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Research-based Learning for Skill Development of Engineering Graduates: An empirical study

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Abstract

The engineering graduates should have interdisciplinary knowledge in addition to theoretical knowledge to survive in dynamic industrial environment. Literature reveals that Indian engineering graduates need to develop problem solving, solution development, social skills in engineering graduates. Research-based learning (RBL), one of the outcome-based learning techniques, closes the gap between theory and application. It involves the learner to design, experience and reflect the entire process of learning. Inquiry forms one of the important elements of RBL which also develops creativity and discovering new techniques breaking the monotonous process for solution development. The present study conducted an empirical analysis to examine the role of RBL in skill development of engineering graduates. The participants are the recent graduates of Birla Institute of Technology and Science Pilani, Pilani campus and those who had done thesis/dissertation. Thesis/dissertation involves the learner in research process such as problem identification, hypothesis formulation, design, data collection and analysis, interpretation, critical review, etc. An online survey questionnaire has been used to assess the skills. The results demonstrated that the use of RBL develops and enhances problem solving, domain knowledge, language and communication, communication & information technology, general learning, academic knowledge, attitude, ethics skills. It is also opined that use of RBL and activities will foster to reduce the gap between the skills required in the industry and learned at the university. Thus, it is important to integrate the RBL in engineering curricula to provide exposure and develop required skills.

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Keywords:skills; problem solving; academic knowledge; RBL;thesis/dissertation; engineering graduates;

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1. Introduction

The demand for skilled engineers is increasing in the emerging nations, such as India [1]. There is an urgent need to develop skills in the formal education system and at the same time skill creation outside the formal education system is required to meet the increasing need of skilled employees [2]. Although the Indian academic engineering education provides strong domain knowledge, there are many studies by KPMG, BCG and FICCI reflecting the need to develop 'problem solving skills' in Indian engineering graduates. Even AICTE report [3] indicated that engineering graduates lack in skills or competency missing in as anticipated by industry or corporate. Thus, it becomes important to impart knowledge and skills to engineering graduates as an inbuilt part of engineering education.

A certain set of skills have also been prescribed by academic-practitioners and accreditation boards: domain/fundamental knowledge [4], critical thinking [5], problem solving [5], social skills (presentation, professional relationship, communication, ethics, attitude, teamwork) [4&6], etc. Though, to improve the quality of engineering education system, the accreditation boards such as ABET [7] and National Board of Accreditation, India have clearly stated learning outcomes in the form of the skills to be possessed by graduates as part of the curriculum. The outcome is not up to the mark, as a recent study revealed that engineers in Indian manufacturing organisations lack in skills like problem solving, teamwork and communication [8]. To close this gap, there is a need to maintain a balance between theory/fundamental teaching and providing real work exposure to students. By combining didactical approaches and existing concepts with emerging topics of the industry resulting in the concept of Learning Factories (LF) can also be addressed to close the gap [9]. LF is an extension of existing labs to make industry oriented learning in educational setting. It provides hands-on experience which emerges to be application and analytical oriented. At the same time, it is also necessary to understand the graduate's perception and satisfaction towards skills developed during their graduate training [10] along with focus on teaching/learning techniques used. This demonstrates the need to investigate the practice based teaching/learning practiced in engineering education and its effect on skills development, also the perception of graduates towards skills.

The present study analyses the research based learning (RBL) techniques used in engineering education. RBL is based on experiential learning which involves both active (learning by doing) as well as reflective learning [11]. RBL is one of the best suited methods to develop, enhance and sustain a deeper and thoughtful learning leading to better teamwork, communication, analytical, etc. skills [12]. RBL emphasizes on research process and problems underlying inquiry-based learning involving students as participants [13]. RBL being experiential and inquiry based, leads to intellectuality as well as development of academic skills (i.e. strategies, planning, decision making, being aware, etc.) [14]. The learners' use of academic knowledge leads to work based learning [15]. According to Huber [16], in RBL, the learners design, experience and reflect the entire process of a research (problem identification, literature review, observation, hypothesis formation, research design, data collection and analysis, results and discussion, report drafting).Thesis/dissertation (T/D) is an activity of RBL with the goal to generate new findings and research. It is one of the important methods by using research elements in teaching/learning process [17]. This develops a particular scientific process of learning which is helpful in real-work environment where they are required to do preplanning before execution considering the positive and negative consequences.

The present study investigates the role of thesis/dissertation (one of the activities of RBL) in engineering education for skill development. An empirical method is used to answer the following research questions:

RQ 1. What is the perception of the engineering graduates towards RBL (T/D)?
RQ 2. Does RBL (T/D) develop required skills in the engineering graduates?
RQ 3. Is there correlations and any difference among the skills developed through RBL (T/D)?

2. Methods and Materials

Based on literature review a conceptual framework (figure 1) is used to find the answers to the above defined research questions. This shows how the standard RBL process can be used to develop the skills such as problem

solving, domain knowledge, ethics, academic knowledge, language & communication, and communication & information technology. The 50 participants were the graduated students of Birla Institute of Technology and Science Pilani (BITS Pilani), India; who did their T/D as one course in their final year of graduation. The students were made to engage in the process: from problem identification to report presentation or publication. The RBL context included instruction based on research-based as one of the paradigm proposed by Healey [13] where the participants were involved completely on problem and learning process.The study used a cross-sectional research design and questionnaire survey method. The questionnaire used by Sota and Peltzer [18] was modified for the Indian context. The final questionnaire contains 38 items based on five point Likert scale where 1 means strongly disagree, and 5 means strongly agree. The questionnaire was validated for the content validity and its thoroughness by the BITS Pilani professors, who are actively involved in academic and research planning. The questionnaires were filled after a thorough discussion with respondents. Some of the specific questions added are: Item no 5, 17, 18, 21, 24, 25, and 26 (table 1).The reliability and validity of the questionnaire have been assessed and discussed in the results and discussion section. The data was analyzed using SPSS for Windows. Following tests/analyses were carried out:

- Corrected-item-total-correlation (CITC) for the purification of the data
- Reliability analysis to assess the data reliability
- Exploratory factor analysis to categorise the items under respective variables (skills)
- Correlation test to see the relationship among the variables (skills)
- Paired sample t-test to see whether any difference exist among the level of skills developed by RBL

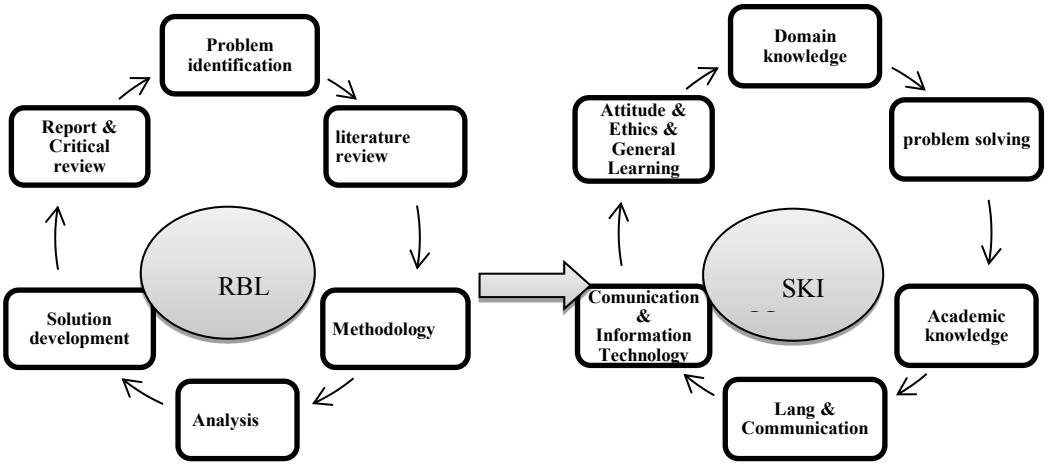

Fig. 1. Conceptual Framework for the study.

3. Results and Discussion

3.1. The descriptive statistics of all the statements (to study the perception of engineering graduates)

During descriptive analysis; purification of data was done based on the corrected-item-total-correlation (CITC) value (table 1). Earlier six items having less than 0.3 CITC value were deleted for further analysis. Further, during EFA more five items were excluded due to cross loadings and finally twenty seven items were considered for EFA and other analysis. The Cronbach alpha as a measure to assess the internal consistency of the items was used. The reliability of the data was found to be excellent for all twenty seven items (α=0.896). The mean score was analysed to understand the perception of participants. The results (table 1) indicate that the mean value of the items ranges from 3.42 to 4.36. This shows that the participants have positive attitude towards the learning developed through T/D. Many

items have mean value of 4.0 or above. This demonstrates that the participants perceive the RBL to be helpful in enhancing their learning to be useful in their work environment. It can be observed that few items (e.g. item no 6 and 24) have lower mean value and higher standard deviation which means these activities should be developed to strengthen the learning.

3.2. Exploratory factor analysis (EFA)

EFA is carried out to explore the natural groups of skills. The EFA reveal that the T/D activities can be grouped into eight skills as shown in table 1. These eight skills are termed as: problem solving, domain/fundamental knowledge, language and communication, communication & information technology, general learning, academic knowledge, attitude and ethics. The EFA findings also reveal that the PS plays the largest role in characterising the eight skills followed by other skills. PS accounts for more than 15.96 of the variance explained by the eight skills. Even in an experimental study it was found that RBL improves learners' ability to think critically, analyse, understand and synthesize in comparison to traditional methods of teaching/learning [14].The mean value of all the items in problem solving group has the highest score which means that the contribution of RBL to the development of problem solving skills is highest. This demonstrates findings of the study are in consonance with theory of RBL which describes that RBL focuses on learning process developing the application and analytical skills [12,17].

3.3. Comparing the mean scores of eight skills(difference between the level of skills developed)and relationship among skills

The results (table 2) indicate that all the skills possess statistical significant correlation among each other. Among all the eight skills, it is AK which is highly correlated with DK, PS, GL and AT. The level of correlation between DK and PS is also good. All these indicate that the skills which are highly correlated can be used to develop other skills or denote the existence of both skills at the same time. Further, based on the correlation, the paired sample t-test (table 2) was conducted. It indicates that among the eight skills developed by RBL, there are statistical significant differences between AK-DK; AK-PS; AK-AT; AK-GL; PS-AT; DK-CT; DK-PS. This reveals that there is a difference between the levels of these skills developed by RBL. It contributed most to the PS (know-how, analysis, application, decision making) and AK (satisfaction, awareness, self realization) which emerges by emphasizing on learning process and complete involvement of learners in the task. The findings also indicate that there is no statistical significant difference between DK-LC, which means that the level of these skills is same.

Table 1. Factor loadings of skills using exploratory factor analysis and descriptive analysis.

Sr. No	Items	Item loading	Mean	SD	CITC	ACID
	Problem solving (PS)		27.1	5.08		
1	I was confident about the quality of my research work	.837	3.78	1.148	.516	.894
2	I could apply the gained knowledge to develop solution for the problem identified	.793	4.10	.863	.511	.894
3	I am satisfied with the sharing of my research knowledge through T/D activities	.766	4.00	1.088	.442	.895
4	I could apply the gained knowledge to develop research gap	.646	3.98	.769	.582	.894
5	I could apply the gained knowledge to develop the methodology for solution development	.605	3.94	.843	.563	.894
6	I am satisfied with my increased knowledge with the group discussion through T/D activities	.493	3.42	1.197	.620	.892
7	I could apply the gained knowledge to develop the topic/title of my thesis	.433	3.88	1.003	.470	.895
	Domain /Fundamental Knowledge (DK)		16.36	2.63		
8	Involvement in T/D activities (discussion) increased my cognition ability	.775	3.92	.900	.503	.894
9	T/D activities like discussions lead to more knowledge acquisition	.609	4.34	.593	.605	.894
10	T/D activities increased my adaptation level by working in groups and teams	.600	3.88	1.189	.426	.895
11	T/D activities helped me to think critically	.504	4.22	.815	.441	.895
	Language and communication (LC)		15.74	3.16		
12	T/D activities can be used to enhance English language skills	.713	3.78	1.183	.357	.897
13	Preparing and using presentations enhanced my learning	.700	4.14	.948	.316	.897
14	I am satisfied with development of English language skills through T/D activities	.636	3.80	1.030	.533	.894
15	Involvement in T/D activities such as presentations, group discussions, etc. enhanced my communication skills	.624	4.02	1.078	.435	.895
	General Learning (GL)		8.12	1.74		
16	T/D activities should be used regularly in classroom teaching	.784	4.10	1.165	.450	.895
17	I gained knowledge from various research designs used in different studies	.730	4.02	.845	.475	.895
	Communication and information Technology		8.12	1.50		
18	T/D activities helped me to learn how to acquire data from website, NGO, consultancy, etc.	.771	3.80	1.030	.327	.897
19	Using proper figures and graphs helped me to learn better	.656	4.32	.768	.487	.895
	Academic Knowledge (AK)		16.06	2.68		
20	T/D activities are required to develop academic skills	.768	4.24	.847	.420	.895
21	T/D activities developed awareness about the process of research and writing report in me	.496	3.98	1.097	.562	.893
22	T/D activities are important to enhance knowledge and skills	.426	4.02	.915	.361	.896
23	I am satisfied with my increased knowledge through T/D activities	.418	3.82	.962	.459	.895
	Attitude (AT)		7.66	2.0		
24	Working with a professor in the newer areas which may not be the preferred domain areas of professor is important	.782	3.66	1.255	.367	.897
25	I have more respect for fellow students/teachers/researchers after T/D activities	.416	4.00	1.107	.626	.892
	Ethics		8.42	1.53		
26	T/D activities helped me to learn how to access data bases for research	.814	4.06	.890	.532	.894
27	Plagiarism check is important in T/D activities	.621	4.36	.964	.330	.897

KMO=.638, Cumulative Variance=71.47, Cronbach alpha=0.896. Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.SD=Standard Deviation, CITC=Corrected Item-Total Correlation, ACID=Cronbach Alpha if Item deleted

Table 2 Correlation and paired sample t-test analysis.

Correlations										Paired Sample t-test				
Skills	DK	PS	LC	CT	AK	GL	AT	ET		Skills	Mean	SD	T	df
DK	1	.44**	.42**	.42**	.51**	.39**	.39**	.32*		AK - DK	-.30**	2.64	-.802	49
PS		1	.34*	.31*	.50**	.33*	.48**	.31*		AK - PS	-11.04**	4.43	-17.61	49
LC			1	.38**	.25	.18	.22	.22		AK - AT	8.40**	2.24	26.50	49
CT				1	.27	.28*	.23	.29*		AK - GL	7.94**	2.34	23.97	49
AK					1	.51**	.58**	.41**		PS - AT	19.44**	4.47	30.70	49
GL						1	.46**	.35*		DK - LC	.62	3.15	1.39	49
AT							1	.33*		DK - CT	8.24**	2.42	23.98	49
ET								1		DK - PS	-10.74**	4.57	-16.58	49

**. Correlation is significant at the 0.01 level (2-tailed).*. Correlation is significant at the 0.05 level (2-tailed). DK: Domain knowledge, PS: Problem solving, LC: Language and communication, CT: Communication and information technology, AK: Academic knowledge, GL: General learning, AT: Attitude, ET: Ethics, df: degree of freedom

The literature on Indian engineers indicate that the current engineers lack in problem solving and communication skills and are good at domain knowledge [8] and the findings of the present study revealed that RBL contributes more to problem solving and academic knowledge than domain knowledge. Consequently, the RBL can help learners in learning process and developing abilities of application, analysis and synthesis. Though the participants in the study showed positive response towards RBL, also opined that the courses based on RBL method need to have more practice based engagements, lab work, independence related to the work. Thus, on the basis of the findings and literature, the present study suggests the incorporation of RBL into courses in engineering education along with labs such as LF to have maximum output. The LF is a paradigm shift to industry partnered, interdisciplinary, real world problem solving in engineering education [19].The LF in an academic environment are to offer a practice-based engineering curriculum, which balances analytical and theoretical knowledge as well as hands-on experience. A study proposed and recommended the integration of RBL using LF into teaching/learning of engineering courses such as energy efficiency in production engineering to improve the engineering problems significantly [6].

4. Conclusions

Based on the empirical study of Indian engineering graduates, it is found that RBL contributes to the development of problem solving, domain knowledge, language and communication, communication & information technology, general learning, academic knowledge, attitude, ethics skills. The study also found that RBL improves problem solving more than other skills. Therefore, RBL is a best fit for Indian engineering education as Indian engineers lack the problem solving skills. The study proposes the necessity of incorporation of RBL using labs such as learning factory for re-engineering the engineering education to meet the increasing revolutions in industrial era and promote the required skills of engineering graduate. However, the present study is quantitative in nature, a qualitative study including the instructors along with the students is proposed to have a wider view and work and to strengthen the

current method of thesis/dissertation at the case organization. The study also proposes to study the RBL using LF for skill development.

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References

[1] A.Leiden, G. Posselt, V. Bhakar, R. Singh, K.S. Sangwan, C. Herrmann, Transferring experience labs for production engineering students to universities in newly industrialized countries, IOP Conference Series: Materials Science and Engineering, 297 (2018) 1-9.
[2] Government of India, Planning Commission. Twelfth Five Year Plan (2012–2017), socialsectors, India: SAGE Publications, 3 (2013).
[3] AICTE , Placements, graduates, enrolments and intake statistics of engineering education in India, (2016).
[4] P.Jäger,DerErwerbvonKompetenzenalsKonkretisierung der Schlüsselqualifikationen: eine Heraus forderungan Schule und Unterricht, Dissertation, Universitat Passau, (2001).
[5] T. Wagner,Overcomingthe global achievement gap (online). Cambridge, Mass,Harvard University, (2010).
[6] S. Blume, N .Madanchi, S. Böhme, G. Posselt, S.Thiede, C.Herrmann, Die Lernfabrik–Research-based learning for sustainable production engineering, Procedia CIRP, 32 (2015) 126-31.
[7] ABET, Criteria for accrediting engineering programs-effective for evaluations during the 2015-2016 accreditation cycle. Baltimore, United States: ABET, Inc. (2014).
[8] F. Sting, Transforming Engineering Education –Learning Factories as a Bridge between Industry and Academia (Master thesis, TU Braunschweig), (2009).
[9] L. Büth, V. Bhakar, N. Sihag, G. Posselt, S. Böhme, K.S. Sangwan, C.Herrmann, Bridging the qualification gap between academia and industry in India, Procedia Manufacturing,9 (2017) 275-82.
[10] C.G.P. Berdanier, S.E. Branch, J.S. London, B. Ahn, M.F. Cox, Survey Analysis of engineering graduate students' perceptions of the skills necessary for career success in industry and academia, 121st ASEE Annual Conference and Exposition, (2014).
[11] M.Fathizadeh, Experiential Learning through Industry Partnership, ASEE Annual Conference & Exposition, (2017).
[12] J. Cachay, J. Wennemer, E. Abele, R. Tenberg, Study on action-oriented learning with a Learning Factory approach, Procedia-Social and Behavioral Sciences, 55 (2012)1144-53.
[13] M.Healey, Linking research and teaching to benefit student learning, Journal of Geography in Higher Education, 29 (2005)183-201.
[14] Yulhendri, E. Syofyan, S.Afridona, The development of research-based learning model and journal as for graduate students' scientific publications of M. Pd. E on Economic, International Journal of Scientific and Research Publications, 8 (2018) 500-505.
[15] J.D. Hawley, H.M.Marks, Student Use of Academic Knowledge and Skills in Work-Based Learning, Online Submission, (2006).
[16] L.Huber, Warum Forschendes Lernennötig und möglichist. InHuber L, Hellmer J, Schneider F.(eds.). Forschendes LernenimStudium. Bielefeld: Universitätsverlag Webler; (2009) 9-35.
[17] V.Choeisuwan, Effects of Research-Based Instruction in Health System Subject of Nursing Students, The Royal Thai Navy College of Nursing, Procedia-Social and Behavioral Sciences, 191 (2015) 948-52.
[18] C.Sota, K.Peltzer, The Effectiveness of Research Based Learning among Master degree Student for Health Promotion and Preventable Disease, Faculty of Public Health, Khon Kaen University, Thailand, Procedia-Social and Behavioral Sciences. 237 (2017) 1359-65.
[19] J. S. Lamancusa, J. L. Zayas, A. L. Soyster, L. Morell, J. Jorgensen, 2006 Bernard M. Gordon Prize Lecture*: The Learning Factory: Industry-Partnered Active Learning, Journal of engineering education. 97 (2008)5-11.