Finding Opportunities Within a Conventional Curriculum to Provide Research Experience to Undergraduate Biology Students: A Collaborative Effort with Teachers

Deepti Gupta, Homi Bhabha Centre for Science Education, India Needa Baghban, Homi Bhabha Centre for Science Education, India Aakansha Sawant, Homi Bhabha Centre for Science Education, India Swapnja Patil, Wildlife Conservation Trust, India
Jyotsna Vijapurkar, Homi Bhabha Centre for Science Education, India

The Asian Conference on Education 2018
Official Conference Proceedings

Abstract
In the past decade, undergraduate courses in Biotechnology and Microbiology in Indian universities have emerged as popular choices among students for their potential for aiding placement into industry and research laboratories. The laboratory curriculum for these disciplines includes an impressive list of experiments; however, they are conducted piecemeal, often by several different lecturers generally focussed on their own narrow topic. The laboratory course thus lacks coherence. Moreover, the laboratory routines largely follow 'cookbook' protocols that emphasise mechanistic aspects, offering negligible scope for building science process skills among students. In an attempt to address these issues, we conducted a workshop to provide a common meeting ground for college teachers to discuss their challenges and to work together to create course embedded research experiences for their undergraduate students. They collaboratively designed simple research problems that integrated individual activities and could scaffold science process skills. Forty five teachers from 23 different colleges affiliated to Mumbai University (and thus following a common curriculum), worked in groups and came up with problems that could engage students in small research projects. They found opportunities within the defined conventional curriculum by either converting the existing experiments into investigative exercises or by clubbing the experiments horizontally (within a semester) or vertically (across the semesters). This exercise not only resulted in useful resource generation but also led to the creation of a community of teachers with the shared objective of improving the teaching-learning process within the constraints of the prescribed curriculum.

Keywords: undergraduate biology, workshop, curriculum based undergraduate research experience (CURE)

Introduction

In the last decade, several reports have highlighted the inadequacies of science education at the tertiary level in India. These reports have concomitantly cited deficiencies in the curriculum design, ill preparedness of the teachers and lack of infrastructure as primary reasons for the poor standards of science degree graduates in the country (Mashelkar, 2005; Varghese, 2006; Balaram, 2010; Nityananda, 2017). It has been especially noted that typical curricula for undergraduate science courses are didactic in nature and do not include any component of research (Balaram, 2010; Phadnis and Pandit, 2011; Nityananda, 2017; Sawant et al., 2018). It has also been reported that practical sessions only serve to involve students in reproducing known results by following "cookbook" protocols (Sawant et al., 2018). The students are exposed to academic research only during post graduate courses (Master's or doctoral degree) which are offered by Universities where the faculty is actively involved in research activities. On the other hand, the faculty at the undergraduate degree colleges is primarily limited to teaching activities with little or no involvement in research. The undergraduate degree colleges are independent institutions which are affiliated to a University but may not be situated in its campus; the teachers and students thus have little access to research facilities. All affiliated colleges follow a common syllabus, mandated by the University, and the students undertake common semester wise assessments, also conducted by the University. These undergraduate degree colleges have evolved both functionally and infrastructure-wise to primarily support teaching activities and generally do not provide for carrying out research activities. A few undergraduate students, mostly self driven, are able to gain exposure to research following the apprenticeship model, wherein individual faculty members, mostly in the Universities, supervise the work of one or several students during summer or winter breaks. Apprenticeships can be beneficial, yet their one-on-one design inherently limits the number of students who can participate in it (National Research Council [NRC], 2010; Locks and Gregerman, 2008).

Currently, in India, there are around a thousand, universities (both public and private) with a total of 39050 undergraduate degree colleges affiliated to them. Every year around 5 million students pass out from these degree colleges but less than 20% of them choose to pursue a postgraduate degree (All India Survey on Higher Education [AISHE], 2017; Nityananda, 2017). It has been established that engaging science students early in research has a positive impact on their conceptual understanding and encourages them to pursue a career in the STEM disciplines (Hathaway et al., 2002). It has also been postulated that involvement of undergraduate students in research increases their self efficacy and creates a greater awareness among them regarding their own learning (Osborne et al., 2003; Allum et al., 2008). Recent discipline-based education studies have proposed course-based approaches for exposing more number of undergraduate students to research. Course-based undergraduate research experience (CUREs) labs have been proposed as an alternative to apprenticeship model: The model involves the entire class in authentic research activity embedded in their curriculum. This approach can be a more effective and accessible starting point for many students (Auchincloss et al., 2014; Bangera and Brownell, 2014). The focus of CURE labs is to enhance science process skills among students by involving a large number of undergraduate students, in a collaborative manner, in research. This model suggests that the laboratory curriculum be based upon research problems to allow students to be engaged in research projects during the college hours. We believe that this model with some modifications could be suitably adapted in the Indian context where large enrolments in undergraduate courses is common. In this regard we examined the laboratory curriculum of undergraduate courses in Microbiology and Biotechnology, offered by several colleges affiliated to Mumbai University, India. It was noticed that even though the syllabus for introductory laboratory component in undergraduate biology courses entails impressive lists of standard experiments, there is a lack of coherence in the laboratory course. Each experiment is designed as a standalone activity, disconnected with others. Further, to gauge the current laboratory practices followed in degree colleges, we conducted an online survey with college teachers, involved in teaching Biotechnology or Microbiology courses. It was found that students are not involved in planning or preparation of the experiments carried out in their colleges and follow standard laboratory protocols as suggested in the common laboratory journal shared by the University. Moreover, the laboratory sessions are often conducted by several instructors who do not collaborate amongst each other and are concerned with only the part of the syllabus which they execute in the laboratory. The teachers reported that the syllabus was overloaded and several experiments were done as only demonstrations due to lack of infrastructure. A lack of institutional support for introducing changes in the curriculum was also noted, although, a change in the order of practicals within a semester was permissible. We also interacted with some teachers and found that most of them had a limited experience of research themselves, hence were ill prepared to design research projects for their students. Based on our earlier study (Sawant et al., 2018), interactions with the teachers and the survey questionnaire, a SWOT analysis was done to pinpoint the strengths and weaknesses of the current system (Figure 1).

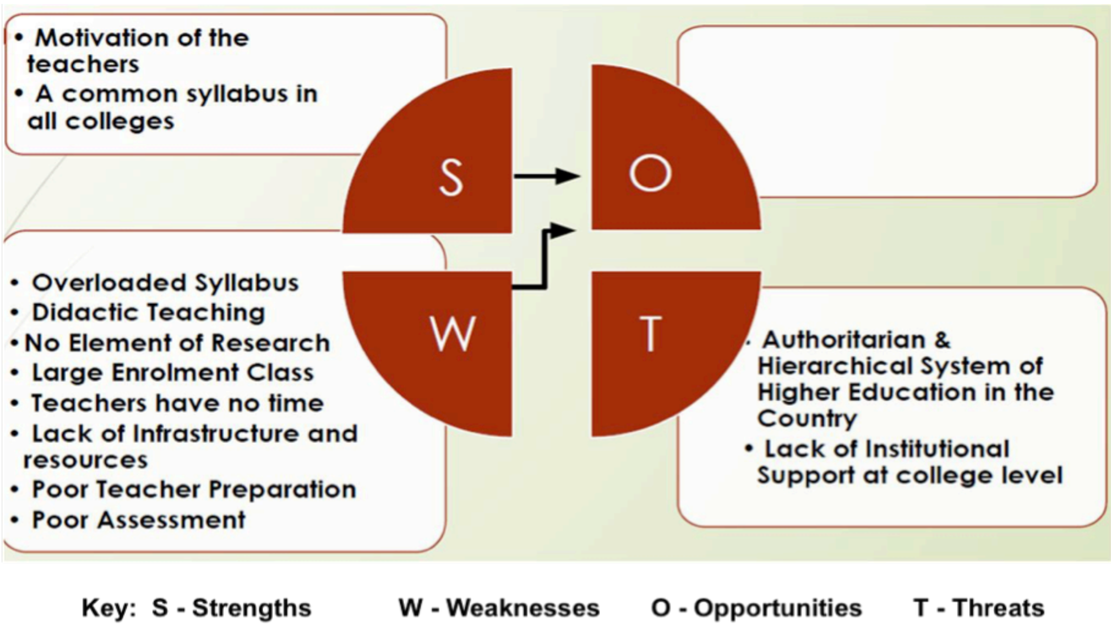


Figure 1: SWOT analysis

The responses to the questionnaire helped the researchers in identifying aspects that needed to be addressed and design a workshop for the college teachers. The analysis of the curriculum revealed that individual experiments could be clubbed as steps for solving research problems by making small changes in executing the practical sessions and making use of large numbers of student enrolment in the class. Therefore a two-day hands-on workshop was conducted with the college teachers to serve as a common meeting ground for teachers and encourage them to provide research experiences to their students by discussing their challenges and working together to seek solutions. The challenge for the teachers and researchers was to convert weaknesses into opportunities by innovating within the constraints of a conventional curriculum.

Workshop

Participants

The workshop was attended by 45 teachers, from 23 different colleges in and around Mumbai, teaching Microbiology or Biotechnology courses at the tertiary level. All colleges were affiliated to Mumbai University and thus followed a common curriculum. The teaching experience of these teachers ranged from less than 6 months to 34 years and they volunteered to participate in the workshop. Details of the participants are given in Table 1.

Table 1: Participant Details

Number of participants	Gender		Courses taught	
	Male	Female	Microbiology	Biotechnology
	6	39	20	25

In the online survey that we conducted earlier, a major fraction of teachers reported that their motivation to participate in the workshop was their interest in the role of integrating concepts in the laboratory and to gain insights on enhancement of student learning (Figure 2). Another notable fraction of teachers reported that the workshop was an opportunity for them to reflect on their teaching practices. A smaller fraction of teachers reported professional recognition and an opportunity to be involved in something other than routine duties as their motivation for participation. We believe that the motivation of teachers to improve students' learning was a strength for this task.

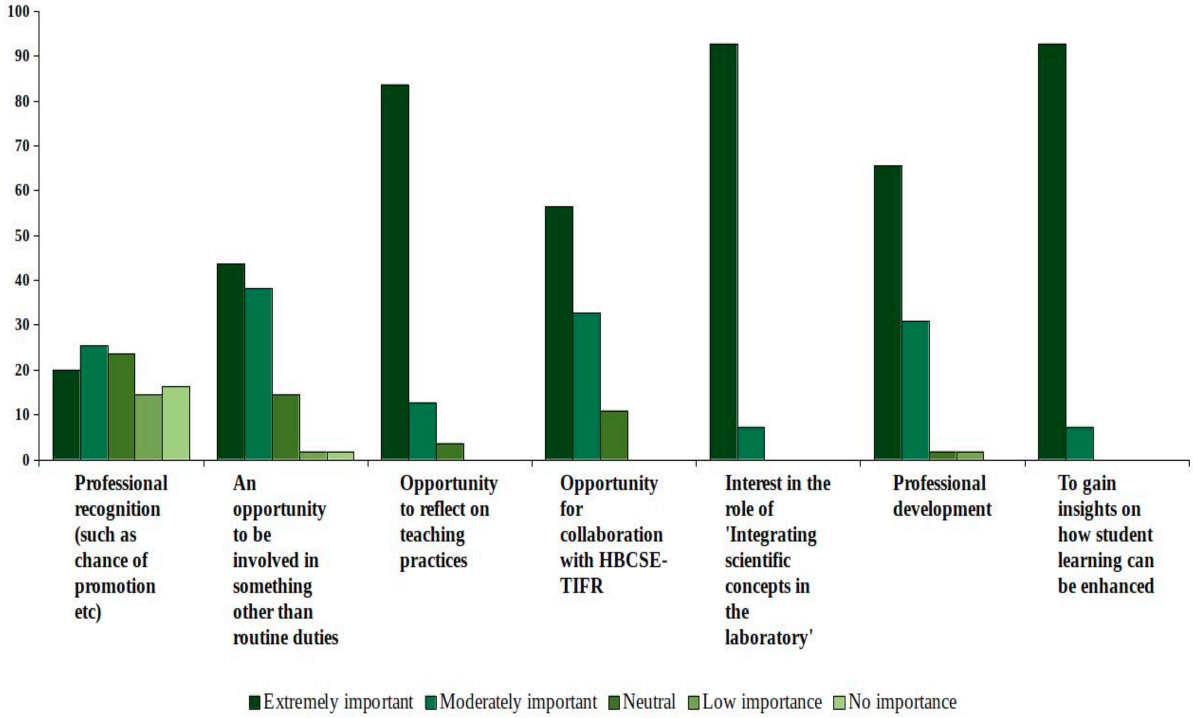


Figure 2: Teachers' reports of their motivation for participating in the workshop

Planning and Preparation

Five experienced teachers from four different colleges of Mumbai helped the research team in designing and planning of the workshop. These teachers were well-versed with the undergraduate biology course curricula and also had some research experiences. They could, thus, provide useful insights on designing practicable research projects in the college environment with its set of challenges for teachers. The resource persons worked closely with the research team to design the hands-on sessions of the workshop as well. As part of resource preparation for the workshop, the syllabi of all the three years of the Biotechnology and Microbiology courses as prescribed by the University was retrieved from its official website. The theory as well as laboratory syllabus were carefully analyzed and the experiments prescribed in the laboratory syllabus were divided into appropriate subject verticals, for example - immunoelectrophoresis was included under the subject head of *Immunology*, restriction digestion was included under the subject head of *Molecular Biology*, and so on. Also, the semesters in which the experiments were prescribed to be carried out were noted. This division of the experiments was done to aid the participants in the subsequent tasks of the workshop; to design problems of their own by clubbing of experiments horizontally (within a semester) or vertically (across the semesters). The aims of the experiments were organized on index cards (size 15 cms x 21 cms) that were colour-coded to represent each of the six semesters of the three-year degree course. A description of the designed cards along with their colour codes is given in Figure 3. Sets of these colour- coded cards were made and provided to the participants for the tasks of the workshop.

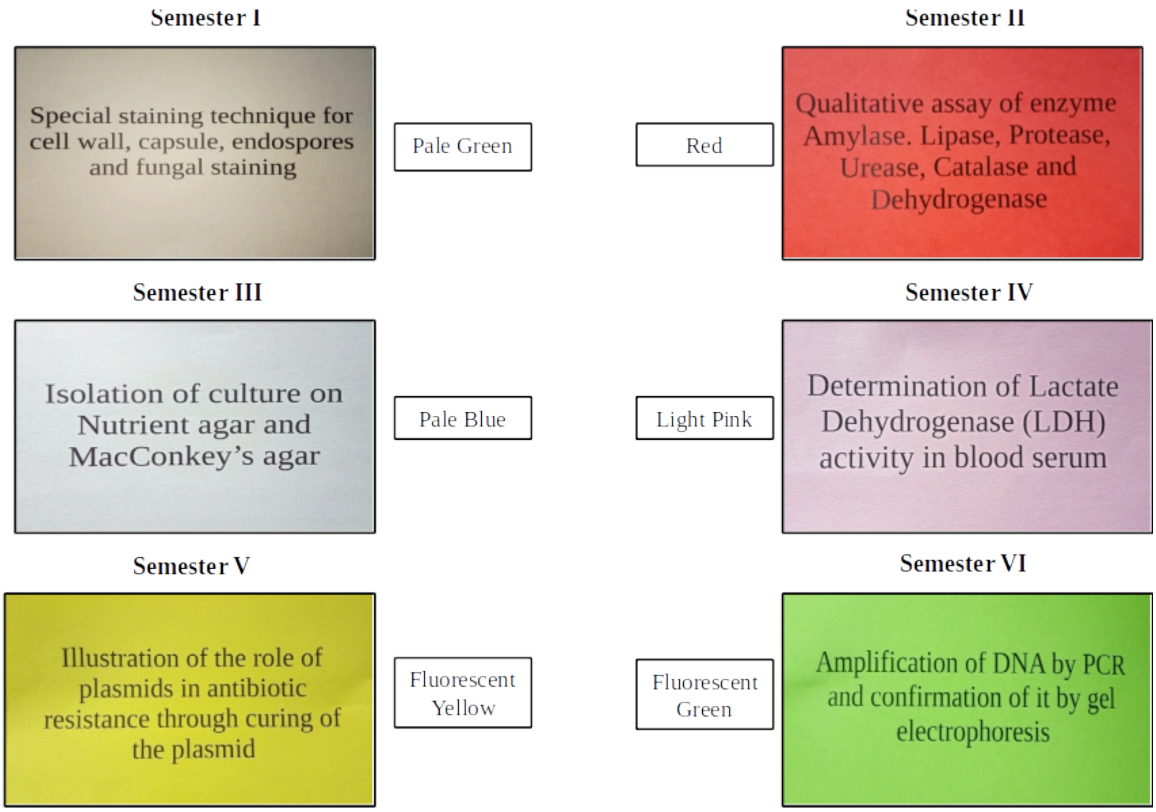


Figure 3: Cards with their colour codes designed for the workshop

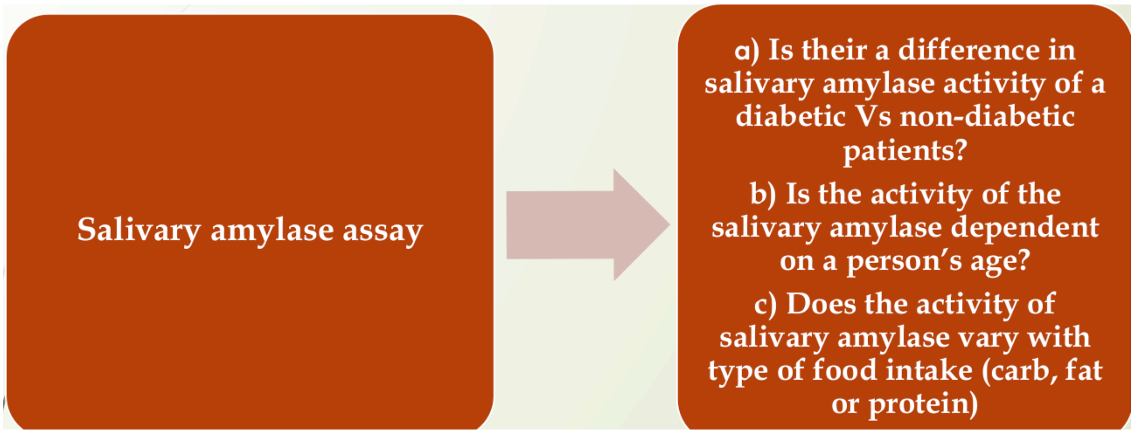
Workshop Details

The teachers were divided randomly into six groups of 6-7 participants each, as per the requirements of the tasks/ activities designed for the workshop by the researchers. In the first session of the workshop, the research team oriented the participants to the need and feasibility of integrating experiments within a given semester (horizontally) as well as across different semesters (vertically) by presenting some sample problems. Following this, the participants were provided with sets of the colour-coded cards containing the aims of experiments and asked to pin them on Styrofoam boards (39 in x 19 in) such that they form the steps of approaching a simple research problem. The participants worked together in groups and, themselves, identified small research projects under which the experiments prescribed in the curriculum can be clubbed. Each group was supported by a resource person. The research problems were presented by each group during the workshop. The resource persons and the researchers conducted different sessions on how the challenges faced by the teachers in laboratory could be turned into opportunities. One of the sessions discussed ways of accommodating negative results obtained during laboratory sessions and how they should be viewed as opportunities of learning for the students rather than as something to be discarded. This was a crucial aspect to be addressed since in the pre-workshop questionnaire, the teachers had mentioned that the laboratory sessions make use of 'cookbook' protocols that have been designed to give expected positive results. Another session introduced the participants to statistical tools and how they can be used for quantification of variations in results obtained by students. This session also discussed how a large number of students can work in groups where effectively results from each group can serve as an iteration of an experiment. This strategy not only saves time required for repeating an experiment to confirm results but also presents an opportunity to enhance quantitative skills of biology students. Further, a session on bioinformatics acquainted the participants with various web-based bioinformatics tools available and how they can be used for teaching different concepts prescribed in the curriculum. At the end of the workshop, teachers' change in approach, if any, towards the laboratory sessions and strategies of student engagement following the sessions of the workshop was assessed by written responses to questions projected by researchers. Also, a formal feedback on the workshop was obtained from the teachers on questionnaires distributed to them.

Outcomes and Conclusions

Although the inadequacies in the curriculum design, especially the absence of any component of research in the undergraduate biology courses, have been widely reported, not many efforts have been directed towards providing remedial measures for the same. The workshop served to address these issues by encouraging teachers to provide research experiences to their students within the limits of the prescribed curriculum and the available infrastructure. The researchers focussed on: 1) converting the existing experiments into investigative exercises by building a context of a real life problem, for example (Figure 4A) Clubbing experiments within a semester (horizontally) or across a semester (vertically) as steps of solving a research problem, for example (Figure 4B).

A.



B.

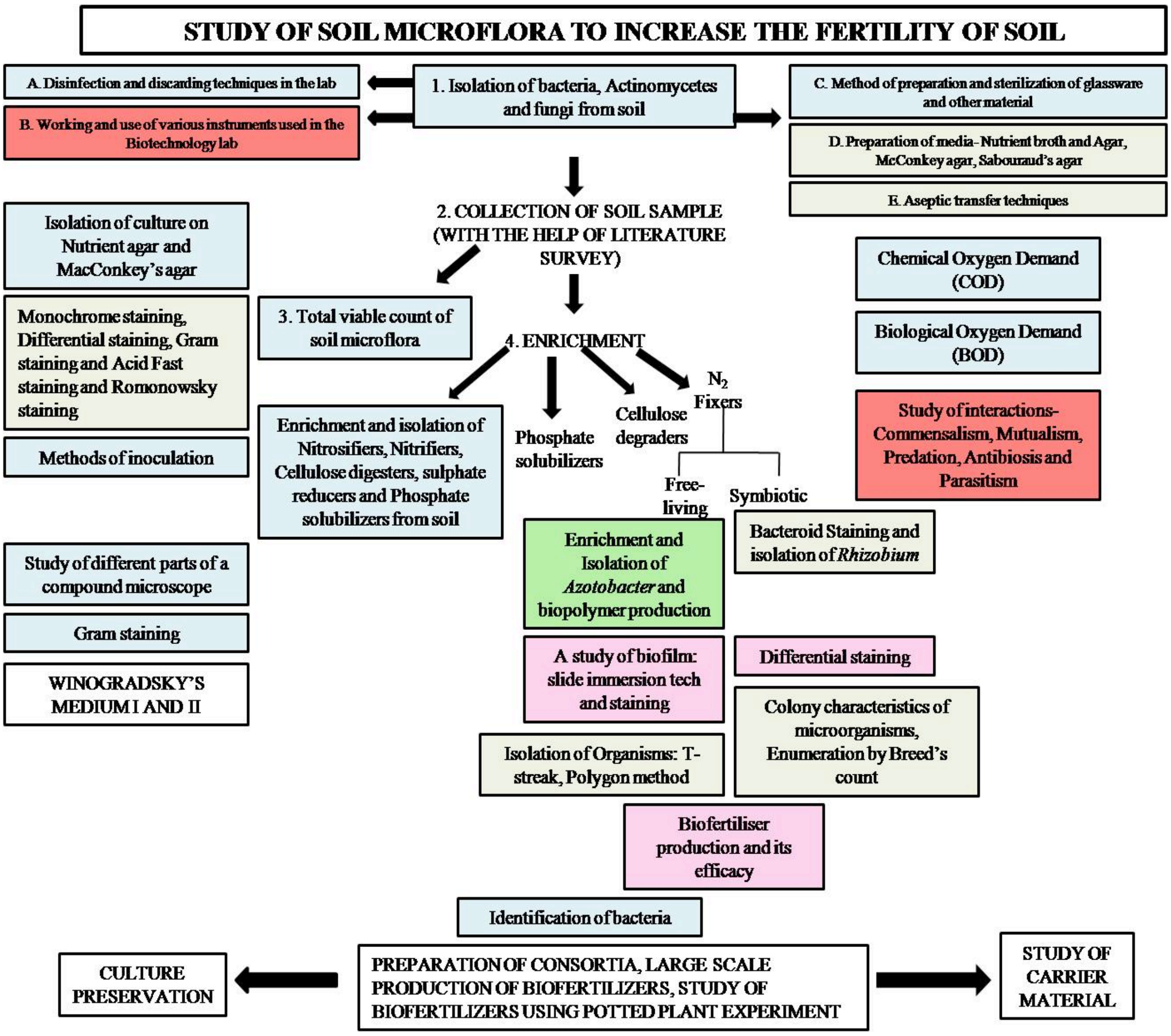


Figure 4 : A. Example of a real-life problem designed by converting the existing experiments
B. Example of a research problem designed by horizontal and vertical clubbing of experiments

The collaboration of teachers during the workshop, facilitated by tasks designed by the researchers, resulted in the designing of about 40 simple research problems rooted in the curriculum. The workshop provided a platform for discussing the importance of development of science process skills among students and also resulted in useful resource generation. Many teachers expressed that it was the first time when they have seen the full syllabus and the workshop helped them connect with the other faculty members. They also mentioned that the workshop helped them build connections between the experiments and gave them novel ideas for designing research projects for their students (Figure 5). An online community of teachers for sharing of ideas and improvement of the teaching-learning process could also be created.

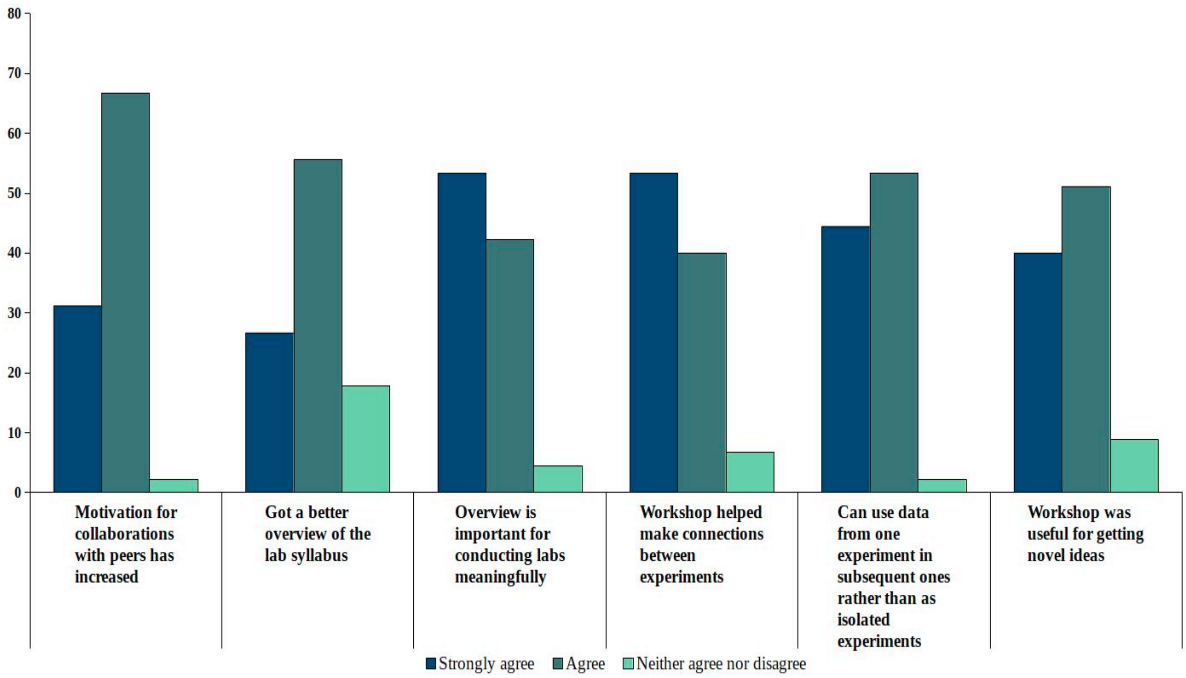


Figure 5: Participants' (n=45) views on the impact of the workshop as reported in the formal feedback

We have reports from some participants of having implemented the learnings from the workshop. However, a systematic follow-up is required to gauge the levels and success of this implementation. Although, the workshop motivated the teachers to implement changes in their current laboratory routines, several other factors may act as impediments to the implementation. As reported by the teachers, they are overloaded with administrative duties which leaves them with little time for introducing changes in their classes. Also, concurrent changes in the conventional assessment system may be required for effective implementation of project-based laboratory sessions. The workshop however gave insights on how the constraints to research can be overcome by making effective use of the available infrastructure, resources and time.

Acknowledgements

We would like to thank the participant teachers for their active involvement in the workshop. We also thank Dr. Shruti Samant, Dr. Aruna Wilson, Dr. Shiney Peter, Ms. Norine D'souza and Ms. Shmilona Jain for their valuable inputs, as resource persons, for the workshop.

References

Allum, N., Sturgis, P., Tabourazi, D., & Brunton-Smith, I. (2008). Science knowledge and attitudes across cultures: a meta-analysis. *Public Understanding of Science, 17*(1), 35–54.

Auchincloss, L. C., Laursen, S. L., Branchaw, J. L., Eagan, K., Graham, M., Hanauer, D. I., ... Rowland, S. (2014). Assessment of course-based undergraduate research experiences: A meeting report. *CBE-Life Sciences Education, 13(*1), 29-40.

Balaram, P. (2010). Higher Education: Rocky Road to Reform. *Current Science, 98* (5), 595-596.

Bangera, G., & Brownell, S. E. (2014). Course-based undergraduate research experiences can make scientific research more inclusive. *CBE-Life Sciences Education, 13*(4), 602–606.

Department Of Higher Education. (2017). All India Survey on Higher Education (AISHE). Final report. Retreived from http://aishe.nic.in/aishe/viewDocument.action?documentId=239.

Hathaway, R. S., Nagda, B. A., & Gregerman, S. R. (2002). The relationship of undergraduate research participation to graduate and professional education pursuit: an empirical study. *Journal of College Student Development, 43* (5), 614–631.

Hunter, A-B., Laursen, S. L., Seymour E. (2007). Becoming a scientist: the role of undergraduate research in students' cognitive, personal, and professional development. *Science Education, 91* (1), 36–74.

Locks, A. M., & Gregerman, S. R. (2008). Undergraduate research as an institutional retention strategy: The University of Michigan model. In: R. Taraban & R. L. Banton (Eds.), *Creating effective undergraduate research programs in science: The transformation from student to scientist* (pp.11-32). New York, NY: Teachers College Press.

Mashelkar, R. A. (2005). India's R&D: Reaching for the Top. *Science, 307* (5714), 1415-1417.

National Research Council (NRC). (2010). *BIO2010: Transforming Undergraduate Education for Future Research Biologists*. Washington DC: National Academies Press.

Nityananda, R. (2017). The case for a broad undergraduate science degree. *Current Science*, *112* (10), 1979-1980.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education, 25*(9), 1049–1079.

Pender, M., Marcotte, D. E., Sto. Domingo, M. R. & Maton, K. I. (2010). The STEM Pipeline: The Role of Summer Research Experience in Minority Students' Ph.D. Aspirations. *Education Policy Analysis Archives, 18* (30), 1–36.

Phadnis, J. & Pandit, I. (2011). Assessment And Evaluation Methods – The Prime Factors Influencing Curricular Outcomes. *International Conference to Review Research on Science, Technology and Mathematics Education, epiSTEME 4 Conference Proceedings* (Vol. 4, pp. 247-251).

Sawant, A. P., Patil, S. A., Vijapurkar, J., Bagban, N. N. & Gupta, D. B. (2018). Is the undergraduate microbiology curriculum preparing students for careers in their field?: an assessment of biology majors' conceptions of growth and control of microorganisms. *International Journal of STEM Education, 5* (42), 1-14.

Varghese, G. (2006). Declining Trends in Science Education and Research in Indian Universities. *UNESCO Forum on Higher Education, Research and Knowledge (Ed.).* Paris. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.540.8459&rep=rep1&type=pdf.

Contact email: deeptigupta.connect@gmail.com