

Designing Open-Ended Experiments by Integrating Courses: An Experience

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Abstract: Integration in teaching and learning approach is required due to increasing use of emergent technologies in research and industry. Integration learning helps students to visualize exact picture of industry. In case of Bachelor of Engineering in Biotechnology, integration of subjects and labs increases their knowledge and get the whole process of bio production. The present work synthesizes the outcomes of integrated learning in Downstream Process Technology lab (DSPT lab) and Bioprocess Engineering lab. Open-ended experiment was given to seventh semester students and anticipated to use the knowledge of bioprocess engineering lab and DSPT lab to complete the task. Open-ended experiment illustrates the flow of processes in Bioprocess industry which involves production of proteins and metabolites. As a result students could relate and use the knowledge learnt in each other lab to complete the task. Performance of the students was assessed as per Accreditation Board for Engineering and Technology's (ABET) 3b & 3g criteria.

3b- Design and conduct experiment

3g- Communicate effectively

Keywords: Integrated learning, DSPT lab, Bioprocess Engineering lab, Open ended experiment

Introduction:

An open-ended lab is where students are given the freedom to develop their own experiments, instead of merely following the already set guidelines from a lab manual or elsewhere. Making labs open-ended pushes students to think for themselves and think harder. Open-ended laboratory classes can be broadly defined as classes where the students are encouraged to design their own experiments or devise their own experimental strategy, rather than required to follow a rigid set of experimental guidelines specified elsewhere as in a lab manual. The students here have to devise their own strategies and back them with explanations, theory and logical justification [Strategies for Effective Teaching]. This not only encourages students to come up with their experiments, but requires them to defend themselves and their experiment, if questioned. It is an important topic based on emergent technologies. In our perspective its use in education is essential because everyone will involve in this activity. In this study openended experiment is performed in Downstream Process Technology Laboratory (DSPT lab). Students of seventh semester who performed this activity have studied Bioprocess Engineering and Downstream Process Technology theory. Even they have Bioprocess Laboratory this semester. DSPT lab involves processes that concentrate the end product of fermentation. In order to make students understand the activities involved in Bioprocess industry, we decided to combine Bioprocess lab and DSPT lab and give openended experiment in DSPT lab. We are proposing an effective assessment strategy to measure the effectiveness of open-ended on 3b and 3g ABET criteria. [2] [6] [7]

Methodology:

Team Formation: For seventh semester students batches were being made prior to start of semester, like batch1, batch2, batch3 and batch4. Bioprocess Engineering lab and DSPT lab were being carried out in these batches. Same

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batches were being formed while giving the open ended topic. They were being informed to carry out the experiment in these batches. Each batch consisted of 12 students. Each and every student of the batch has to work on achieving the goal of solving the open-ended task.

Open-ended Task: Student batches were given the task to produce and purify lipase enzyme from *Bacillus* species. The batches were sanctioned complete freedom in choosing the equipment, experimental parameters, and the data analysis methods. We acted as consultants, giving hints and suggestion. As expected, students faced many problems forcing the students to come out with innovative means to solve the problem. For example, how to purify the end product and analyze it.

Methodology for Assessment: Students were given with task of performing an experiment to meet the objective. Rubrics for assessment were made in order to assign marks for individual students of the group. Rubrics were designed in such a way that it addresses both the criteria i.e b and g. the rubrics for assessment is as shown below [6]

PIs	Exceptional - 75-100%	Acceptable 50-74%	Marginal 0- 49%
Select appropriate equipment & tools to meet desired needs OE (b) -1B	All materials and the setup used in the experiment are clearly and accurately listed	Most of the materials and the setup used in the experiment are accurately listed	Many materials are listed inaccurately
Use laboratory instruments following Standard Operating Procedure (SOP). OE (b) -2A	Procedures are listed in clear steps; each step is numbered and in a complete sentence; the experiment could be easily replicated based on the procedures provided	Procedures are listed, but seem to be missing some information that would allow one to successfully replicate the experiment; some steps are not numbered and/or are in incomplete sentences	Procedures do not accurately list the steps of the experiment
Record the data in the required format OE (b) -2C	Lab report is typed/written using the appropriate format specified	Lab report is mostly typed/written using the appropriate format, but revisions are necessary	Lab report is not typed/written using the appropriate format

Ability to write laboratory reports, including figures, tables and graphs OE (g) -1B	Professional looking and accurate representation of the data in tables, graphs, and written form; graphs and tables are appropriately labeled and titled	Accurate representation of the data in two of the three possible forms (written, graphs, tables); graphs or tables are not appropriately labeled and titled, something is missing	Data are inaccurate and/or represented in only one of the three possible forms (written, graph, tables), a lot is missing
Verify and conclude experimental results OE (b) -3D	Conclusion includes a summary of the experiment, whether the findings supported the hypothesis, possible sources of error, and what was learned from the experiment	Conclusion includes a general overview of the experiment and what was learned from the experiment; something is missing	Conclusion shows little effort and reflection, a lot is missing

Table1: Rubrics for assessment of students

Depending on the work and report of each student marks were allotted based on the rubrics in the above table.

Results and Discussion:

Students were given with the task and analysis of their work was a task for us, which we performed using ABET a-k criteria. Experiment which our students performed was addressing b and g criteria of ABET where b stands for ability to design and conduct experiments, analyze and interpret data and g stands for ability to communicate effectively. We analyzed the results

Student USN	OE (b) - 1B	OE (b) - 2A	OE (b) - 2C	OE (b) - 3D	OE (g) - 1B	Total
2BV09BT01 6	2	3	2	2	3	12
2BV09BT02 7	4	3	3	3	3	16
2BV10BT01 5	2	2	2	2	2	10
2BV11BT00 1	2	2	2	2	2	10
2BV11BT00 4	4	4	4	4	4	20
2BV11BT00 5	3	4	3	4	4	18

2BV11BT006	4	4	4	4	3	19
2BV11BT007	4	4	3	3	3	17
2BV11BT008	3	4	4	3	3	17
2BV11BT010	4	3	4	4	4	19
2BV11BT011	4	3	3	4	4	18
2BV11BT012	4	4	3	4	4	19
2BV11BT014	3	3	4	3	4	17
2BV11BT015	3	3	4	3	4	17
2BV11BT016	3	3	4	4	4	18
2BV11BT017	3	3	4	4	4	18
2BV11BT018	3	3	4	4	4	18
2BV11BT019	3	3	4	4	4	18
2BV11BT020	3	3	4	4	4	18
2BV11BT021	3	3	4	3	4	17
2BV11BT022	4	4	4	3	4	19
2BV11BT025	3	3	4	3	4	17
2BV11BT026	3	3	4	3	4	17
2BV11BT029	3	3	4	3	4	17
2BV11BT031	3	3	4	3	4	17
2BV11BT032	3	3	4	3	4	17
2BV11BT035	3	3	4	3	4	17
2BV11BT037	3	3	4	3	4	17
2BV11BT039	3	3	3	3	4	16
2BV11BT041	3	3	4	3	4	17
2BV11BT042	2	2	3	2	3	12
2BV11BT044	3	3	4	3	4	17
2BV11BT045	3	3	4	3	4	17
2BV11BT046	3	3	3	3	4	16

2BV11BT047	3	3	3	3	4	16
2BV11BT049	3	3	4	3	4	17
2BV11BT051	2	2	3	3	3	13
2BV11BT052	3	3	3	3	4	16
2BV11BT053	3	3	3	3	4	16
2BV11BT054	4	3	4	4	4	19
2BV11BT055	3	3	3	3	4	16
2BV11BT058	3	3	3	3	4	16
2BV11BT059	3	3	3	3	4	16
2BV11BT061	4	4	3	4	4	19
2BV11BT062	3	3	3	3	4	16
Total	140	139	157	144	169	
Average	3.11	3.08	3.48	3.2	3.75	16.64
	1	8	8	4	5	4

Table 2: Marks obtained by individual student for each PI

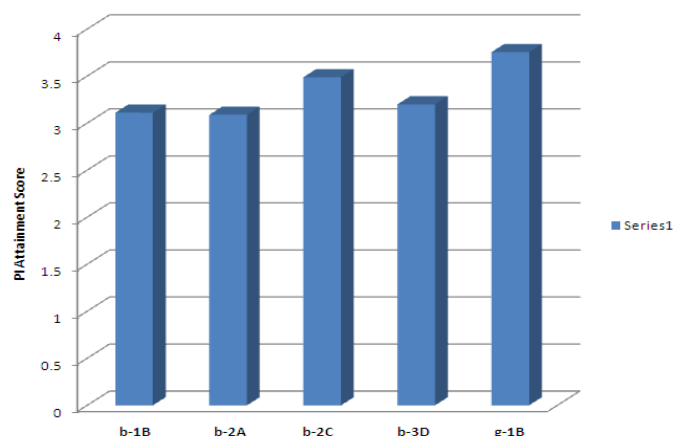


Figure 1: Score obtained for PIs in consideration

Students were able to perform the open-ended experiment by selecting appropriate equipments and tools to meet the desired needs of the task and were also able to follow correct operating procedures. From this open-ended experiment students were able to connect the relation between Fermentation technology laboratory to that of Downstream Process Technology laboratory. This helps students to understand the flow of Bioprocess Engineering.

Students were assessed based on ABET's 3b criteria, where students were assessed and attainment on

criteria 3b was done in order to check the understanding of students and criteria 3b was assessed using the above rubrics and attainment was found to be 8.25% out of 10%. The attainment was found to be satisfactory.

Students were assessed based on ABET's 3g criteria, where students were assessed and attainment on criteria 3g was done in order to check how students write their report and conclude the results and criteria 3g was assessed using the above rubrics and attainment was found to be 9.35% out of 10%, which was excellent.

At the end students were made to share the results with other groups in order to check their results. This will make students to come to know which downstream method has given accurate results and it was found that Ultrafiltration used to purify the enzyme provided better results compared to other downstream methods. Authors find that handling big teams (More number of students in a group) is a challenge for assessment and hence in future more groups with less number of students in each group can be formed for open-ended experiments.

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