ORF ISSUE BRIEF
FEBRUARY 2019
ISSUE NO. 277

Improving Research in India: Introducing Undergraduate Research in Higher Education

Antara Sengupta

ABSTRACT This brief examines the status of research in Indian higher education and offers an overview of the concept of undergraduate (UG) research as a means of reform. It reviews the government efforts to improve higher education research, and underlines the limitations of their scope as well as their implications. Through an expansive review of existing empirical and qualitative studies, this brief shows the benefits and impacts of UG research on development of scholarly traits in students as well its effect on institutions. Finally, it recommends ways of inducting this concept in the present system of undergraduate education in India, based on prescriptions by the Council on Undergraduate Research.

Attribution: Antara Sengupta, "Improving Research in India: Introducing Undergraduate Research in Higher Education", *ORF Issue Brief No. 277*, February 2019, Observer Research Foundation.

ISBN 978-93-88262-83-5

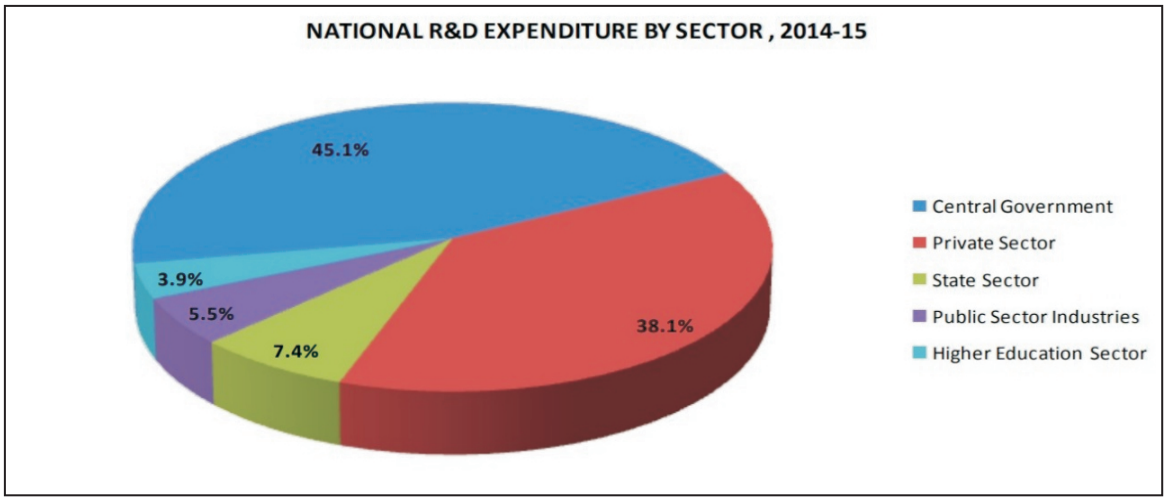
INTRODUCTION

Prof. Jayant Narlikar, an astrophysicist and Professor Emeritus at Pune University, once said, "The reason [of decline of science in India] is the lack of experimentation as part of learning science." Indeed, India's education system has maintained status-quo for over many decades now, and no revolutionary attempt has been made to upgrade the quality of content or its delivery.[1] Past efforts have been modest and fragmented, and have failed to impact the education system in any significant way. The state of research,[#] in particular, has not only failed to improve, but has suffered tremendously—and the blame can be placed on both the government and the educators themselves. Owing to the segregation of teaching and research in the country, entire generations of students have graduated from the university system without producing even a single original research.[2] Many of these graduates lack the skills required to be employable as well as knowledge of the industry they were to work in.[3]

Of India's 1.3-billion population, there were only 216 researchers per million population in 2015.[4] India's investment in research is a measly 0.62 percent of GDP. These numbers are well below global best practices. France, for example, spends 2.25 percent of its GDP on research, and the United States, 2.74 percent; both countries have some 4,300 researchers per million population.[5] China, for its part, invests more than 2.11 percent of its GDP on research and has 1,200 researchers per million population. In higher education, in particular, India's research expenditure is only four percent of GDP.[6]

There are some 161,412 students enrolled in PhD programmes in 2018. This comprises less than 0.5 percent of the total student enrollment in higher education in the country – which constitutes students enrolled in universities, colleges and standalone institutes pursuing undergraduate and postgraduate programmes.[7]

Figure 1



Source: Research and Development Statistics at a Glance, 2017-18, Department of Science and Technology, Government of India

When using the word 'research', this brief refers to research in both hard sciences and social sciences.

To be sure, policymakers have long been aware of the dismal state of research in India. Time and again, questions have been raised on the quality and authenticity of the research output. The Government of India (GoI) has launched, beginning in 2013, a string of initiatives to boost the number of researchers in higher education. For starters, the Ministry of Human Resource Development (HRD) launched the Rashtriya Uchchatar Shiksha Abhiyan or the National Higher Education Mission to strategically fund higher education institutes in the country. In 2015, the National Institutional Ranking Framework (NIRF) was launched to rank universities and institutes in various parameters, including research. Subsequently, the GoI announced the 'Institutes of Eminence (IoE)' scheme, where it initially pledged to support 20 institutes to become world-class universities – of which six have already been announced and more than a dozen are awaiting the status upgrade.[8] A "world-class" university, however, cannot be devoid of research; teaching and research go hand-in-hand. IoEs are chosen on the basis of, among others, their research performance in NIRF.

In March 2018, in the annual budget, Finance Minister Arun Jaitley announced the 'Prime Ministers Research Fellowship', with an initial budget allocation of INR 16.5 billion. Under the scheme, undergraduate and postgraduate students with a Cumulative Grade Point Average (CGPA) of at least 8.0 from elite Indian institutes such as the Indian Institute of Science (IISc), Indian Institutes of Technology (IITs), National Institutes of Technology (NITs), Indian Institutes of Science Education and Research (IISERs) and Indian Institutes of Information Technology (IIITs), will be eligible for direct admission in PhD programmes of IITs and IISc. They will also be fairly compensated under the scheme.

While it may be too early to judge the implications of such measures, the question that must be asked is whether the research crisis in the country is only about scarcity of compensation or funds for scholars. Moreover, it needs to be examined why the schemes are restricted to a select few elite institutes that constitute only two percent of student enrollment in higher education.[9]

Yet, the woes of India's education system are rooted in early schooling. Analysts have long pointed to the problem of students "reproducing" textbooks in examinations without applying critical thinking—and such culture is carried all the way to higher education.[10] Therefore, it is essential that students be inducted in the culture of research as early as is pedagogically possible, i.e., in the undergraduate level. This is true for both the hard sciences and social sciences. One way is by introducing UG research in the higher education curriculum.[11] If students are systematically taught competent research at the undergraduate level, they will get interested in the subject and might become more inclined to take up research-intensive academic programmes and careers in the future. Prime Minister Narendra Modi, too, in his January speech at the 106th Indian Science Congress, called upon policymakers to suggest ways to induct research in Central and State Universities in India.[12]

'UNDERGRADUATE RESEARCH': CONCEPTS AND DEFINITIONS

The Council on Undergraduate Research (CUR) defines "undergraduate research" (UR) as "an inquiry or investigation conducted by an undergraduate student that makes an original intellectual or creative contribution to the discipline."[13] CUR is the leading body that oversees and affiliates institutes to perform undergraduate research on campuses. The concept was initiated in 1969 by Margaret McVicar, then the Dean of Undergraduate Education at the Massachusetts Institute of Technology (MIT), under the name of Undergraduate Research Opportunities Program (UROP). Typically, an undergraduate student in any discipline assists a faculty, researcher, graduate student and/or other undergraduates in research in areas of similar interests. Undergraduate students support collaborative research by either pursuing their own research ideas or joining established research projects.[14]

In different parts of the world, the most common ways of incorporating undergraduate research experience in institutes are Undergraduate Research Experiences (URE) and Course-based Undergraduate Research Experiences (CURE).[15] In URE, a handful of students are selected to assist a mentor in their research in a laboratory, working over a few semesters. The students are selected through competitive tests and a perusal of their academic records. Meanwhile, CURE is a class-based programme presided over by a researcher or a graduate student and consists of lectures, grades and assignments. CURE is firmly integrated in undergraduate courses to enhance student learning. Consequently, it is also a longer-term programme when compared to UREs. URE consists of one mentor to one student whereas CURE has one mentor to many students in a class.[16] Overall, CURE is a more inclusive form of undergraduate research as it gives a large number of students—in fact a whole class—the opportunity to experience conducting research. Although, URE is more competitive, it provides access to only the self-motivated and the interested students. In several cases, the eventual objective of a CURE is to secure a URE placement.[17]

The Course-Based Undergraduate Research Experiences Network (CUREnet), in a study undertaken in 2013, states that "... CUREs involve students in work that fits into a broader scientific endeavour that has meaning beyond the particular course context."[18] Students pursuing CUREs should produce, if not a co-published paper, other output in the form of policy documents or reports that contain a certain amount of original findings. While it is not always necessary for a student to "discover" a new theory or practice, their experiences and findings, if documented, can help further research as well as provide lead to a solution to any research question they have been tackling so far.

While UG research began with URE, it was soon recognised that it is an expensive affair and that various institutions faced a multitude of problems in strengthening UG research on their campuses. Thus, CURE emerged as an alternative to attain a similar goal.

In a monograph, CUR commends institutions that have a "research-supportive curricula" by way of documenting their efforts in it.[19] The authors state that such a curriculum "expose" students to the importance of

research and even if they do not participate in research in the future, it helps them gain an "appreciation for research methodology in their area of study".

BENEFITS, IMPACTS AND BEST PRACTICES

The CUR lists various benefits of undergraduate research: enhanced student learning, effective mentorships, increased enrollment in graduate education, increased retention, higher critical thinking prowess, creativity, problem solving skills, intellectual independence, and understanding of research methodology.[20] There have been several efforts to understand and link the benefits of undergraduate research to a student's aptitude for sciences and social sciences, as well as their inclination to pursue graduate studies and eventually research-intensive careers. While most of these reviews are based on self-report surveys, some of them have analysed the end research product as well to show a direct correlation between UG research and higher education. Some of them even use the Grade Point Averages (GPA) secured at the end of the course to quantify the success and benefits of participation in UG research.[21] For example, professor of Psychology, George Spilich's experience in his department at the Washington College reveals that the students' marks for major subjects dramatically improved since they introduced "research-based" programmes.[22]

Students who pursue CUREs or research for prolonged periods of time during their undergraduate years tend to benefit more from such experiences. However, there seems to be little benefit, if at all, from short-term research experiences.[23] Studies show that undergraduate research enables enhancement of knowledge, writing skills, research ability and also boosts confidence of the participants in their respective fields.[24] It is essential for students to spend enough time on their agreed area of research, understand the depth of the problem, come up with research questions, and base their findings on credible data analyses. Basic qualities such as writing and research, if learnt at an earlier stage, can help students write authentic and original research papers at advanced levels.

In the US, a quantitative analysis using a sample size of 1,135 students representing 41 institutions showed the following results: students reported enhanced "technical and personal skills"; and 87 percent of them either proceeded to pursue graduate science education or began planning for one.[25] Furthermore, various qualitative analyses reveal an increase in participation of underrepresented students (first-generation students, women and minorities) by way of participation in undergraduate research. Their experience in undergraduate research prepared them for graduate studies and helped them decide on a career in science.[26]

However, as stated earlier, the subsequent impact of UG research is largely dependent on the form of mentorship students receive throughout their research endeavour. At a stage when students are academically vulnerable and have yet to decide the course of their career, it is imperative that they are guided voraciously by a well-meaning and competent mentor. A mentor helps students work intricately in a collaborative environment with researchers, scientists, technicians and

colleagues to not only analyse their chosen research area, but to tackle the peripheral issues as well. Some even refer to UG research as "apprenticeship", where students learn by critically analysing problems and undertaking "intellectual ownership" of the performed task.[27] Students can gain remarkably by learning from their mentor's experiences, their expertise in their subject and nuances of research methodology, and eventually have the pleasure of forming their own research questions, question the unanswered, and develop a culture of science.

Mentors can be graduates, post-doctoral fellows or faculty members. There are also "peer mentors": in a team of researchers, a senior undergraduate student can mentor a junior.[28] David Lopatto, an education expert in the US, with support from the Survey of Undergraduate Research Experiences (SURE), found that about 80 percent of the respondents felt that working with other undergraduate teammates moderately or significantly improved their UG research experience. The results also showed that the peer mentor likewise gained significantly through the process – they "enjoyed" their role as mentor/teacher, became confident, sharpened their communication skills, and understood their research topic significantly better.

Faculty members, therefore, do not have to directly involve themselves in mentorship at all times; fellow classmates can do the job all too well if the ecosystem is created around them. Moreover, working in teams is a norm in research processes and engaging in the same can help students develop leadership skills, team spirit, better interpersonal skills, as well as research expertise.

To gauge the impact of UG research on different institutions, there are a few success stories that provide valuable lessons for India. At the Washington College's Psychology department, a "research-based curriculum" was introduced after meticulous consultation with students, even in the absence of their department faculty.[29] The faculty begin by discussing their research projects in the first and second year classes and inviting students to join them if they find the topic of interest. Another effective way that the faculty has incorporated in middle and upper level classes is inducting their research projects in laboratory sessions. The results are multifarious – students either take these projects as "starting points for their own ideas", or branch out more ideas based on their interest area from these projects. This helps build a sustainable student-mentor relationship. The paper concludes that the results have been more than satisfactory and the exercise has also improved the faculty's approach to teaching undergraduates.

While several universities and departments have implemented and are reaping results of introducing UG research in their curriculum over the years, it is worth looking at the MIT, considered a pioneer in the field. For its impact on improving the quality of undergraduate courses and encouraging interdisciplinary research, MIT's UROP has been emulated by various institutes across the world, including Boston University, the University of Delaware, the University of California at Irvine, and the Royal Institute of Melbourne.[30] Other institutes like Johns Hopkins University, University of California at Berkeley's School of Engineering, University of Minnesota, University of Utah and Stanford University

have similar programmes, albeit with different nomenclature.

Through a student survey carried out in 2013, MIT reported that UROP gave the students skill sets that enabled them to decide on their research careers (either graduate school or professional career), to work in a collaborative environment, understand their subject areas better, and contribute to a body of knowledge. They were also found to be more confident as participant researchers and could communicate well in a "professional research environment".[31]

Given the coherent impacts and benefits of UG research, and understanding the state of research in Indian higher education institutes, this brief recommends that they promote undergraduate research.

THE CASE FOR INDIA

One of the causes of the problems plaguing higher education in India is the system of affiliation, where a university can have as many as over 500 colleges attached to it. This simply makes the university, "ungovernable".[32] Besides being a logistical and administrative nightmare to the parent university, these colleges function in isolation and there is no real communication amongst the academic disciplines. It defeats one of the fundamental principles of a university—of being an institution where students and teachers are able to exchange ideas and the different disciplines mingle, in the process learning from one another and finding ways to innovate.[33] Indian universities and affiliated colleges have failed miserably in this aspect. As such, much of the research in India happens *in silos* and are either irrelevant or redundant for any practical purposes. Moreover, research in India happens mostly in specialised research institutes rather than in university campuses.[34] However, about 80 percent of the students enrolled in higher education are contained in these university campuses that run undergraduate programmes.[35] Aside from basic research, due to minimal interaction between departments, there is a lack of interdisciplinary education and research in these campuses.

Undergraduate research can therefore serve as a way to initiate dialogue between departments and enhance relations between faculty and students. Moreover, this will also help build an inclination for research among undergraduate students and faculty who usually end up writing overnight projects as final-year research. Indeed, it has been found that a huge amount of this work is merely copied from websites that are not even credible, to begin with.[36] This in turn will increase the number of doctoral and post-doctoral candidates, who can then not only fill faculty positions,[37] but also rethink and redesign curriculum for relevance and jobs of tomorrow. Introducing research at the UG level can both directly and indirectly address issues in higher education, including the lack of quality and quantity of publications produced, faculty vacancies, the absence of scholarly instincts in students, and outdated syllabi. Undergraduate research can also help in the overall upliftment of delivery of classroom education.

While the experiences of other countries can provide valuable lessons, these models may not be able to capture the complexities

and diversity of the Indian education system.[38] Thus, UG research needs to be embedded in programmes in such a way that it complements the current system of teaching, rather than disturbs it. The CUR prescribes a roadmap for institutions that aim to begin the process of collaborative research on their campuses, irrespective of whether the institution has a bandwidth of 'scholarly' faculty or just a teaching faculty. In its guidelines, called the 'Characteristics of Excellence in Undergraduate Research (COEUR)', CUR spells out several steps that are necessary to setting up such arrangements; however, they need to be customised for the Indian higher education system.[39]

Role of institutions: "Institutional commitment" has been given high priority in the order of affairs in COEUR. In India, initially, Grade 1 and Grade 2[40] autonomous colleges under the University Grants Commission (UGC) can begin the process of initiating such research-integrated programmes in their three-year undergraduate courses. This is because they have a higher degree of freedom from regulations and a track-record of excellence in delivery of quality education. The institution will also have to duly recognise the efforts and contributions of the faculty and students, and formally set up an office for UG research to institutionalise the process. The internal budgets of these institutes should set aside some funds exclusively for nurturing of UG research and activities under them.

Types of UG research experience: For reasons such as scarcity of financial and infrastructure resources with the government-run universities, to begin with, CURE can be a valuable experience for undergraduate colleges. Moreover, given the large number of students in the higher education institutes, CURE will offer a more inclusive system of research and education by giving opportunities to a larger group. Given the typical characteristics of a CURE, such courses will need capable instructors. In India, such instructors can be faculty, PhD students or post-doctoral students. A valuable way of involving external instructors is from specialised research institutes in India such as IISERs, IISc, Tata Institute of Fundamental Research (TIFR), Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR), among others. Some researchers from elite research institutes should dedicate certain credit hours in helping undergraduate students understand the nuances of ethical research and involve them in ongoing activities. It is time for this segregation of research and teaching institutes to fade out and make way for the blending of high-quality research in specialised institutes, and university teaching. The same has also been recommended by the 2009 Yashpal Committee Report on 'Renovation and rejuvenation of higher education'.[41]

Optimal use of resources and external collaboration: The CUR also recommends "doing more with less", and by involving professionals from research institutes as instructors of UG research, the higher education system will be able to deal with shortage of faculty and reduce their workload.[42] While this can be one of the ways of sourcing an instructor, it is highly recommended that faculty in undergraduate colleges get involved in this process eventually for a profound impact of the system of UG

research. Having said that, faculty/instructors need to be rewarded for their engagement in the process to ensure fruitful collaboration and quality output. Since the faculty in undergraduate colleges have heavy work-load, a committee must be set up to deliberate on ways of distributing the work among various faculty within departments.[43] The University and state governments need to jointly mull over the degree and form of reward needed to encourage such a system.

Preserving multidisciplinary nature: To maintain the multidisciplinary nature of this programme, UGC's choice-based credit system needs to be intertwined with the UG research programme, so as to allow mobility of students within disciplines, campuses and external organisations.[44] The course content needs to be carefully designed by scientists and experts, in collaboration with all streams of education. Such a curriculum should set a tone for research for students before they formally enter into a collaborative research environment.

Integration of basic research skills: Students should be inducted in the first year through CUR's 'professional skills workshops' that train them in basic skills such as writing research papers and reports, designing posters, conference presentations, networking with resources, identifying paper competitions, fellowships and graduate programmes, among others.[45] They can also be asked to write mock papers on topics in the textbooks. In the second year, students can choose their area of interest and attach themselves with either an ongoing research or initiate one with the help of their mentors/instructors. However, the choice to participate in UG research should be voluntary and optional. In the third year, students should undertake writing their papers and submitting papers for conferences. There should be continuous capacity building of mentors by senior faculty or external resources, assuring high-quality mentoring to students. Research-educated UG students will also be informed PhD students; thus in India, while accepting a PhD proposal, preference should be given to students with UG research experience.

Inter-institute network of conferences: In line with CUR's guidelines, bodies like UGC should initiate conferences where UG researchers can present their papers before their peers, so that it becomes a trial ground for them for larger, national or international conferences.[46] Mentors should also assist students in getting published in existing UG research journals and/or offer them co-authorships. While institutes can modify and customise various ways to implement UG research, certain basics prescribed by CUR can be followed for a purposeful programme.

To be sure, UG research is not *completely* absent in India. The problem is that it is not being practiced—in a structured, systematic way—in universities and affiliated colleges thus far. An interesting concept is the National Initiative on Undergraduate Science (NIUS) by Homi Bhabha Centre for Science Education, TIFR. Conceptualised in 2004, this initiative aims to address the declining number of meritorious students in Bachelor's and Master's Science courses and subpar undergraduate education across the country. It shortlists 150 students from across colleges in India through competitive exams and admits them in a two-year 'nurture'

programme. Students go through two one-month camps in summer and two two-week camps in winter, and learn theory, problem-solving skills, attend student seminars and laboratory sessions. The first year is spent on training for the research, and the second year is for performing actual research under the mentorship of scientists from institutions such as TIFR and Bhaba Atomic Research Centre (BARC).[47] Similarly, at the Indian Institute of Science Education and Research (IISER), students in the five-year integrated BS-MS Degree programme participate in a year-long research project. They are encouraged to publish in peer-reviewed journals and also present their papers in international conferences.

This brief makes the case for embedding research in UG courses. The aim is to make research commonplace and push it out of specialised research centres and into the University system.

CONCLUSION

India is attempting to enhance its global footprint through programmes such as 'Institutes of Eminence' (IoE)[48] and 'Study in India',[49] as well as by preparing a New Education Policy.[50] It is crucial at this time, therefore, to focus on the quality of undergraduate education. India has a rich demographic dividend that, if harnessed successfully, can contribute to the country's economic growth. However, the Indian education system needs an overhaul. While a handful of institutes have been given the tag of IoE for greater autonomy in conducting research and programmes, there are numerous state public universities, affiliated colleges and autonomous colleges that are striving to compete with the raised standards.

Institutes around the world are reaping the benefits of adopting UG research as a practice; there are some universities such as the MIT that have moved over to a second phase of Super UROP as advanced UG research.[51] In India, to control the dwindling number of researchers and tackle the problem of substandard research output, it is imperative for both central and state governments to experiment with a concept that has proven results in many other places across the world. The Indian education system has about 20 million first-generation learners, who will eventually need systematic induction to utilise education as a tool to tackle real-world challenges. Moreover, the girls among them will need particular attention to encourage them to pursue fields in STEM (Science, Technology, Engineering and Mathematics).[52]

The Indian education system must explore ways by which it can upgrade its current, textbook-heavy learning system. Introducing UG research in institutes will not only enhance the quality of students and faculty in the system, but also help India generate relevant scholarly research that will contribute to the country and beyond.ORF

ABOUT THE AUTHOR

Antara Sengupta is a Research Fellow at Observer Research Foundation, Mumbai.

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20, Rouse Avenue Institutional Area, New Delhi - 110 002, INDIA
Ph. : +91-11-35332000 Fax : +91-11-35332005
E-mail: contactus@orfonline.org
Website: www.orfonline.org