Empowering Engineers for Research Careers – Role of Undergraduate Research Experience and Institutional Support

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Abstract — Promoting a research mindset among undergraduate students is crucial to fostering a culture of inquiry, critical thinking, and innovation. HEI's impetus on research at undergraduate levels has garnered increased attention in recent years across the country. For India to make a mark in research, especially in publication at an international level, HEIs must recognize the value of a research-oriented curriculum. The paper attempts to study the effect of undergraduate research experience and institutional support among engineers on research mindset and the impact of research mindset on career aspirations in research. The study followed a descriptive & relational research design. With a theoretical background of expectancy-value theory, four study variables were identified through literature: Undergraduate Research Experience (URE), Institutional Support, Research Mindset, and Career Aspirations in Research. Final and Prefinal year engineering students from tier 1 and tier 2 engineering institutions were the target respondents. Validated scales were adopted and used to collect data. The hypothetical model was formulated and tested with three direct effect hypotheses and indirect effects. Structural equation modelling (covariance-based method) was administered to prove the theoretical framework. Opensource GUI Software, Jamovi, was used for this purpose. The test results indicate a positive impact of URE and Institutional support on research mindset, and research mindset has a positive impact on career aspirations in research among engineers. Suitable suggestions and recommendations follow.

***Keywords* — Career aspirations, institutional support, Research Mindset, Undergraduate Research Experience, Structural Equation Modeling**

***JEET Category* — Research**

I. INTRODUCTION

While India is a country that has more than 25% of engineers in the world, there is a huge gap in research and publication. India's research output is an indicator of the same. Developing a research mindset at the undergraduate level is a fundamental goal in higher education institutions worldwide. Promoting a research mindset among engineers at the undergraduate level and providing institutional support is crucial for creating a research-driven education environment that has garnered increased attention in recent years.

Institutions that prioritize and provide resources and infrastructure to support research engagement can significantly enhance students' research experiences. Moreover, institutional commitment like establishing research-focused courses, technical support, funding for research-related initiatives, and ensuring library and research infrastructure contribute to developing a research-oriented culture that promotes student engagement in scholarly activities. Undergraduate Research Experience (URE) can impact a student's learning, and it is a transformative opportunity that fills the gap between classroom learning and real-world application. This study attempts to establish the linkages between Research experience, institutional support, research mindset and career aspirations in research. The critical contribution would be suggestions and recommendations to policymakers and engineering institutions on building a research culture at the UG level.

II. LITERATURE REVIEW

Wigfield, Allan, and Jacquelynne S. Eccles (2000) developed the Expectancy-Value theory, which posits that individuals' motivation and engagement in activities are driven by their expectations of success and the perceived value or importance of the outcomes. As this research attempts to measure the impact of student experience and academic / research rigour in the environment to foster research inclination, expectancy-value theory forms the theoretical background.

A. *Undergraduate Research Experience (URE)*

Undergraduate Research Experiences have become transformative learning opportunities that bridge the gap between classroom learning and real-world application. Previous research has demonstrated that students who engage in UREs report enhanced research skills, critical thinking abilities, and an increased interest in research-related careers (Lopatto, 2004; Russell et al., 2007). UREs have been linked to improved academic performance, increased retention rates, and a stronger sense of intellectual curiosity and motivation to pursue advanced degrees (Hensel et al., 2012; Hunter et al., 2006). Undergraduate Research experience constitutes the overall impression of the research/internship/project experience of an engineering student during the entire duration of his program.

B. Institutional Support

Institutions play a vital role in fostering a research-oriented culture by providing resources, funding, and institutional support for undergraduate research initiatives. Previous studies have shown that institutions that prioritize and invest in undergraduate research programs have higher rates of student engagement in research activities (Kardash et al., 2012; Russell et al., 2015). Institutional support is also linked to increased research productivity, enhanced research skills development, and a greater sense of belonging and academic engagement among students (Strayhorn, 2015; Wright & Jenkins-Gibbs, 2019).

C. Career Aspirations in Research

A student's career aspiration in research is propelled by his/her exposure to research projects/internships and a supportive environment on campus. Studies have shown that engaging in UREs positively influences students' interest in research topics and their desire to pursue research-related careers (Jones & Barlow, 2015; Seymour et al., 2004). Research interests and aspirations are linked to higher motivation levels, persistence in research activities, and a sense of purpose in pursuing research-related endeavours (Hunter et al., 2007; Russell et al., 2018).

D. Research mindset

It encompasses students' attitudes, beliefs, and behaviours towards research. Students' research mindset was identified to measure students' inclination towards research. Studies exploring research mindsets among undergraduate students have shown that UREs, faculty mentorship, and institutional support significantly influence students' inclination to think critically, engage in scholarly activities, and view research as an essential component of their education (Linn et al., 2015; Nagda et al., 1998). A positive research mindset is associated with increased research productivity, persistence in research activities, and a higher likelihood of pursuing graduate studies or research-related careers (Kardash, 2000; Thiry et al., 2012).

The literature review demonstrates that the variables in the conceptual model, namely Undergraduate Research Experiences, Institutional Support, and Impact Research Mindset, thereby positively influencing Career Aspirations in Research — are interrelated and collectively contribute to promoting a research culture among undergraduate students. Existing theoretical models and empirical research highlight the significance of these factors in enhancing learning, fostering future researchers and innovators, and promoting a culture of innovation and evidence-based decision-making in higher education.

III. RESEARCH GAP

Despite enormous literature in the area of URE, there is a need for longitudinal studies to investigate the long-term effects of UREs on students' research mindset, career choices, and research productivity. Studies about URE from the Indian perspective are very few. Many studies measuring the undergraduate research experience focus more on the knowledge, skill and capabilities gained and the need to study the experience per se. Likewise, very few studies measure the impact of URE and Institutional support on students' research mindset. Further, there is a need to identify specific factors relating to UREs and HEI initiatives that contribute to increasing research interest and aspirations for research-related careers. Scales / Measures for research mindset/inclination towards research are not available, making this study unique and helping to add value to the contributing discipline.

Based on the review of the literature, the objectives of the study are

1. To assess the impact of Undergraduate research experience (URE) and institutional support (IS) on research mindset
2. To explore the impact of research mindset on career aspirations in research
3. To measure the mediation effect of URE and IS on Career Aspirations in research

IV. METHODOLOGY

The research design followed in this study is descriptive and relational, as it attempts to measure the phenomenon as it exists (Creswell (2012)) and study the linkages between the different study constructs.

Undergraduate students from Tier 1 (NIT/IISc) and Tier 2 Engineering institutions from Tamilnadu and Karnataka were chosen for the study. Students in their final year and prefinal year who have undergone research/project/internship experiences were the target audience for the study.

The study adopted a convenience sampling method. According to Kline (2011), an acceptable sample size of at least 200 is required for studies where Structural Equation Modeling/path modeling is administered. For the present study, the total responses received were 272, out of which 215 responses were complete and valid in all respects. While 65 students from tier 1 institutions and 150 from tier 2 institutions participated in the survey, a list of students from different institutions is given in the annexure.

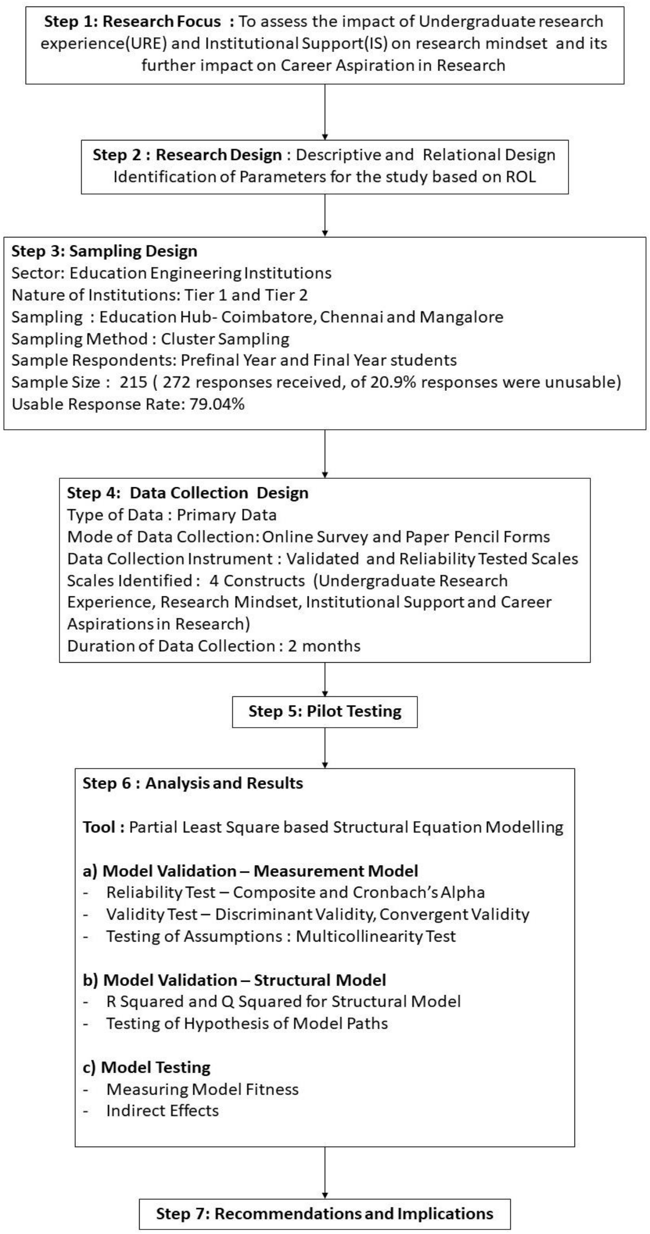
The research used Primary data collected from the respondents using a structured questionnaire. The data collection instrument was reliability tested, and questionnaires were validated. The details of the questionnaire used for the study were identified through a thorough literature study and given in detail below:

A. Measures /Questionnaire Scales

1) Undergraduate Research Experience (URE)

URE was measured through a scale adopted from Luchini-Colbry, K, Wawrzynski, K.S. and Shannahan, M. (2013); the scale had 13 items and sample statements include "Participating in the research experience helped prepare me for graduate study / helped define my career goals".The scale statements were rated 1 to 5, 1 for strongly disagree and 5 for strongly agree.

Fig. 1. Flowchart Depicting the Robust Research Methodology



2) Institutional support (IS)

For measuring Institutional support, the scale developed by Lent, R. W., Singley, D., Sheu, H.-B., Gainor, K. A., Brenner, B. R., Treistman, D., & Ades, L. (2005). The scale had six items. The statements included the encouragement received from the college for research initiatives, the department's role in undertaking research work, emphasis on publishing papers, and the support of mentors and classmates. A Likert 5-point scale was used to measure the statements.

3) Research Mindset (RM)

The research mindset scale had five items. The statements about whether students considered research essential to academic and intellectual growth, motivation to pursue research, and deepening appreciation for scientific inquiry were included. Similarly, students' openness to new ideas, solving research questions, and the positive influence of research on overall learning and knowledge acquisition was enquired. As there were no scales to measure the same, a new scale was generated through a generative artificial intelligence tool.

4) Career Aspiration in Research (CA)

Career Aspiration in Research was measured using the Tigard & Makransky (2017) scale. The original scale was in STEM research and was modified to suit the current study for measuring career interests in Research. The scale consisted of 4 items using the Likert 5-point option.

Hypotheses formulated to study the impact of the variables and the conceptual framework are given below:

H_1: Undergraduate Research experiences positively impact Research Mindset
H_2: Intuitional support positively influences the Research Mindset
H_3: Research mindset has a positive influence on engineering student's career aspirations in research
H_4: Undergraduate research hypothesis and institutional support have an indirect impact on engineering graduates' aspiration for research careers

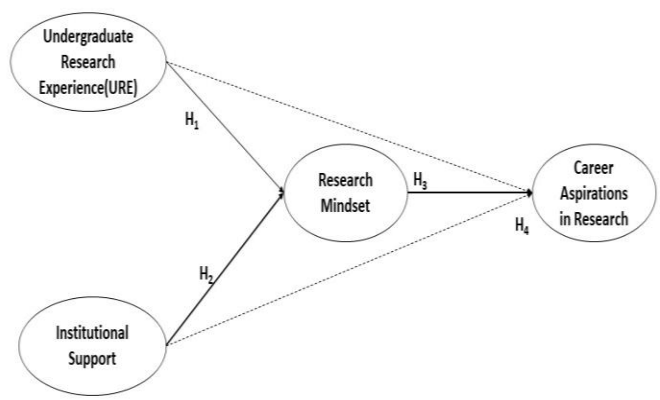


Fig. 2. Conceptual Framework *(H4 measures Indirect effects)*

V. Results and Discussion

Structural Equation Modeling, a covariance-based method, was used to test the hypothesis. JAMOVI Version 2.4.8 was used for the same. The outer model (measurement model) was initially assessed, followed by the inner model (structural model) analysis.

An essential precursor to analysis will be testing for the assumptions. The Ramsey Reset test tested the linearity assumption (Fernandes *et al.*, 2015). The results are depicted in Table 1, as all the p values are below 0.05, which indicates that linearity exists and the assumption is met.

Most research studies also test the normality assumption; the results are shown in Table 2, and the assumption is met.

A. Measurement Model Validation

The measurement model explains how the endogenous and exogenous constructs are measured through observed indicators/variables. The characteristics of the survey items (observed variables) are essential because measurement variables are the basis on which the abstract hypothesis is studied. It also helps identify the errors that may occur during the survey process. The Measurement model of the study consisted of four constructs, and all the constructs had reflective indicators. The reliability and validity of the study constructs were assessed. Factor loading for the indicators, indicator reliability, reliability for internal consistency, and convergent and discriminant validity for the constructs were computed. The following section discusses the above parameter and evaluates the measurement model.

TABLE 2
RELIABILITY, VALIDITY OF STUDY CONSTRUCTS

Variable	Cronbach's α	AVE	VIF	Shaprio Wilk Normality
URE	0.916	0.583	1.88	0.94*
IS	0.892	0.705	1.88	0.927*
RM	0.84	0.629	1	0.92*
CA	0.834	0.626	-	0.929*
Heterotrait-Monotrait (HTMT)	**URE**	**IS**	**RM**	**CA**
URE	1			
IS	0.782	1		
RM	0.784	0.769	1	
CA	0.563	0.585	0.685	1

(Note: URE – Undergraduate Research Experience, IS- Institutional Support, RM – Research Mindset, CA- Career Aspiration in Research)

Table 2 explains the reliability and validity of the latent variables. Cronbach's α coefficient for each construct was above 0.8, indicating the adequate reliability of the constructs measured. The average variance explained was found to be above 0.5. According to Hair and Anderson (2010), the above results indicate convergent validity of the constructs. Likewise, they also indicate internal consistency reliability. Internal consistency is the degree to which the survey statements in one dimension are cohesive. Literature studies show that a score of 0.6 - 0.7 and 0.7 or more is suitable for exploratory and descriptive studies. (Diamantopoulos, A., Sarstedt, M., Fuchs, C., Wilczynski, P., & Kaiser, S. (2012))

HTMT criterion has recently gained momentum, replacing the Farnell and Larker (1989) criterion, as it is a comprehensive and not-so-constrained measure of discriminant validity. The key aim of HTMT is to check whether the ratio approaches 1. The closer the HTMT value is to 1, the lesser the discriminant validity. According to Henseler et al. (2015), the suggested threshold is 0.85 and 0.90, respectively. The results in Table 2 indicate that the HTMT value is below 0.85 for each construct, thereby confirming discriminant validity.

TABLE 3
MEAN, SD AND CORRELATION

Constructs	Mean	Std dev	URE	IS	RM	CAR
Undergraduate Research Experience (URE)	4.14	0.53	**0.763**			
Institutional Support (IS)	4.13	0.58	0.68*	**0.839**		
Research Mindset (RM)	4.15	0.54	0.66*	0.63*	**0.793**	
Career Aspirations in Research (CA)	3.95	0.70	0.43*	0.47*	0.53*	**0.79**

The mean, SD and correlation coefficients for all four study constructs are shown in Table 3. All four constructs have significant (<0.05) correlations with each other. The correlation values range from 0.43 to 0.68.

TABLE 4
ESTIMATES OF LOADINGS

Latent variables	Measurement variables	Loading	Standardized estimates	p-value
URE	URE1	0.706	0.797	
	URE2	0.7	0.776	< .001
	URE3	0.587	0.698	< .001
	URE4	0.633	0.778	< .001
	URE5	0.621	0.692	< .001
	URE6	0.75	0.767	< .001
	URE7	0.783	0.84	< .001
	URE8	0.71	0.751	< .001
	URE9	0.668	0.745	< .001
	URE10	0.686	0.734	< .001
	URE11	0.708	0.754	< .001
	URE12	0.759	0.821	< .001
IS	IS1	0.778	0.894	
	IS2	0.785	0.836	< .001
	IS3	0.744	0.759	< .001
	IS4	0.745	0.851	< .001
	IS5	0.733	0.857	< .001
	IS6	0.805	0.835	< .001
RM	RM1	0.721	0.782	
	RM2	0.649	0.743	< .001
	RM3	0.847	0.889	< .001
	RM4	0.636	0.721	< .001
	RM5	0.754	0.82	< .001
CA	CA1	0.735	0.686	
	CA2	0.726	0.794	< .001
	CA3	0.745	0.801	< .001
	CA4	0.801	0.872	< .001

Another notable aspect of the correlation coefficients is that all the values are less than 0.9, which is an appropriate measure, suggesting no multicollinearity among the four constructs (Tabachnick & Fidell, 2012). The Variance Inflation Factor (VIF) depicted in Table 2 to diagnose collinearity confirms the same. If the VIF values are high, it indicates collinearity, especially when they cross a threshold of 5. According to Hair et al. (2022), it is ideal if the VIF values are less than three.

Confirmatory factor analysis (CFA) was carried out using JAMOVI to measure the dimensionality of the study variables. The factor loadings, estimate and p values of the constructs are presented in Table IV. It can be noted that all the factor loading values are greater than 0.7 and significant with p values less than 0.05. For social science research studies, a factor loading of 0.71 is suggested by Hulland (1999). Very low factor loading scores, which are less than 0.40, do not contribute to the model (Hair et al., 2021)) and are removed from the measurement model. There was no loading below 0.40 in this research, and all the items were retained.

B. Structural Model Validation

The goodness of fit indices for the model is depicted in Table 5. Root Mean square error approximation, which measures the extent to which the conceptual model is away from an ideal model. However, the most commonly cited indices are the Comparative Fit Index (CFI) and the Lewis Index (TLI). These incremental fit indices attempt to relate the hypothesized model to the model with the worst fit (baseline model). Hu and Bentler (1999) suggest that an RMSEA should be below .06. They further indicate that the CFI and TLI values should be larger than .95. If the above two are fulfilled, it indicates a relatively good model–data fit. The above cut-offs recommended by Hu and Bentler (1999) have been widely cited in literature and are adopted in SEM analysis which follows maximum likelihood approach and continuous data sets.

TABLE 5
GOODNESS OF FIT INDICES

Fitness Parameters	Model
Root Mean Square Error Approximation (RMSEA)	0.066
Standardized Root Mean Square Residual (SRMR)	0.057
Goodness of Fit Index (GFI)	0.985
Comparative Fit Index (CFI)	0.994
Tucker-Lewis Index (TLI)	0.994
Parsimony Goodness of Fit Index (PGFI)	0.709
Bentler-Bonett Normed Fit Index (NFI)	0.983
Parsimony Normed Fit Index (PNFI)	0.896

TABLE 6
RESULTS OF HYPOTHESES TESTING

Paths	Direct Effects	Indirect Effects	Z	R Squared	Hypothesis
1. URE ⇒ RM	0.725	-	4.46*	0.676	Accepted
2. IS ⇒ RM	0.473	-	3.72*		Accepted
3. RM ⇒ CAR	0.401	-	8.87*	0.526	Accepted
4. URE ⇒ RM ⇒ CAR	-	0.343	3.94*	-	Accepted
5.IS ⇒ RM ⇒ CAR	-	0.291	3.59*	-	Accepted

*p value <0.01

All the quality criteria were acceptable, and hence, the model's goodness of fit was accomplished. This further leads us to hypothesis testing, the results of which are depicted in Table 6 (Sholihin, M. and Ratmono, D., 2013). The R squared value, or coefficient of determination, for measuring the impact of Undergraduate research experience and institutional support on Research Mindset was 0.676, while the R square coefficient for Research Mindset's influence on Careers aspirations in research was at 0.526.

This explains that the dependent variables measure 67.6 per cent and 52.6% of the variation in the dependent variable. The direct effects of URE and IS on Research Mindset were 0.725 and 0.473, respectively. The path coefficient for RM to CAR was 0.401; all three paths were significant and accepted. The indirect effects for URE and IS on CAR through RM were 0.343 and 0.291, respectively, and z value was significant.

This indicates that undergraduate research experience helps engineering students imbibe a research mindset. The results establish the linkage between Undergraduate research experience and research mindset (Zigler et al., J. K. (2021)). Likewise, for colleges and engineering institutions, it is crucial at this juncture to inculcate a culture for research, support the initiatives taken by students and help them imbibe a research mindset.
Osborne, N. J. (2023). With increased inclination and a focused mindset for research, students will opt to look for opportunities and improve their awareness of research careers. This, in turn, will create a curiosity among students to aspire to careers in research.

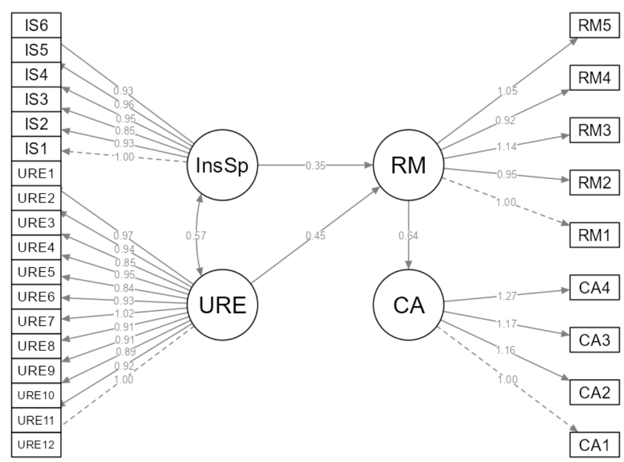


Fig. 2. Results of SEM Model using Jamovi

VI. RECOMMENDATIONS

Mirasol, Joy & Inovejas, Christian. (2017), in their research work, identified a context-based forecasting model to build a research culture in higher education institutions. HEIs can formulate a separate committee to garner the efforts of students and teachers in building a research culture that not only supports an institution's research capabilities but also aims to utilize the students' research advancement. A research culture will ensure student engagement in many ways and create avenues for progression in research.

Institutions mainly provide mentors or research guides who, in turn, motivate students to undertake research. Library resources, access to databases, and training in the specific databases help students fully utilize the research infrastructure and facilities. They can support by providing technology/ lab/specialized software or computational support. Some institutions support by providing funding for research work and publication. Access to IT/language/writing helps improve the research work. All of these targeted efforts help improve the students' research mindset.

Career guidance cells can attempt to bring in research organizations for placements. An increase in research-based openings in placements will enable students to equip themselves with research skills. Students in tier 2 or lesser-raked institutions need more awareness of research-related careers. Workshops and seminars on engineering research careers will improve their awareness of such careers and help them build their research competencies.

When Higher Education Institutions shift their focus to support research at the undergraduate level, provide support for carrying out research and provide career services through placement cells, it will help not only their student and faculty fraternity but also enable an institution to improve their overall research climate, which in turn will improve their ranking at national and international levels.

VII. Limitations

The research was undertaken in colleges where the researchers had access, and a more comprehensive geographic coverage of institutions in specific states or regions could have yielded better results. There were no scales to measure research mindset, so it was developed using Generative AI tools, and the scale's validity was tested. The research study period could be immediately after the student internship/project work. Although scientific and adequate, the sample size could be improved, which could also improve the quality of the results.

VIII. Scope for Future Research

The study can incorporate or test the difference between HEIs with a research focus, like Tier I -IIT/NIT, and other state universities and colleges in the Tier II category to understand if the results can be generalized. The impact of demographic details and student background on the study variables can yield more insights. The forthcoming studies include more latent variables like peer support, mentor/project supervisor role, and students' confidence and self-efficacy levels. Likewise, the students' awareness of patents, copyrights, and R&D and their level of participation in competitive events and conferences can be explored. As already indicated, most of the research studies only attempt to measure students' Knowledge skills and capabilities in undergraduate research experience; a pre-post study to measure its effectiveness can be undertaken.

IX. Conclusion

The study attempted to measure the impact of undergraduate Research experience and institutional support on research mindset and career aspirations. A scientific and systematic methodology and analysis fulfilled the objectives of the study. The results indicate that if institutions take proactive steps to improve research capabilities among students. Some institutional support initiatives identified through the study were a) availability and access to the research mentor when students need guidance or support, b) to institute recognition at the department and college level for research initiatives, c) assistance for undertaking research activities fully or partially d) peer group influence for research initiatives e) research mentor in every department who can inspire and be role model for students.

Recognizing the value of research-oriented education, institutions have implemented various strategies to actively provide students with opportunities to participate in research activities. To enable students to imbibe a research mindset institution, we should educate students to view research as a path to intellectual growth and encourage students to pursue the same beyond academic requirements, academic bank of credits, and unique electives in research. Workshops and competitions to deepen students' appreciation for scholarly processes, including small research elements in course components, will help improve the students' focus on research.
These initiatives will further help foster the institution's research capabilities, leading to overall benefits in ranking and publication and accelerating the student's interest in research-related careers in engineering fields. Specific, measurable, and time-bound activities and initiatives from departments will enable and create a culture of research and enhance innovation.

Appendix

Participants Institutions (Tier 1)	**Respondents**
Amrita Vishwa Vidyapeetham	3
Indian Institute of Science Bangalore	2
Institute of Road and Transport Technology	2
National Institute of Technology Karnataka, Suratkal	58
Total Students (Tier 1)	65 (30%)
Participants Institutions (Tier 2)	
Coimbatore Institute of Technology	18
Kumaraguru College of Technology	45
PSG college of Technology Coimbatore	28
Sri Ramakrishna Engineering College	51
SRM Institute of Science and Technology	8
Total Students (Tier 2)	150(70%)

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