley; Manning, Mark L.; Johnston, Natasha; Gething, Katrina. "Enhancing the Research-Teaching Nexus: Building Teaching-Based Research from Research-Based Teaching" International Journal of Teaching and Learning in Higher Education, v23 n1 2011 p1-10