Using Collaborative and Problem-Based Learning in an Undergraduate Bioinformatics Course at BITS Pilani

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ABSTRACT

Critical thinking, communication, collaboration, creativity, and problem-solving skills are five essential attributes that ensure that students are well equipped in working under 21st-century challenges across research and practice settings. Despite their importance, only a few Biology Undergraduate courses have implemented these graduate skills fully or partially or tried to change their course structure to evaluate curriculum activities. The current study reports on implementing a hands-on tutorial programme designed to enhance students' active learning, collaboration, communication, and problem-solving skills of undergraduate biology students. The blending of collaborative and problem-based learning in the hands-on tutorial course was administered two subsequent years to 51(2019-20) and 75 (2020-21) third-year undergraduate students in Bioinformatics. The qualitative feedback of students revealed that students preferred this problem Based hands-on tutorial teaching style over the traditional lecture-based format. Also, the individual-specific problem approach generates interest, engagement, and positive experiences among the students. The assessment of such pedagogical intervention was evaluated by the quality and novelty of the students' manuscripts or end semester reports and their respective feedback about their perception of this new intervention. The findings also suggest that the development of collaborative, problem-based actively engaged the students in the hands-on sessions, which helped them gain much-needed practical experience by getting exposed to various tools and databases. These hands-on sessions allowed students to acquire the required graduate skills to achieve learning outcomes and complete their end-semester project. The results also revealed that students rated hands-on experiences as coherent and well-structured as it has a rationale that helped them understand the theory better.

Keywords
Problem-based learning; Collaborative learning; Hands-on tutorial; Bioinformatics; Experiential based learning

Sub-theme(s) as per the conference:

Innovative Pedagogical Practices	**Y**

Introduction

Bioinformatics is a computational form of biology that deals with macromolecules by applying "informatics" techniques to understand and organize the information associated with these molecules on a large scale (Luscombe et al., 2001). In India, bioinformatics education research is in continuous progress that involves the creation of bioinformatics centers, training human resources, consortium projects, participation in international sequencing projects, and the development of tools (Som et al., 2019). The current undergraduate course in biology often lacks bioinformatics skills that are required for 21st-century employment opportunities. There is also a need to fill the gap between theory and practice in bioinformatics education at different educational levels (Attwood et al., 2019). To overcome this challenge, we need to develop hands-on modules that teach the student about the necessary skills of bioinformatics and help them learn and apply those skills in real-world problems like genome annotation, drug designing, etc. These hands-on based sessions will allow students to learn how to assemble, annotate, and analyze next-generation sequencing data and get meaning out of it. Various studies have shown if students are engaged in active learning. They can retain more and get motivated enough to pursue their studies further at the higher or postgraduate level. The key ingredients for active learning modules are experimental design, collaborative effort, hands-on experiments, hypothesis generation, and real-life scientific questions. Students' achievements can be evaluated by their reports describing the evidence for the candidates' involvement. Collaborative learning also has specific multi-student characteristics that promote peer interactions and enhance the learning performance of students. An effective collaborative-learning technique provides active learning opportunities, motivates students to solve problems in groups, and makes them more confident. Collaborative learning is better than conventional methods that only focus on cognitive and psychomotor aspects rather than peer learning, communication, teamwork, and student engagement. Cooperative or collaborative Learning in an online course also promotes active engagement of students (via interactions or discussions) that are helpful in the development of problem-solving skills. These student-centered interactions lead to sharing of ideas, promotion of discussions, negotiations, and opinion exchanges that are helpful in the improvement of foundational knowledge, i.e., remembering and understanding, along with the building of critical thinking skills among students. Problem-based learning's primary goal is to strengthen the students regarding problem identification, analysis, formulation and solving, and development of four essential skills, i.e., communication, corporation or collaboration, critical thinking, and creativity. There are significant benefits of using Problem Based Learning in hands-on tutorials as it is helpful for students to acquire independent knowledge, skills, and competencies at an advanced level (Higher-Order Cognitive Skills) (Jailani et al., 2017). Problem-based learning encourages students to cooperate and authentic solve real-world or professional, or scientific problems (Costa-Silva et al., 2018). Problem-based learning also develops students' creative abilities and prepares them for the labor market (Anazifa & Djukri, 2017). It also ensures the interaction of the student with its instructor (i.e., rapport). Problem Based Learning works quite well when it integrates with small group strategies like cooperative or collaborative learning. Problem Based learning promotes small group activities as it leads to knowledge sharing, academic discussions, collective decision making, mutual critical feedback, and action coordination among the group members (Sugiharto et al., 2019). Problem Based Learning also promotes students to become self-directed learners as students are responsible for their learning achievements. This self-reflection plays an essential role in students' academics as they can see their own work efforts and basic knowledge of a given problem or experiment. The student also feels responsible for their corporation in the group activity and the learning process that help him to understand the course and its outcome.

Literature Review

Bioinformatics education is still in the initial phase of becoming an established scientific discipline. Sczyeba et al. introduced a hands-on bioinformatics course at the University of Bielefeld for second-year undergraduate students, where they showed that using an online platform improves students' learning and promotes rapport between students and instructors (Sczyrba et al., 2008). A semi-qualitative study was conducted in a bioinformatics laboratory-based research project using pre-and post-module quizzes, which incorporated process and content-specific questions. The study showed increased students' engagement, practical bioinformatics skills, and process-specific knowledge (Brown, 2016). Another study found that structured collaborative learning, i.e., Team-Based Learning (TBL), effectively enhances student engagement and learning and promotes communication and teamwork (Vlachopoulos et al., 2020). Cooperative-based learning was implemented by Kumar et al. in a system biology course at The University of Michigan, Ann Arbor. The result of the study showed a positive impact of joint exercises in student learning (Kumar, 2005). A flipped teaching style was conducted as an Integrated group-centered problem-based learning (PBL) by Davies et al. for master students. The result of semi-structured interviews showed the effectiveness and likeliness of problem-based learning (PBL) as compared to traditional teaching (Davies et al., 2019). Another problem-based learning was performed by Lim et al. using e-learning bioinformatics tools for second and third-year undergraduate bioinformatics courses at the National University of Singapore. The survey results showed that sixty-three percent of students of the third year and ninety percent of students second year agreed about the usefulness of this pedagogical intervention and positively impacted the learning process (Lim et al., 2009). An Application-centered project-based learning was conducted in the bioinformatics training course by Emery et al. to determine engagement, active thinking, interaction, and discussion among the students. The results showed increased class participation, higher satisfaction, and greater awareness of Bioinformatics resources among the students (Emery & Morgan, 2017).

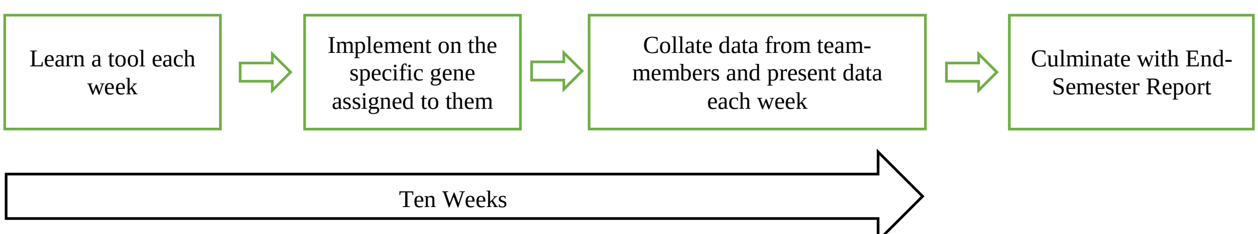
Methodology

In a modification to the earlier offering of the course *BIO F242*, instead of having three lecture classes and one tutorial hour, we had scheduled two lecture hours and a tutorial-cum-practical session of two hours per week. Right at the beginning of the semester, each student was assigned to work on a unique gene, on which he/she had to perform the analysis based on the bioinformatics tool taught that particular week (see Table 1 below). Each hands-on session began with a live demo of the tool by the instructor, following which students had to implement it on the gene assigned to them.

Table 1 List of weekly experiments and their basic learning outcomes

Sessions	Learning Activity	Learning Outcomes
1	Investigation of gene variants from the available database and basic information about Python	Capturing the basic understanding of the problem of the gene sequence and improve existing bioinformatics platforms.
2-4	Use Python libraries and other bioinformatics tools to locate genes, transcripts, start, stop codons, TFBs, ORFs, etc.	Analysis of gene sequence data and prediction of the possible protein sequence to infer its function.
5-6	Sequence alignments, i.e., pairwise and multiple using Dynamic Programming, BLAST, CLUSTAL-W for finding out homologous sequence, conserved domains in different gene sequence variants.	They are gaining familiarity with alignment tools and algorithms, i.e., predicting the function and consensus of the gene sequence.
7-8	Use of Phylogenetic analysis algorithms to find out the origin of the gene and generate an optimal tree	Prediction of the origin of the disease, including orthologs, and paralogs, and indicating the recent recipient of the mutated gene.
9-10	Use of various algorithms and tools to analyze consensus data of protein sequence to predict the secondary and tertiary structure of proteins and visualize the active site within the protein structure	To gain familiarity with structural aspects of the protein, and to be able to design ligands to block or minimize the activity of protein

Additionally, in the 2020-21 offering of the course, students were grouped based on the gene assigned, but with each member of a group working on the same gene, but of a different organism (ortholog). Each week, students had to compare the results obtained by each group member for the same gene and present the comparative analysis at the beginning of the hands-on session.



The course culminated with an end-semester report collating and presenting the results obtained each week. Student learning experience was assessed through a survey taken at the end of the semester.

Analysis

Our study demonstrates the impact of problem-centered pedagogical interventions or practices on students in the bioinformatics course. Through these interventions, students actively participated in the hands-on tutorial sessions. The students contributed towards end-semester assignment submission, but they generated lots of information in the end-semester report that can be utilized further for higher-order research like drug designing and pipeline. For instance, one group submitted an assignment on Comparative analysis of CLK2 gene sequence in Rhesus Monkey, House Mouse, Dog, Human, Cattle, Rat. The conclusion of their work showed that %GC was similar across the organisms. The results also revealed no role of CDS in the function of the CLK2 gene because it is not conserved across the organisms. In the case of poly-A tail regions, isochores and segments were conserved across species, playing a vital role. The length of the protein-coding region was approximately equal and found in the positive frame of ORFs among all the species. The Global and local alignment of the nucleotide sequences gave Human, Dog, and Rhesus Monkey similar species that also correlate with phylogeny results. The sequence alignment using BLASTn and BLASTp revealed the conserved genes of Rhesus Monkey, dog, and Human and Rhesus Monkey and Dog, respectively. The phylogenetic results reveal that humans and rhesus monkeys are closely related. In the end, the secondary structure of proteins showed that alpha helices, beta sheets, and turns and coils are crucial for protein function and found to be constant across the species. The experiments that the group performed revealed a close relationship between Rhesus Monkey and humans. A survey was conducted after completing the course in 2019-20 and 2020-21. Nearly seventy-six and eighty-one percent of students have given their feedback to the open-ended and Likert scale question for the year 2019-20 and 2020-21, respectively

Parameter	**Mean student rating for the 2019-20 offering**	**Mean student rating for the 2020-21 offering**
How well was the problem integrated and aligned with the course contents	4.4	3.84
Personal rapport between the instructor and students	4.28	3.82
Clarity of instructions and planning of the experiment	4.36	4.03
Usefulness of the experiment handouts and video demo	3.92	4.4
Were online sessions (post-Covid) as effective as face-to-face sessions?	3.77	2.9
Overall rating of PBL based hands-on tutorial class	4.23	3.82
Should the same model be continued in the future?	4.67	4.17

Discussion

Bioinformatics has an interdisciplinary nature, so the current study adopts innovative teaching approaches to meet the needs of biology education. Problem-based learning serves two aspects; first, it provides technical expertise to achieve research outcomes. Second, it provides learning opportunities, induces collaboration, promotes division of work, generates a sense of accountability and responsibility. Problem-based learning is in complete alignment with the Taxonomy of Significant Learning, as it is covering major domains like foundational knowledge, application, caring, and human dimension. In addition, collaborative learning intervention encourages communication, collaboration, and simultaneous reporting among teammates and groupmates. In this study, we report results of implementing problem-based learning (PBL), with and without collaborative learning in two successive batches of students who took their first bioinformatics course as part of their master's degree program. For the 2019-20 batch of 51 students, there was no collaborative activity conducted, while in 2020-21, the PBL was combined with a small group activity for the seventy-five students registered in the course. The results analysis showed an increase in class participation of seventy-six percent in 2019-20 and a fourteen percent increase with eighty-seven percent in 2020-21. Our findings indicate that our students preferred the Problem Based hands-on tutorial teaching style over the traditional lecture-based format. Also, the individual-specific problem approach generates interest, engagement, and positive experiences among the students.

Conclusion, Limitations, and Future Studies

Our study demonstrates the effectiveness of two pedagogical interventions on student learning and class participation in a third-year undergraduate bioinformatics course. Students have given very high ratings to the problems given during the tutorial sessions, demo videos, or experimental sheets for better learning, planning of hands-on sessions, and the personal rapport with the instructor over post covid sessions held online and level of engagement in collaborative learning. This study also highlights that students rated demo worksheets or videos as a strong determinant for enhanced learning, performance, and motivation for study. The average participation of students in 2020-21 was found to be fourteen percent higher than 2019-20. We also have found that students felt lab assignments and end semester reports were a kind of hectic job for them as they think burdened doing the same task with their group mates. In the future, we are thinking of restructuring the hands-on session by the inclusion of a more flip mode of teaching by using more demo sheets or video, which students have rated highest. This change may help students get more time to collaborate during hands-on session hours, clear their doubts, and perform the assignment on the same day.

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