Building Research Competence in Undergraduate Students*

Smitha Hegde and Indrani Karunasagar

Higher education in India is currently challenged by the expansion of the system to cater to the needs of her large youth population. In this process of rapid expansion, India is battling equity of educational opportunities and maintenance of the quality of teaching and research. Research-based pedagogy is one of the approaches that ensure a quality teaching-learning experience. In the current study, we have attempted to undertake a research-based pedagogy program that can aid undergraduate teachers to guide and conduct research projects. As a part of the curriculum, a six-step pedagogy was drawn up, which comprises: inspiring, ideating, action, refining, reporting, and rewarding. One hundred and sixty five undergraduate biology students participated in this program. A questionnaire was framed to collect both quantitative as well as qualitative data from the participants. Research skill development, research supervision, infrastructure and funding, self-learning capacity, time management, and the presence of research environment was assessed. Our findings indicate that learning through research-based pedagogy program improves students' confidence towards problem-solving and self-learning. A significant number of students expressed improvement in communication skills and their capacity to work in a team. The grounds of dissatisfaction were placed on the lack of availability of time, supervisor competence, technical support, and adequate funding to purchase chemicals and avail services. We hope this pedagogy based study and the student feedback will enable undergraduate teachers to plan, conduct and get quality output in research-based learn-

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Keywords

Research-based pedagogy, biological sciences, undergraduates, National education policy, knowledge ownership.

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ing at the undergraduate level.

1. Introduction

Our New Education Policy (NEP)-2019 aims to make significant changes in the methods of imparting education, which will nurture and develop qualities in individuals towards a meaningful future to meet the changing needs of individuals and society.

Our New Education Policy (NEP)-2019 aims to make significant changes in the methods of imparting education, which will nurture and develop qualities in individuals towards a meaningful future to meet the changing needs of individuals and society [1]. NEP-2020 states that "Higher education must form the basis for knowledge creation and innovation thereby contributing to a growing national economy." Further it envisages "development of an enlightened, socially conscious, knowledgeable, and skilled nation that can find and implement robust solutions to its own problems" [2]. It is based on providing access, equity, quality, affordability, and accountability in education. As per NEP-2019, research is one of the key parameters in higher education. The undergraduate phase of education is particularly important as these formative years help students to develop and grow as independent investigators. The quality of existing teaching practices at school and pre-university levels have had a long term effect on the production of quality candidates for the higher education sector. Pre-university teaching methods are classroom-based and didactic to a great extent. The students are equipped with theoretical knowledge and trained to crack several competitive examinations. Coaching classes as a parallel education system dominates the pre-university phase. Students are subjected to memory-based rote learning methods, which has affected the quality of teaching-learning. When these students join the university system as undergraduates, they have to unlearn and relearn new approaches towards experience-based learning.

Undergraduate education can be opined as the weakest link in our higher education system. Inadequate attention towards teaching-learning has resulted in the weakening of our education system. It lacks quality manpower and research capacities.

Undergraduate students constitute the crucial core for the future of science in the country. Hence developing skills useful for

research should be an important mandate at the undergraduate level. Research will play a key role in the three types and grading of institutions of higher education in tomorrow's India. Several academic bodies have, therefore, included research component as a part of the undergraduate curriculum. The present study is an attempt to apply a simple pedagogy tool to solve the perennial demand for a meaningful exercise for undergraduate student projects with the involvement of undergraduate departments, premier research institute, and local communities.

The current study was conducted to evaluate the outcome of one such research-based learning exercise undertaken in an autonomous undergraduate college. The study also attempts to develop a productive research-based pedagogy, which can be practised by the teachers or adapted to various existing conditions of our science education system in science, technology, engineering, arts, mathematics (STEAM).

2. Methodology

Final year students from three major streams, i.e chemistry as the common major followed by two other optionals—chosen from botany, zoology, microbiology, biochemistry, biotechnology—were included in the study. A total number of 165 student volunteers took part in the first workshop in July 2016. However, 44 students completed the entire exercise. Ten teachers and ten scientists were involved in the study.

2.1 *The Pedagogy*

The pedagogy design was inspired by the workshop conducted by the Centre of Excellence in Science and Mathematics Education (CoESME) at IISER Pune for science teachers. The authors have modified the basic concepts of research-based pedagogical tools (RBPT) that was introduced in the workshop conducted by CoESME. The RBPT concept is based on the 5 Rs, namely—recognise, require, refine, reward, and report (*Figure* 1). We opine that inspiration plays an important role in undergraduate research

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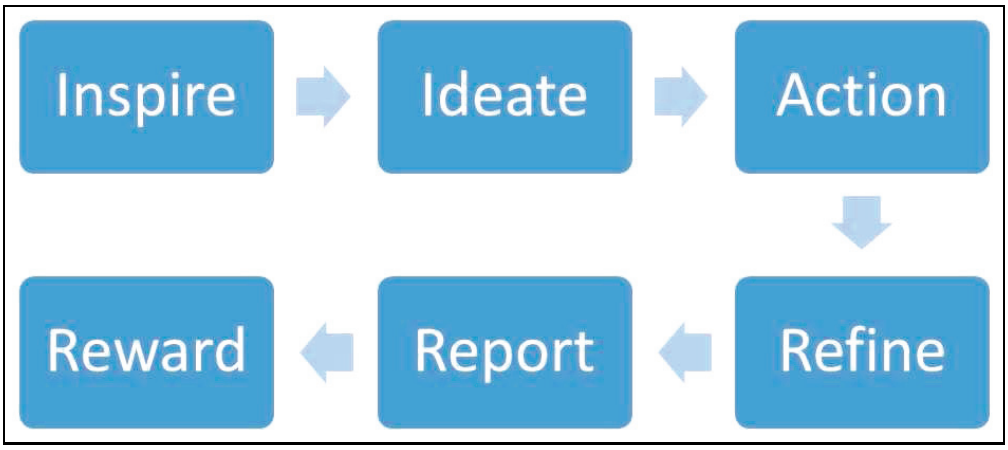

Figure 1. Schematic representation of research-based pedagogy developed and undertaken by the authors during the study period.

projects. We also observed that students of this age have a lot of unrealistic ideas. Thus, it is important to have a session on ideation to sieve real issues and solutions from the impractical propositions.

a. *Inspire*: A one-day workshop was conducted by the management of the institution. Renowned scientists from premier research institution were invited to the college campus. This is based on the concept of 'hand-holding' proposed in NEP-2019. Two lectures on the importance of research were conducted followed by interaction with scientists, students, and staff. A closed circle brain-storming session with the teaching staff was held to discuss the kind of projects that could be conducted during the year. A time-bound plan was developed.

b. *Ideate*: One month time period was given to members of the teaching staff willing to be part of this exercise to shortlist a few concepts and probable topics. Students were encouraged to think of research topics, problems, and possible solutions in the areas of ecology and biodiversity. The teachers assisted the students who did not have any specific preference to select topics from a few proposed topics. Such topics were based on faculty expertise. The role of the teacher was to mentor, encourage, and

facilitate. Each teacher was assigned 2–3 topics to guide. Few experienced senior teachers (who were assisted by PhD scholars in their research group) mentored a maximum of 5 topics. Each project team had a group of two students. The task of selection of topics and guide, and review of literature was conducted during July–August. The mentors carefully confirmed the maintainace of clarity in objectives and methodologies, and ensured economic and time-scale feasibility of the topics selected by the students. The topics chosen were related to ecology, environmental issues, waste management, and biodiversity.

c. *Action*: Based on the student requirements and topic selection, suitable resource persons were invited to conduct a three-day workshop in August 2016. During the workshop, 165 student volunteers were trained in field trips, sample collection, GPS tagging, and biochemical analysis by scientists from premier institutes of science. Students' response to field visits and workshop were overwhelming with proactive participation. On the first day, the morning session of the workshop was common to all participants. Later, the students, the visiting scientists, and staff were divided into smaller groups for specific field visits, based on the student's choice, e.g., a batch of 20 students who chose estuarine ecosystem studies were taken to a nearby estuary in a dedicated vehicle along with subject specialists and local guide. The parallel groups visited beaches, and fishing harbours, while a few visited local forest patches, riverbanks, industrial sites, etc. The sample collection sites were of local importance. The data generated by the study would contribute to the ongoing project of community biodiversity registry drawn up by the ENVIS, CES group of IISc, Bangalore. On the second day, samples were collected from the marine and estuarine mangrove habitats. Smaller groups for biodiversity studies of birds, fishes, crabs, butterflies, farming practices, trees and shrubs were formed with subject experts along with local guides. On the third day, the samples collected were brought back to the lab and methods of analysis was taught hands-on in small groups. The training involved safety and proper handling instructions of equipment, making stocks,

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reagents, standards, quantification, handling microscopes, image capture, and data handling. The process of data collection, analysis and documentation continued for three months under the supervision of mentors.

The students conducted the lab experiments, repeated a few collections, and validated the documentation. The teacher mentors monitored, guided, and facilitated the entire study.

d. ***Refine*****:** The students conducted the lab experiments, repeated a few collections, and validated the documentation. The teacher mentors monitored, guided, and facilitated the entire study. At the end of three months, the same teams of scientists were invited to evaluate and refine the student projects. Students prepared a synopsis and a 20-minute presentation of the work progress. The review committee comprised the mentor, internal and external experts. Individual student progress was monitored with attention by the staff mentor and visiting scientists. The challenges and obstacles faced by the student were addressed. They were guided on improving the quality of data collection and analysis. The mid evaluation was followed by repetitions, validation, and application of statistics wherever necessary.

e. ***Report*****:** The students were given practical training and lecture sessions on scientific writing skills by in-house mentors. They were trained in oral poster presentation and scientific paper-writing. Twenty-two abstracts were prepared and sent to an international conference to be held in December at an institute of repute. This conference had a separate session for undergraduate student presentations. Five full length papers were drawn up. Four posters and 18 oral presentations in the undergraduate students sections were accepted for presentation. Upon the completion of the project, reports were submitted as a thesis to an assessment committee as a part of end semester assessments in the college.

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f. ***Reward*****:** The experience of conducting independent research and knowledge ownership is a reward in itself. No additional fees were charged for the project. The expenses of field trips, sample collection, and the cost of chemicals were budgeted from the regular student fees. During the conference, student registration, accommodation, and travel costs were supported by the college

management. The students won prizes and got an opportunity to interact with 650 delegates scientists of national and international stature. The reward also included marks. The students were evaluated, and marks were awarded at the end of the semester as the study was a part of their curriculum and syllabus. No other form of reward such as, exemption from regular lab work or compensatory attendance was practiced. The motivation for participation was based on access to lab facilities, weekly guidance, and support.

2.2 *Data Collection and Analysis*

The present pedagogy-based study enables step-wise experiential learning. It also ensures uniformity in progress and the quality of project assessment and improvement. As a part of the curriculum, 4 hours per week was earmarked in the student's time table for project work. It was also a part of the teacher's time table for workload consideration; it ensured supervision and guidance as weekly follow-ups, reporting, and troubleshooting.

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The students were not charged extra fees for this project. The funds were managed from the annual departmental funds allotted by the management. Travel during sample collection was arranged by the college.

A student feedback questionnaire consisting of two parts was developed. Part A had randomized quantitative questions on a Likert scale of 5 values ranging from strongly agree to strongly disagree, and Part B comprised qualitative, open-ended questions. Twenty-one questions were drawn up in consultation with Dr Julie Jordan, Principal Lecturer, Sheffield Institute of Education. Students were invited to opine the statements based on this scale at the end of the study. The questions addressed the issues of research skill development, learning autonomy, and knowledge ownership as an expected outcome. It also assessed the other factors influencing the study such as teacher preparedness, infrastructure, peer-support, and research climate and time manage-

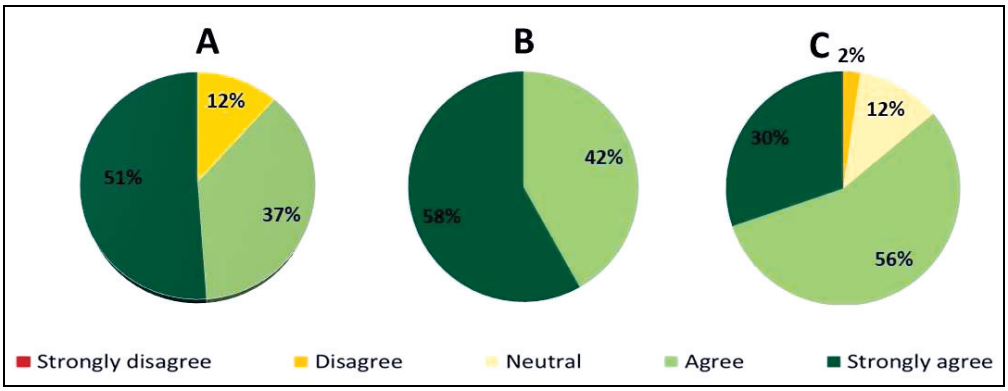

Figure 2. Confidence of students towards self-learning. **(A)** The research-based study approach made me confident of problem solving; **(B)** Research-based learning made me confident to pursue my own interest and strengthened my learning process; **(C)** This approach made me confident of self-learning.

ment. The feedback was also taken in the form of personal interviews by the authors upon completion of the research project.

2.3 *Data Analysis*

The data was collected in form of questionnaires with five options–strongly disagree, disagree, neutral, agree and strongly agree–and the questionnaires were scored and plotted using EXCEL, Microsoft. The qualitative data was collected as narratives and descriptions in the feedback forms.

3. Results and Discussion

Quantitative and qualitative data was collected after a series of personal interviews. The questions pertaining to research skill development, teacher preparedness, infrastructure, peer-support, research climate and time management showed the following results. Majority of the students were of the opinion that research based approach of study is more demanding in terms of time and physical, mental exertion as compared to regular practicals. However, every student expressed excitement of having an opportunity to pursue a problem-solving exercise in a subject of their choice (*Figure* 2B)

Several students expressed the need for better support from the technical staff in the laboratory. Undergraduate research is very demanding on the infrastructure. It needs constant laboratory trained supporting manpower to ensure the safe conduct of quality research.

During the action phase of the project, there was an urgent need for the allocation of dedicated work benches. The demand for ba-

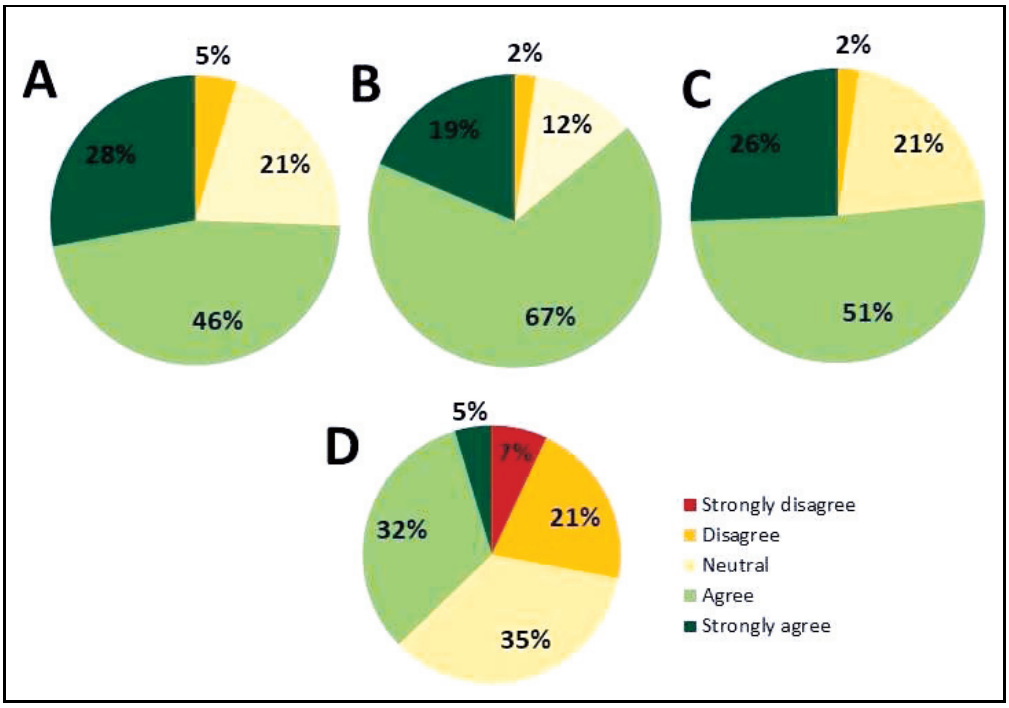

Figure 3. Response of the students towards research supervision and time. **(A)** Guidelines given during the selection of research topics by guide; **(B)** Research guide provided constant, helpful feedback and refinement during the conduct of the project; **(C)** Research guide helped with literature search and access to research journals; **(D)** The present curriculum provides time to conduct quality undergraduate research.

sic equipment such as balances, pH meters, colorimeters, microscopes, and centrifuges was high. Several students expressed the need for better support from the technical staff in the laboratory. Undergraduate research is very demanding on the infrastructure. It needs constant laboratory trained supporting manpower to ensure the safe conduct of quality research.

All the faculty members who guided the students had prior research experience. One of the teachers discontinued the program to avail maternity leave leading to a disconnect amongst a few students. Thus, we strongly advise the concept of co-guide in every student project to ensure continuity and support (*Figure* 3(A, B)).

The students expressed the need for improved funding and technical assistance provided as they had to find protocols to suit the available instruments, e.g, most of the analytical studies were done using analogue colorimeters with limited filters rather than

more recent, digital spectrophotometers of variable wavelengths.

Thus planning an undergraduate research project in the curriculum needs funds, infrastructure, and technical resource planning in advance, for smooth uninterrupted time management of project work. The scientific community of several developed countries recognize the importance of undergraduate research and provide funding initiatives, e.g., the National Science Foundation (2008), USA had allocated 33 million USD for Research Experience for Undergraduates Program [3]. In India, for the very first time, the proposed National Research Foundation (NRF) will focus on funding research within the education system, primarily at colleges and universities. It is proposed to have an allocation of Rs. 20,000 cr (0.1% of GDP) per year initially, to be increased annually commensurate with inflation, and with unspent funds held in a corpus for the future [4].

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The importance of research in education was recognised very early in the Indian education system. The National Education Policy-1986 [5] proposed to "modify curricula and methodologies of learning through appropriate research and development to incorporate elements of problem-solving, creativity, and relevance". The draft of the proposed new NEP-2019 [1] recognizes weak research output from the Indian universities and has made several recommendations towards its improvement. Some of the options suggested are liberal basic research funding and teacher training programs. The challenges in this context are the numbers. The number of students enrolled for undergraduate education in India poses a Herculean task ahead. In 2018–19, 37.4 million students registered for undergraduate higher education [6].

The entire exercise presented ample opportunities for students to engage with the process of knowledge generation, knowledge ownership, and autonomy with respect to learning. It also gave them an opportunity to work on topics of their interest. While 12% of the students were neutral to the demands of the research projects, a vast majority stated that research demands time, ef-

forts, analytical thinking, problem-solving, preparation of scientific reports, and presentations.

Students expressed difficulty in conducting a research project in addition to studying five theory papers and two practical papers in one semester. They expressed the need to have a dedicated semester for project work with no theory and other practical papers, to enable quality research at the undergraduate level. When we analyse the pedagogy phases and student responses, the students were most active during the action phase. However, the importance of planning and the role of the guide was recognized by the students during the ideate phase of the pedagogy. Mid evaluation by external members during the refine phase helped in improving the quality of the work. It also gave the students the opportunity to repeat experiments to reduce errors and refine the quality of work. Practical training in report writing and workshops improved the research output significantly in terms of abstracts and full-length manuscripts. The concept of reward in the pedagogy was critical in boosting confidence in self-learning and knowledge ownership. Thus the pedagogy of 'inspire, ideate, action, refine, report, and reward' was successful in generating a well-trained batch of 44 undergraduate students without compulsion.

Teamwork and peer support was mixed in the groups. The faculty observed that few highly competitive students do not help fellow students. It required the proactive intervention of the faculty in the delegation of work to a few teams. However, towards the end of the semester, the students were acclimatized to working together in teams. 80% students felt that the research ambience in the department and fellow students stimulated their work.

The limitation of the study was the large number of drop-outs. Out of 165 students, only 44 completed the study till the report and reward phase of the pedagogy. A discussion with the drop-out students resulted in a few interesting observations. The students stated that they were not interested in higher studies/research or

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careers in science. An undergraduate degree is a basic eligibility for several other careers such as banking, management, etc., and they wished to pursue alternative career options. Six students said research projects were time-consuming and caused wasting of several productive hours of extra-curricular activities such as dramatics, music, arts, debate clubs. The authors reflected on this limitation and opine that choice based research projects and not projects by compulsion at undergraduate levels might be a healthy option for holistic growth and academic development of undergraduate youth.

4. Conclusions

Today our education system is poised for massive changes. The benefits of research are immense for the students in terms of developing confidence, and experiential learning skills related to the subject of their choice. Research-based pedagogy methods can be used by the faculty to organize and conduct undergraduate level research projects. The proposed pedagogy provides a practical and comprehensive plan for the guide/mentor to organize and obtain the desired quality of research training for an ideal group of 45–50 interested students. It is also a simple and well-framed approach to achieve a meaningful, research-based learning experience for the student.

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accounted for its success. The authors sincerely acknowledge the active participation of students and staff of St. Aloysius College, Mangalore, towards conducting the study.

Suggested Reading

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