

Undergraduate research in physics: an Indian perspective

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It is now widely believed that research should be an essential and integral part of undergraduate studies. In recent years there has been a conscious effort to bring research opportunities to the physics undergraduates in India. We argue that the need of the hour is a methodical evaluation of the existing undergraduate programmes for their effectiveness in preparing the students for a career in physics.

Following the Boyer Commission Report (1998) and subsequent recommendations by a number of academic bodies, the higher education policy in the US underwent a paradigm shift by recognizing research as an essential and integral part of the undergraduate (UG) education. A number of studies have already demonstrated the range of personal, professional and intellectual benefits for STEM (science, technology, engineering and mathematics) students participating in UG Research (UGR)¹.

Of late, we have observed a similar paradigm shift in the Indian context too. A couple of decades ago an UG student had little access to research. However, as the benefits of UGR become apparent, in terms of students' learning retention, graduation rates and entrance into graduate programmes^{2,3}, there has been a change in the higher education policy supplemented by generous grants from funding agencies. This has been hailed enthusiastically both by practising scientists as well as the student community, particularly because UGR is increasingly being considered as a critical qualification for graduate admissions abroad as well as in India.

Recent studies also indicate that the growth of physics as a field and the retention of students desirous of taking physics as a career is the lowest among all STEM subjects⁴. It appears that the development of a professional identity is important for student retention and UGR can play a major role in this direction. UGR is where a student realizes for the first time that the classroom setting provides answers while the research experience focuses on asking and answering questions. This ultimately helps UG students to 'become scientists' through the growth and development of their professional identity⁵. Therefore, scholarly studies defining and measuring the metric against which the UGR experience can be evaluated are of great importance

in the context of physics research in India. This essay argues for a need of such studies by considering the situation with the physics UGR opportunities that are currently available in the country.

UGR (physics) in India

There are basically four types of institutions (excluding defence laboratories) where physics research is conducted in India. They could be classified as follows:

1. The traditional universities with a number of affiliated colleges (Bombay, Calcutta, Delhi, Madras, Pune, etc.).
2. The stand-alone autonomous universities (Cotton College (Guwahati), Jadavpur (Kolkata), JNU (Delhi), Visva-Bharati (Shantiniketan), etc.).
3. The specialized STEM-only universities (IISc (Bengaluru), IITs, IISERs, BITS, etc.).
4. The elite research institutes (HRI (Allahabad), IMSc (Chennai), PRL (Ahmedabad), RRI (Bengaluru), TIFR (Mumbai), IUCs, etc.).

While the emphasis is on UG teaching (UGT) in the first three categories, the primary activity is pure research for the fourth. However, with the introduction of integrated Ph D programmes, a number of research institutes (such as HRI,

IMSc, TIFR, etc.) are also engaging in UGT now. Even though the prevalence of UGR is a recent phenomenon, the understanding of the importance of a research component in the UG curriculum and a conscious effort to incorporate such an element in the Indian system has existed for quite a long time. Initially, the efforts were restricted only to a few universities (mostly IITs), but now students from almost all academic institutions can access research opportunities in one form or the other. Interestingly, these UGR opportunities belong to a few distinctive types (Figure 1), which can be classified under the following two categories – curricular and extracurricular

Curricular UGR

A curricular UGR project is a part of research undertaken to fulfil the requirements of the university syllabus where a student is enrolled for her/his UG (Bachelor's/Master's) degree. One type of curricular research that is becoming increasingly popular is the short-term course project, forming a part of a standard course. Usually these are undertaken in lieu of the end-term examination and may end up being nothing more than a longish take-home examination. However, depending on the situation, such a project could involve reading a research article, understanding it and perhaps taking some of the calculations a little

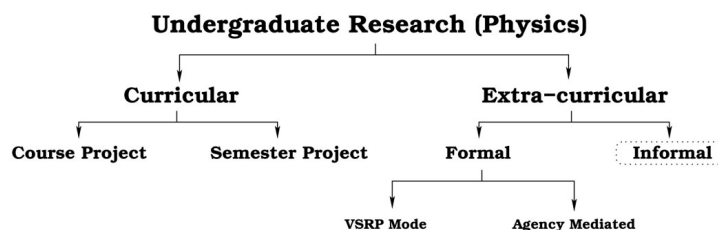


Figure 1. Types of undergraduate research in physics that are currently being offered in India.

forward. Though these typically do not produce any serious research output, they offer the students a quick look at the methodology of research. On the other end of spectrum of curricular research is the semester-long project, where the duration could even span an entire year. Depending on the university, a student is either required to work with a professor in the home institution (sometimes continuing to do other course work alongside) or is given the option to work with a scientist from another academic institute. Because of the longish duration, the students usually get time to pick up some background and/or acquire certain necessary skills (computational/experimental/instrumental) before starting the actual work.

The single-most important feature of these curricular projects is that a degree of sincerity and seriousness is automatically ensured, because the research performance gets reflected in a student's graduating grade which plays a decisive role in his/her subsequent placement. Consequently, good amount of research work come out of these projects. Often, an important part of a larger study (theoretical/experimental/observational) is successfully set up by an UG student, irrespective of whether or not it ends up into a full-fledged publication. At GMRT (the Giant Meterwave Radio Telescope, maintained by NCRA-TIFR, Pune), a good amount of engineering and software support has, over the years, been generated through such research projects⁶. Overall, the impact on UG learning and output from these projects appear to be quite positive.

Most of the stand-alone and STEM-only universities have now incorporated such research projects (both short and long-term) into their UG programmes. However, traditional universities are yet to adopt these measures and the research component is still mostly absent from their curricula.

Extra-curricular UGR

In contrast, an extra-curricular research is something a student embarks upon of his/her own volition. The motivation for such an undertaking has a wide range – from a genuine desire for research, to securing an early admission to a prestigious graduate programme, or perhaps to simply affect an improvement to the bio-

data. These could be formal, structured by particular academic institutes or by umbrella organizations (like the Indian science academies). By far the best-known and likely the oldest running programme in this category is the 'Visiting Students Research Programme' (VSRP) run by TIFR (similar programmes are now offered by many more research institutes). Applicants from across the country are filtered through a stiff selection criterion. Upon being selected, a student works on a research project, typically lasting for 8–10 weeks, under close supervision of a faculty member. The highlight of a such a programme is that at the end of their stay, the students are evaluated for their suitability to join the research programme of that institute upon completing their respective UG degree.

A new addition to the formal, extra-curricular research is something we term as an agency mediated one. The NIUS (National Initiative on Undergraduate Science) programme run by HBCSE-TIFR, or the SRFP (Summer Research Fellowship Programme) jointly sponsored by the three science academies (Indian Academy of Sciences, Indian National Science Academy and The National Academy of Sciences) are examples of this type. Once again students are selected from a huge applicant pool. Then they are assigned to faculty mentors working in different academic institutes across the country. The mediating agency basically pairs up the aspiring UG student with an appropriate mentor and funds the entire activity. Though these allow immense structural freedom (the student and the supervisor can choose a convenient time-frame or the number of visits the student makes to the host institute, and so on) conducive to serious research, the programmes may not always be achieving their goal. One of the reasons could be certain shortcomings of the selection procedure. With a completely uneven grading system of our universities, the probability of selecting students with inadequate background training or motivation is quite high when the selection depends mainly on their university grades. In contrast, the probability of making similar mistakes is much smaller in individual institutes where the number of selected applicants is usually quite modest. On the other hand, a fraction of students also considers these programmes as opportunities for improving their bio-data. In such

cases, non-performance is not an issue unless and until the student requires a reference letter from the faculty-mentor.

In fact, this last point brings us to the emergent trend of informal research projects. All of the UGR that has been discussed so far involves 'structured' programmes, managed by academic institutions. However, the need for an impressive bio-data and a set of reference letter writers are now compelling students to informally contact potential mentors looking for research opportunities. To be sure, a fraction of these requests arise out of genuine motivation. Sometimes, a student who has earlier worked with a particular mentor (through another form of UGR) returns to complete the work, resulting in a publication⁷. Research institutes usually provide infrastructural support and funding for these, if a faculty member agrees to mentor a student. These projects can range from a few weeks to even a year depending upon the situation. Excellent pieces of research work have come out of such projects. However, because many of these project requests are initiated by students who have been unable to secure a place in one of the above-mentioned formal programmes, it appears that a number of disturbing issues have become associated with this particular form of UGR.

Unfortunately, the requests for informal projects have reached such proportions that scientists working both within and outside India are getting completely overwhelmed by the huge volume of unsolicited and mostly irrelevant e-mails. It appears that in many universities the student community has developed computer scripts by which they have automated the process of selecting potential mentors (by trawling through internet repositories of scholarly articles. These requests should really be considered as 'spams', which hope to find at least one gullible person somewhere and are driven by the sheer desperation of students. To be honest, this craze is also nurtured, in part, by individuals or groups that require a large 'non-expert' workforce to help conduct big experiments, or analyse huge volume of data, or run monstrous simulations.

Concerns

Easy access to UGR opportunities for a large UG community is a recent

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phenomenon in India. Evidently, there are quite a few issues that need to be looked into. Clearly, the older and structured programmes (like VSRP) do better than the more recent ones. However, it is not yet clear if every type of UGR is as effective as naively expected. For example, it is not uncommon to see students going through a string of short-term UGR on totally unrelated topics and gaining neither a feel for the methodology nor any real training in a particular area of research. The unduly excessive emphasis placed on UGR experience for admissions into graduate programmes is likely the reason for this obsession, often even to the exclusion of any physics learning.

The selection of under-prepared and/or under-motivated students to a UGR programme is another source of serious problem. As this is mainly associated with agency-mediated programmes where the applicant pool could be enormous, a better methodology needs to be adopted for the selection process. Introduction of a 'tiered structure' to such programmes could also be thought of,

where the present structure can be followed for students properly equipped for research; and the under-prepared students could be inducted into 'summer school'-like programmes, where they reinforce their UG learning itself. The REAP (Research Education Advancement Programme) run by the Jawaharlal Nehru Planetarium (Bengaluru) is one such example.

To conclude, even though the inputs to the present essay are mostly anecdotal, there is a clear indication on the need for quantitative studies on the effect of UGR on physics research in India. Whether the resource spent (in terms of person-hours, direct funding and infrastructural support) is actually helping the indigenous research community, or it is simply producing students who are better equipped to ensure admission in a graduate programme abroad is something we seriously need to look into.

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Smile with Science

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