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| Perspective

# Developing a faculty support program for fostering enriching undergraduate laboratory experiences under limited resource conditions

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**ABSTRACT** Meaningful pedagogical reform requires good faculty training and support programs. Such support is particularly valuable when colleges and universities are trying to bring research and inquiry into the laboratory curricula under resource-limited conditions. In this situation, it may help to extend the scope of the faculty support program to include training for practicing experimental techniques, sustainable networking opportunities, and a space to learn about pedagogical reforms. From this perspective, we share our experience about building a faculty development program for public college teachers who teach undergraduate biology in India. Though we designed the program for low-resource settings, the experiments curated could very well represent core biological concepts typically identified by the international community. The activities and overall design of the program can be useful for initiating pedagogical reform in any college/university where the traditional approach to biology laboratory instruction predominates, and high-end research is not easy to access.

**KEYWORDS** faculty development program, India, hands-on, *Hydra*, *Drosophila*, laboratory, inquiry-based instruction, cookbook, traditional laboratory, limited resources

Pedagogical reforms require providing opportunities to STEM teachers to support them in modifying their teaching-learning practices. In India, agencies, like the University Grants Commission, are regularly involved in conducting undergraduate (UG) faculty development/induction programs (FDPs) (1). Most of these programs are not discipline-specific and usually cover a wide range of topics like understanding student psychology, research methodology, innovative pedagogical methods, and interdisciplinary studies. India also has online platforms for sharing experiences related to school and undergraduate biology education (https://indiabioscience.org/educators) and for freely accessing the theoretical content of various courses, including sub-disciplines of biology at the undergraduate level (https://swayam.gov.in/about). However, there are very few reports of discipline-specific undergraduate biology FDPs in India. When conducted, these programs often include short training courses for a specific experimental technique—such as a half-day course on PCR. The outcomes and designs of such FDPs are rarely accessible. Also, there are multiple financial constraints on many of the teaching faculty and their colleges/universities. Our informal communications with teaching faculty suggest that, in such a situation, developing engaging laboratory sessions is not prioritized by college/university administration. Lack of teacher support exacerbates these issues. As a result, undergraduate laboratory experiences continue to suffer.

In this view, we reflected upon the need to develop a faculty support program for enriching undergraduate biology laboratory experiences at our institute. Many Bachelor of Science (B.Sc.) and even Master of Science courses across India are still struggling to

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include hands-on demonstrations for various sub-disciplines of biology. Therefore, the component involving training for experimental techniques was retained while developing the FDP.

Limitations of resources and infrastructure, ethical constraints regarding animal model use (rodents/amphibians/fish), and relevance to suggested university curricula were considered while deciding the experiments. The first program focused on performing experimental techniques. Informal follow-up with the participants in the following year led to a modification of the design of the FDP in the second year, emphasizing additional components—networking and pedagogy improvement. Some essential features of our program were developed following recommendations from successfully conducted FDPs reported in the literature (2–4). Specifically, participating faculty were also collaborators. The faculty actively engaged in different hands-on activities; the laboratory setup emulated inquiry-based instructional practices the faculty hoped to implement in their classrooms. Furthermore, faculty could attend the workshop in teams of two from an institution. The schedule and duration of the workshop were decided after a Zoom consultation with the participants. Lastly, developers provided continued support to participating faculty in the implementation post the FDP.

So far, we conducted two faculty development programs (February 2022 and 2023) as a pilot project. Informal feedback revealed that the model followed in the second program (Table 1) was more wholesome and could be continued for extending the reach of the program. We kept the invitation open to all the local government-aided colleges (public colleges) teaching either zoology or life sciences at the B.Sc. level. A total of 25 teachers from 17 colleges participated. Five teachers participated in both programs. We will sequentially describe each component of our program in the following sections.

## Design of the program

Laboratory environments can be demonstrations, inquiry, and research experiences (6). Traditional laboratory includes demonstration experiments. They usually show how an established scientific principle works. These are recommended for the introductory years of the UG laboratory, where students master these techniques and learn to interpret their results. We noticed that many theoretical concepts are not demonstrated in Indian UG biology laboratories. While one of our motivations behind organizing the FDPs was to train the teachers with experimental techniques using invertebrate models, we also wanted to develop an environment where the participants could reflect on how they instruct and assess students in the laboratory courses.

**TABLE 1** Schedule of the second undergraduate FDP[a]

| | | | |
|---|---|---|---|
| Day 1 | | | |
| | Morning | Talk-I | |
| | | Dissonance activity (what makes a lab least engaging with lowest learning outcomes?) and identifying lab environment (Table 2.1) | |
| | Post-lunch | Open-ended inquiry (Table 2.2) | Laboratory sessions |
| Day 2 | | | |
| | Morning | Talk-II | Laboratory sessions |
| | Post-lunch | | |
| Day 3 | | | |
| | Morning | Talk-III | |
| | | Assessment activity (what concepts matter while assessing students for their laboratory coursework?) (Table 2.3) | |
| | Post-lunch | Participants share their ideas and experiences | Laboratory sessions |
| Day 4 | | | |
| | Morning | Talk-IV | Laboratory sessions |
| | Post-lunch | Feedback and concluding remarks | |

[a]Briefly, dissonance activity and understanding different lab environment activities were scheduled at the beginning of the program. A few hands-on activities and one interaction session with the scientists were scheduled on each day of the program.

**TABLE 2** Three activities related to practicing modified laboratory instruction[a]

| |
|---|
| **1. Understanding different laboratory environments** |
| Excerpts from lab journals (student handouts) of introductory biology lab are given below, can you guess the lab environment? (Traditional/inquiry/research lab). In case of inquiry further, classify as structured/guided or open-ended inquiry (three examples from the quiz, respective expected answers, and brief explanations are mentioned below)<br>1. Aim: Using upright microscope to observe methylene blue staining of onion cells. Learning objectives: Using common microscopic techniques to examine cells. Materials provided: Ocular and stage micrometer, Methylene blue stain, Onion, Upright microscope, Slides, Coverslips. Protocols: Protocols for methylene blue staining, and wet mounts are provided to you separately.In traditional laboratories, the students follow an exact set of instructions to visualize the theoretical concept of the structure of an onion cell under a microscope.<br>2. *Hydra viridissima* is used as a model system to study ecotoxicity of different chemicals and metals to freshwater habitats. Assess the health index of laboratory culture of *Hydra*. Design experiments using *Hydra* as a model system, to study if the lake waters of your city are habitable for fresh water ecosystems.Research experience, assuming *Hydra*'s habitability in the local freshwater sources has not been studied before; however, the students do not get to choose the research problem here.<br>3. Alcohol is used as a sterilizer in routine microbiological work. However, exposure to lower percentage of alcohol may not be extremely toxic to the micro-organisms. Design experiments to check whether addition of alcohol to the culture medium differently affects growth rate of *E. coli* and baker's yeast.Open-ended inquiry, the question is well-studied in the scientific field, but answers are not known to the students. Protocol or literature is not provided to the students. |
| **2. Using detailed assessment rubric for evaluating experiment designing competencies** |
| A prompt and set of student responses [adapted from Killpack and Fulmer (5)] were provided to participants for a detailed evaluation of the students' experiment design competencies. For example, for the first scoring assessment task about forming a "Hypothesis," teachers were asked to give student 1 mark for each of the criteria fulfilled. The criteria were<br>(i) Develops and states a hypothesis. (ii) Attempts a response. (iii) Hypothesis provides a testable statement (e.g., not written in the question form). (iv) Hypothesis states both an independent variable and a dependent variable, which are specific and related to the provided scenario. (v) Hypothesis states a specific direction for the relationship between the independent and dependent variables, which indicates the expected outcome (Examples of students' answers and prompts are mentioned in the supplemental material). |
| **3. Designing and experimentally answering on open-ended inquiry** |
| The following prompt was provided to the participants:<br>A brine shrimp cyst supplier provided the same batch of cysts to different customers. He received feedback of varying percentage of cysts hatching after 48 hrs of incubation. They all had used 3.3 g/100 mL saline water (pH 6.5) and 5000 lx light to hatch the cysts. He wants to design an experimental test to explore if there is any factor(s), other than the light and saline water, that contributes to this difference in percentage hatching.<br>The participants were then tasked to develop a hypothesis, suggest biological rationale, plan control and experimental groups, data collection strategies, statistical analysis, etc. They also performed the experiment they designed. |

[a]The first and second were presented as quiz with multiple choices of answers/grades. The third activity was presented as an open-ended inquiry.

To begin, we adapted a reflective strategy where we recognize cognitive dissonance to initiate pedagogical reform at the individual faculty level [adapted from the workshop conducted by Ryker (7)]. Cognitive dissonance occurs when an individual holds contradictory thoughts when presented with different contexts or when their actions do not support their thinking. Recognizing the dissonance, and the reasons behind, may help in resolving it. In this activity (7), participants answered: "What is the worse laboratory experience with poor engagement and the lowest learning outcomes for the students?" The question was open-ended, and no time was provided to reflect before submission of the answers. By doing so, we intended to know about what criteria are foremost in the thoughts of the participants. Most teachers mentioned the cookbook approach to instruction, lack of resources, and lack of sufficient hands-on modules. Some teachers specified particular labs—like identification using preserved specimens and karyotyping using paper cutting to be uninteresting. Teacher responses are categorized and represented as a pie chart (Fig. 1B). Later, the teachers reflected upon whether they conduct such labs, and what they can do to make labs more engaging. We hope that the activity motivated the teachers to improvise their laboratory courses.

Later, we conducted a quiz to understand the types of laboratory environments and how we could build them (Table 2.1). The teachers had to identify the type of lab environment (traditional/inquiry/research) and the level of inquiry (structured/guided/open) in different laboratory sessions (6, 7). The teachers discussed and reflected upon

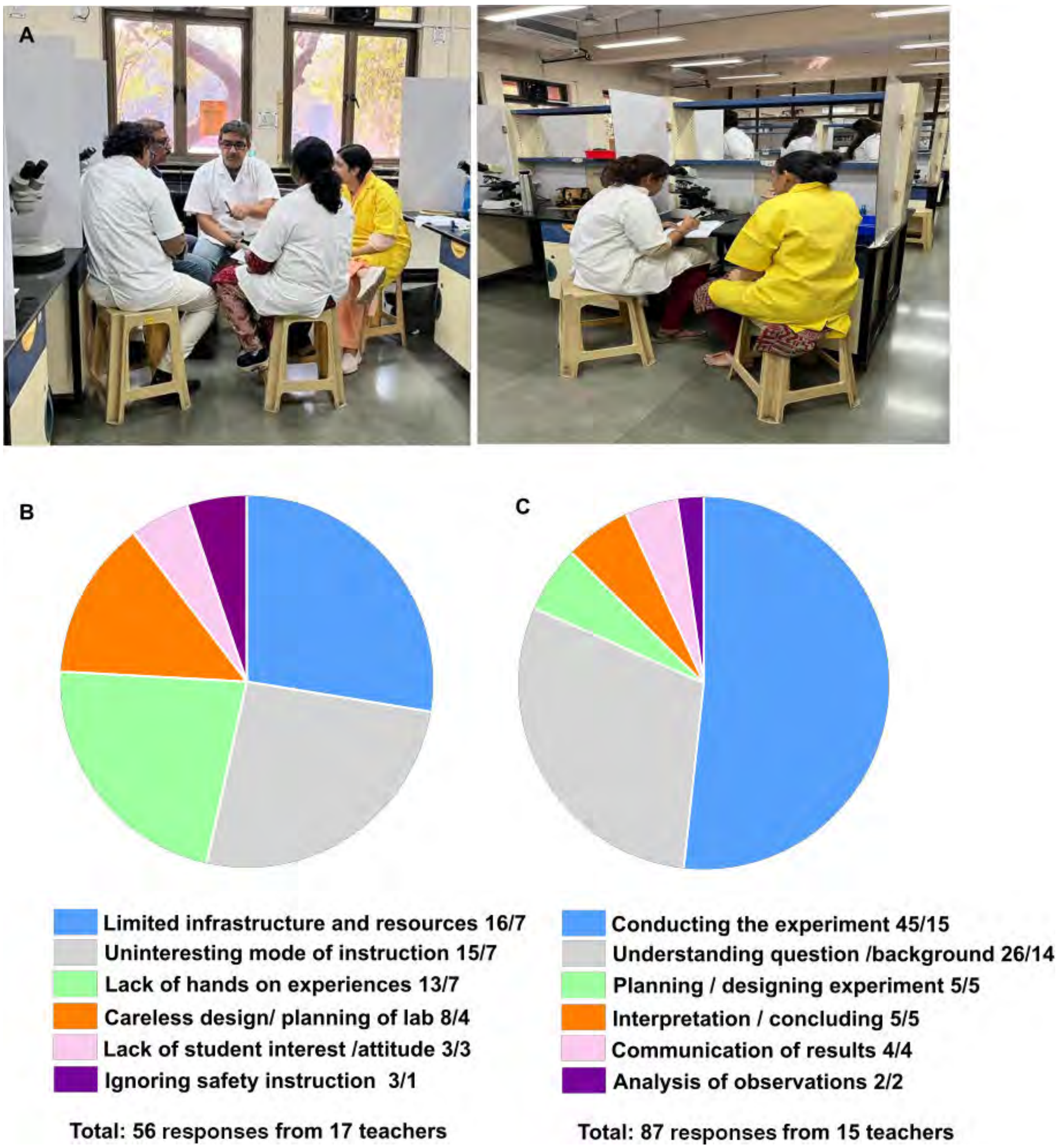


**FIG 1** Teachers' responses to reflective activities in the program. Photographs of teachers actively discussing their ideas (A). Pie chart for teachers' responses (B and C) to the question "what makes a lab least engaging with the lowest learning outcomes?" (B) and "What concepts matter while assessing students for their laboratory coursework?" (C). Teachers' answers were categorized into six groups. The numbers in each category indicate total responses for that category followed by the total number of teachers specifying at least one response in that category for both questions (B and C). Two teachers chose not to respond to the second question (C).

their choices with peers. When inquiry-based instructions are followed in a laboratory setup, results are unknown to the students but known to the instructor or are already established in the field (8, 9). A guiding rubric to classify the level of inquiry was shared with the teachers (see the supplemental material). After this activity, the participating teachers appeared more in control of the degree to which inquiry is to be facilitated while adapting to their students' needs, laboratory curricula, and infrastructural constrain.

Even for a motivated teacher, implementation of inquiry-based instruction is often hard (10, 11). Teachers need to develop deeper content knowledge, get acquainted with different ways of data analysis, and build different assessment strategies when they shift from traditional labs to inquiry-based labs, with a focus on students' learning outcomes (4). Discussing all the challenges in implementation was difficult in the short time we had. However, we managed to dedicate two sessions for discussions about assessment strategies. Initially, the teachers briefly shared their thoughts about "what concepts/competencies/skills matter while assessing students for their laboratory coursework." All teachers mentioned factors related to conducting experiments, like, ethics, good lab practices, and skills. Many of them also specified sound background knowledge and understanding of the task at hand. However, very few mentioned designing experiments, analytical skills, and interpretations in their answers (Fig. 1C). This response was not unexpected as the cookbook approach still dominates most laboratory coursework of Indian undergraduate colleges. Sustained interactions and combined efforts from the teaching community would be needed to work on modifying assessment strategies in a traditional laboratory setup. Later, we used a tool developed by Killpack and Fulmer (Table 2.2) (5; also see the supplemental material) as an exemplar of a detailed assessment rubric for the experiment design.

One of the key recommendations for designing successful FDPs is to emulate the practices faculty wish to bring about in the classes (4). Hence, the participants answered an open-ended inquiry in the program. They designed an experiment based on a prompt (Table 2.3) and the list of available reagents provided to them. Each participant individually performed the experiment designed by them in the following days. Teachers communicated that practicing assessing experimental design competencies (Table 2.2) helped them minimize errors in this task (Table 2.3). All techniques were practiced individually or in groups as demonstrations to save time.

## Familiarizing participants with experimental techniques

Students' theoretical knowledge, accessibility of investigation techniques, and practical constraints of the learning environment are some of the challenges in implementing inquiry-based learning (12). Considering these, we demonstrated techniques relevant to undergraduate curricula using invertebrate model systems. We focused on *Drosophila* and *Hydra*, which are relatively inexpensive to maintain and well-established for use in laboratory pedagogy (13, 14). The references for protocols of the experiments performed in the FDPs are in Table 3. The participants also discussed feasible ways of increasing the level of inquiry in their laboratory courses, using these experiments. For example, once the students learn to image *Drosophila* embryos under live conditions (15), they can then

**TABLE 3** List of the experimental techniques curated and demonstrated[a]

| Sub-discipline of biology | Experimental techniques |
|---|---|
| Behavior | Quantification of induced feeding behavior and phototactic behavior of *Hydra*[c] (14, 16, 17). |
| Cell biology | Macerating *Hydra* to observe different types of cells and symbiosis[b] (18, 19). |
| Developmental biology | *Hydra* regeneration assay[b] (14,20), identification of developmental stages of the life cycle of *Drosophila,*[b] and identification of male/female and virgin flies[b,c] (21–23). Dissection and staining of imaginal discs[b] and live imaging[c] of *Drosophila* embryos (15,24). |
| Genetics | Setting up *Drosophila* crosses and identifying mutants and balancers[c] (25). |
| Organ systems /physiology | *Drosophila* gut physiology, dissection, and visualization of nephrocytes and salivary glands[c] (26, 27). |
| Reproduction | Calculating percentage of hatching of artemia cysts[c] and calculating budding rate of *Hydra*[b,c] (14). |

[a]Referred literature includes protocol for each of the techniques.
[b]Indicates incorporation of the technique in the first program.
[c]Indicates second program.

answer inquiries about whether changing the temperature of the environment would affect the development of fly embryos.

Many of the techniques mentioned in Table 3 can be creatively used to visualize core theoretical concepts of biology. For example, a comparison of the pH gradient in the midgut of *Drosophila* with that of the human gastrointestinal (GI) tract can be effective to understand the similarities and differences in the physiology of insects vs mammals or to discuss whether *Drosophila* could be used as a model system to study human GI disorders. Both *Drosophila* and the human GI tract are segmented into an anterior neutral zone, an acid-secreting mid-region, and a base-secreting posterior end (26). The acidic nature of the stomach is a common feature among all animals and helps in guarding against infections. An example of a difference includes malpighian tubules at the anterior end of the hindgut of insects, which can be seen upon dissection of the larval intestine. These tubules are organs of osmoregulation and excretion and help small insects in water conservation (28). Another example is the visualization of the structure of cnidocytes, before and after chemically induced feeding response. How tentacles and cnidocytes sting and paralyze prey could very well explain the structure-function relationship in organisms. Likewise, *Chlorella* living inside the endothelial cells of *Hydra* can be visualized to teach complex symbiotic relationships between biological systems. Participating teachers were experts in theoretical content knowledge, and they could readily understand and assess the relevance of demonstrated experimental techniques with undergraduate curricula.

After the first program, we took detailed feedback from the participants about the usefulness of each of the experiments performed by them. The participants thought most techniques were engaging and relevant to their curricula. Participants could envision designing an inquiry-based laboratory based on these experiments in their college (Fig. 2).

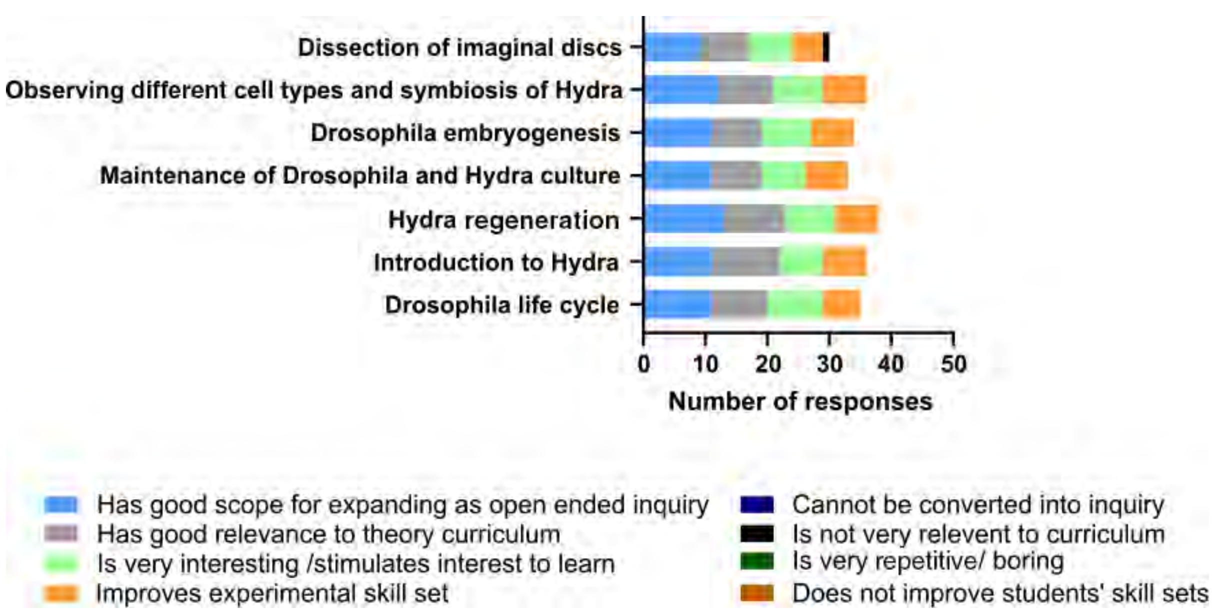


**FIG 2** Detailed feedback from the teachers about the usefulness of hands-on experimental techniques performed in the first meeting. A binary scale questionnaire was used to note the teachers' opinions about the feasibility of presenting the experimental techniques as inquiry in their laboratory classes, their relevance to the curriculum, engagement level, and skills imparted. Total number of responses for each of the experimental techniques is plotted on the graph. Numbers of responses under each category are specified as per the legend. A maximum of 13 and a minimum of 0 (*N* = 13 for the first meeting) responses could be possibly marked for each category.

## Providing networking opportunities and increasing dialogue between scientists and teachers/ educators

Evidence-based teaching in science, technology, engineering and mathematics (STEM) courses greatly benefits from building support and encouraging environment for the faculty (29, 30). We envisioned establishing successful mentorship or collaborations to begin a dialogue and provide opportunities for networking across the teaching-centered colleges and research institutes. We invited scientists working on cutting-edge research to share their findings and experiences with the teachers. The talks were followed by interactions where ideas and techniques suitable for implementation in undergraduate laboratories were discussed. The scientists were informed about the ground realities and limitations of undergraduate laboratories in public-funded colleges. Photographs of the talks and voluntary feedback received over email from two of the scientists are shared (Fig. 3). We hope such sessions encourage active collaborations between scientists and undergraduate educators in due course.

## Outcomes and reflections

While focusing on the hands-on component, we kept in mind the constraints of space and resources when we designed both the FDPs. Thus, we did not envision a large number of participants. Even in the limited cohort, the faculty who joined had varying

**Excerpts from feedback received from two of the scientists**

"It is a very useful initiative and a much needed one. There is a large gap in the theory and practical experience that we provide the students at undergraduate level currently. Training the trainers will surely help in bridging the gap. It was evident by the immense curiosity and an eagerness to learn that the attendees exhibited. Please let me know if you need any further assistance from me."

"I really enjoyed giving the talk and interacting with the participants. I think it was a wonderfully organized workshop, combining lab work with carefully curated seminars, which I am sure would help these teachers inculcate research culture in their respective colleges. I also got an opportunity to observe some practical sessions, and it was fun learning about various model systems like *Hydra*. The questions asked during and after my talk gave me some great experiment ideas that can be pursued in the futur e. I would be happy to contribute to similar initiatives in the future."

**FIG 3** Representative photographs of the talks of scientists and excerpts from two of the scientists' feedback received via email.

years of teaching experience—ranging from 2 to more than 20 years and different expertise. Only a few had previously worked in an institute with access to state-of-the-art research facilities. Individually, they very likely had different expectations from offering and receiving mentorship. We understand that we will need to build a network of educators and scientists working across varied domains of biology and at different stages in their careers to foster meaningful support for all the present and potential participants. We also recognize the huge need to expand the scope of such programs beyond local colleges. Certainly, it will be more challenging to reach educators situated in regions away from cities and clusters where high-end research institutes are located. Therefore, we are reflecting upon the need for separate formal events to connect interested teachers with a focus on cross-institutional interactions and mentoring, like the approach discussed by Moore et al. (30).

The first faculty development program was organized following an informal discussion with a few of the participating teachers and institute authorities. After the first program, two of the six participating colleges incorporated similar modules in their regular laboratory coursework. Two colleges built mentored research experiences for a few students following this program, one of the mentored projects also received appreciation at a local undergraduate research competition. A science exhibition was held at another participating college using these model systems. Most participants reported that they are working on expanding the scope of their undergraduate laboratories, creatively finding their way through multiple difficulties. Many participating colleges informed us about the lack of dedicated space and incubators. Our institute and colleges are in Mumbai, a city with hot and humid weather that always carries a high risk of fungal contamination. Though inexpensive, the invertebrate model systems are challenging to set up and require consistent efforts. Small developments, like procuring incubators and managing to culture *Hydra* in clay vessels, were visible in informal follow-ups with the teachers in the following year.

Enthused by an encouraging response to the first program, the design of the second program was modified and finalized. The program was carried out under the National Initiative on Undergraduate Science of the Government of India. The program received support and helpful input from institute authorities. Five biology cell staff members contributed to the execution of the program. Preparations for the second program included discussions and reading relevant literature within the biology cell, coordinating the availability of scientists, teachers, and staff of the biology cell, scaling up *Drosophila* and *Hydra* cultures, and curating, designing, and practicing experiments. While modest honorariums and travel reimbursement were available for the participating scientists and resource persons, most of them chose to volunteer their time and services. The experiments involved were relatively inexpensive and required minimal procurement. Attendance and participation in both programs were not directly rewarding for the professional development of the teachers. Managing regular duties at college while the staff attended the programs was strenuous for many small local colleges. All this limited the participation of teams of two or more from the same college.

Including multiple hands-on experimental practice sessions that are inexpensive and relevant to the theoretical curriculum was a crucial component of the program. The experiments curated for this program, complement some of the core biological concepts (31), like evolution, structure and function relationship, and complex interactions in biological systems, e.g., symbiosis. They could be particularly useful in community colleges or government-funded public colleges when access to resources is constrained. However, the participating teachers have not yet assessed if there is any advancement in the students' understanding of core concepts after the intervention or modification in laboratory pedagogy. The dissonance activity, identifying lab environment quizzes, and designing open-ended experiments and assessment tasks gave the attendees a glimpse of what a modified laboratory experience could mean. Such activities can be used as a primer for developing FDPs in places and countries where cookbook-style laboratories are still prominent. Discussing biology education research or reading relevant literature could not be accommodated in the 4 days of the program. We wish to extend the scope of our program to include such journal clubs in the future, perhaps as a part of the teacher networking events.

Furthermore, we would like to mention that the immediate feedback of the participants was very encouraging. All of them rated the overall experience of the second program as excellent/five (12 participants) or very good/four (five participants) on the Likert scale of 1–5. Most (8 out of 17) participants mentioned that they enjoyed the open-ended artemia hatching-related experiment (from a total of seven experiments performed by them) the most. They clearly appreciated the open-ended inquiry approach and could envision using the same for their students.

Based on our experience, for a 4-day long FDP designed for advancing laboratory pedagogy in traditional settings, we recommend: (i) including exercises to bring clarity about how instructional approach/assessment strategy can be modified, (ii) collaborating with scientists and field experts to foster an exchange of ideas between scientists and teachers (Important if the participating institutes mainly focus on teaching.), (iii) designing experimental components considering the curriculum of the participating institutes, practical difficulties in implementation (e.g., university schedule), and budget as well as infrastructural constrain.

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Anuttama Kulkarni, Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review and editing

## ETHICS APPROVAL

Participants provided informed consent before the program. All activities carried out in the program were approved by the institutional review board. Feedback and all the written responses were collected anonymously.

## ADDITIONAL FILES

The following material is available online.

### Supplemental Material

**Supplemental information related to Table 2 (jmbe00141-23-s0001.docx).** A) A rubric to characterize inquiry in the undergraduate laboratory (related to Table 2.1, adapted from Buck et al. 2008); B) The detailed assessment rubric for evaluating experiment designing competencies (related to Table 2.2).

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