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An Integrated Pedagogical Approach for Effective Teaching of Research Methodology for Biotechnology Engineering

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Abstract : Research Methodology is a systematic, theoretical analysis of the methods applied to a field of study, which comprises the body of various techniques. The course assumes significance from the Biotechnology perspective, since the domain is research centric. The objective of the course is to give an insight into the nuances of research methods to facilitate the students in the handling of Mini, Minor, Capstone and REU projects at higher level semesters. The course poses a challenge from the teaching-learning perspective owing to its heterogeneous content of the chapters. In order to address this question of overcoming the challenge of learning the course with heterogeneity and provide meaningful learning, the present study with an integrated approach was practiced for undergraduate students of Biotechnology for enhancing the effectiveness of learning. Various in-classroom activities and online tools were undertaken to give hands-on learning experience. The active learning techniques employed were instrumental in keeping the students engaged while enhancing the effectiveness of learning in a course with diverse contents, which otherwise would have been difficult by conventional rote teaching methods. The exercise resulted in addressing different graduate attributes related to demonstration of competence in mathematical modeling, basic science, comprehend technical literature, use modern engineering tools and understand the philosophy of research methodology, with a decent scale of attainment. It is concluded that an integrated approach with multipronged activities can lead to effective learning. Further scope for the study exists in the form of fine-tuning of activities in terms of better assessment and widening the horizons of the concepts dealt with.

Keywords: Research Methodology, Active learning, Teaching-learning.

1. Introduction

Research is a logical and systematic search for new and useful information on a particular topic. Research Methodology is a systematic study about research which involves the strategies adopted for undertaking research and predicting the underlying phenomena. It is a composite of philosophies, ideals, hypothesis and foundations that drive the methods. It explains how research is carried out. It differs from Research Methods which entails the theoretical procedures, sample collection, experimental studies, and numerical schemes statistical approaches.

It is generally observed that students at various levels (graduate and under-graduate) find Research Methodology as a difficult and challenging course to study. The present paper is a reflection of the various

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active learning practices adopted to enhance the learning of the concepts which has culminated into a presentable form.

Similar approaches of student-centered activities have been successfully implemented which facilitated the students with an experiential learning [1,2]. Lundahl [3] reports of teaching research methodology through active learning mode. Benson et al. [4] made an attempt to redesign the curriculum of Research Methodology course to enhance the learning process through activity-based learning approach . Project-based learning [5] and problem-based learning [6] practiced in research methods course was found to improve the performance in course and benefit the students significantly. The learner-focused pedagogies are important so as to keep the students engaged and at the same time impart learning outcomes. The active learning has been proved to be a successful pedagogical approach in the classroom as it keeps the students' cognitive thinking involved during the learning process [8]. Many universities are adopting these paradigm shifts in the educational field such as, science, technology, engineering, mathematics etc. Active learning as an educational methodology is reviewed and presented as one of the best pedagogical practices [9].

In view of this, teaching framework for research methodology has been well designed with active learning set of resources and assessment for effective learning. Studies have experimentally investigated the successful impact of the design of effective interactions using pedagogical conversational agents in student-centric learning environment [10].

The exercise was carried out in Research Methodology course for undergraduate students of Biotechnology.

2. Objective and Challenges of Research Methodology as a Course

Research of late has become an integral part of academic programs owing to the need for continuously improving the existing processes and products. The objective of introducing the Research Methodology course was to give an insight of nuances of a typical research. The course was incorporated in the middle of the graduate program (V Semester) to enable the students to adopt and implement the concepts learnt, for their academic projects (Mini, Minor and Capstone projects) during their subsequent higher semesters.

The pre-requisites of the Research Methodology course were a modest knowledge of Biotechnology domain, basics of statistics and skill for technical writing.

Research Methodology as a course posed several challenges from teacher and student perspective in terms of teaching and learning [7]. The contents of the course across the chapters were heterogeneous in nature and therefore demanded different methods of teaching. The initial chapters of the course, fundamental to understanding of the course were theoretical and subtly ambiguous in terms of concepts to be taught. Another challenge perceived during the handling of the course was to apprise the relevance and applications of the concepts in research and report writing. There was every possibility of the students treating the course as stand-alone without applying the concepts intended for projects in the ensuing semesters.

3. Methods

3.1. Design of the Activities:

The various activities designed were spread across the different chapters of the course and were undertaken by either individual student or in small groups (of four members).

The following table (Table 1) outlines the different activities practiced during the delivery of the course.

Table 1. Chapters of the Course and Corresponding Activities Undertaken.

Sl. No.	Chapters	Activity
1	Introduction to Research and Research Methodology	• Collecting the different titles of research articles and classifying them into different types of research.
2	Research Philosophy and Formulation of Research Problem	• Formulating a research problem statement following different sequential steps.
3	Sources and Review of Literature	• Collecting the hard copies of different types of research literature. • Numerical calculation of Bibliometric parameters (Impact factor and H factor)

4	Sampling & Data Analysis	• Data interpretation
5	Statistical Analysis of Data	• Statistical Analysis of research data by using Minitab
6	Design of Experiments	• Design experimental matrix using Minitab
7	Research Communication	• Review of papers for IMRAD parameters. • Drafting of review article • Use of software tool for referencing
8	Environment, Ethics and IPR in research.	• Use of software tool for plagiarism. • Image-based quiz for identifying different IPR

3.2. Implementation of the Activities:

Activity 1. Identifying the type of research.

The objective of the activity was to percolate the concepts of different types of research (Fundamental & Applied; Qualitative & Quantitative; Descriptive and Analytical) by identifying the research articles that best explained them.

The activity was individual student-based and comprised of selectively collecting the titles of research articles from journals, aligning with different types of research followed by explanation. This helped in applying the concepts of types of research by mapping them to the different titles collected.

Following is an illustration of the activity:

The activity helped the students in deeper understanding of the various types of research.

Activity 2. Formulating a research problem statement.

The aim of the activity was to engage the students in formulating a research problem statement by themselves in group.

The four sequential steps in formulating a research problem statement (Statement of the problem in a general way, understanding the nature of the problem, literature survey, developing the ideas through discussion and rephrasing the problem statement into a working proposition) were practiced by the students in group.

The activity gave a first-hand feel of formulating and refining research problem to arrive at a statement.

Activity 3. Sources of literature

The aim of the activity was to complement the theoretical notions of the different types of research communications by a simple practice.

The students were to collect the different types of research communications which included original research articles, review articles, short communications, books and popular science articles.

This helped the students in knowing the sources of various research communications and selectively differentiating among them.

Activity 4. Numerical calculation of bibliometric parameters .

The aim of the activity was to introduce the bibliometric parameters and method of calculating them.

The bibliometric parameters- Impact factor and H- factor were calculated with numerical problems.

Calculation of the parameters helped in understanding the qualitative and quantitative aspects of the terminologies.

Activity 5. Interpretation of results based on data.-

The objective of the activity was to make the students apply their domain knowledge to interpret the results presented in the research article and derive concrete conclusions based on the outcomes of the experiments conducted.

The group-based exercise involved the students to analyze and interpret the results from the excerpts of selected research articles related to Biotechnology.

This helped in honing the analysis and interpretation skills of the students which is significant from research perspective.

Activity 6. Statistical Analysis of research data using Minitab.

The objective of the activity was to acquaint the students to use Minitab software for statistical analysis of research data.

The students used the tool to design the experimental matrix, insert the yield values, examine the Pareto charts, ANOVA, significant effect plots, interaction plots and Response plots .

The activity resulted in giving an insight of the working knowledge of Design of Experiments and its applications in optimization of Biotechnology related processes involving multiple parameters.

Activity 7- Review of papers for IMRAD parameters.

The purpose of the activity was to apprise the students of the various constituents and their expected contents of an ideal research article.

The students were made to choose a research article of their interest and a template containing details to be filled-up was provided. The details sought were Title of the article, name of the journal, volume , issue, first author, corresponding author and publisher. They were to critically analyze , if the article had Abstract, Introduction, Materials & Methods, Results & Discussion, Acknowledgment and References sections with relevant contents.

The activity was instrumental in comprehending the various constituents and dimensions of a typical research article.

Activity 8. Drafting a review article

The aim of the activity was to give a hands-on experience of writing an article.

The students collected a bunch of research articles related to a topic and made a blue-print for a review article by articulating key subtitles from different research articles collected. The subtitles were then elaborated for their contents and a draft of review article was written.

The exercise gave a first-hand experience of writing an article which involved reading, comprehending and rewriting in one's own words with logical flow of contents.

Activity 9. Image-based quiz for identifying different IPR

The goal of the activity was to drive home the concepts of different types of IPR's related to research.

A quiz with images reflecting different types of IPR (copyright, patents, trade-marks, geographical indicators and industrial design) was conducted. The students were to identify the type of IPR relevant to the image.

The activity enabled the students to recall the notion of different types of IPR.

Activity 10. Use of software tools for plagiarism and referencing.

The aim of the activity was to acquaint the students to plagiarism and its testing. The students were made to select a stretch of article content, edit it consciously and submit the edited version for plagiarism testing through open source tools like (http://smallseotools.com/). The activity gave an exposure to the concept of plagiarism, means of checking it and parameters involved in the process like uniqueness and source of plagiarized text.

Likewise, the students after being taught about the significance and method of arranging the references in a research article or report. The activity was tool-based and made use of open sources available (www.neilstoolbox.com/bibliography-creator). The activity introduced a smart way of reference arrangement which was hitherto performed manually, which was cumbersome and error-prone.. The activity comprised of selecting few random references and arranging all of them in a predefined uniform format.

3.3. Assessment of the activities:

The mode and means of assessment of the exercise varied according to the kind of activities undertaken. Quantitative rubrics-based assessment was practiced for all the activities (except for activities 2, 3 & 10) mentioned in the Table- 2. Activities 2, 3 & 10 were assessed qualitatively.

3.4. Attainment from the activities:

The activities undertaken were instrumental in attaining the various Graduate attributes, Competencies and Performance indicators as shown in Table 2 below.

A formal feedback to reflect upon the effectiveness of the exercise was undertaken with the following questions:

Tab 2. Activities Mapped with Graduate Attributes, Competencies and Performance Indicators

Sl. No.	Activity	Graduate Attribute	Competence	Performance Indicator
1	Identifying the type of research.	Engineering knowledge:	Demonstrate the competence in basic sciences	Apply laws of basic science to
2	Formulating a research problem statement	Conduct investigations of complex problems	Demonstrate ability to conduct investigations of technical issues	Define a problem to carry-out i nvestigation with its scope & importance.
3	Identify s ources of literature	Research aptitude	Demonstrate an understanding of philosophy of research methodology	Optimally use the sources of literature to review
4	Numerical calculation of bibliometric parameters .	Engineering knowledge:	Demonstrate the competence in mathematical modeling	Apply mathematical techniques to solve problems
5	Interpretation of results based on data	Conduct investigations of complex problems.	Demonstrate the ability to conduct investigations of technical issues	Correlate the experimental outcomes with underlying theoretical concepts and principles
6	Statistical Analysis of research data using Minitab.	Engineering knowledge	Demonstrate the competence in mathematical modelling.	Apply the concepts of statistics.
7	Review of papers for IMRAD parameters.	Communication	Demonstrate an ability to comprehend technical literature	Read, understand and interpret technical information
8	Drafting a review article	Research aptitude	Demonstrate an understanding of philosophy of research methodology.	Demonstrate an ability to draft scientific and technical report/paper.
9	Image-based quiz for identifying different IPR	Research aptitude	Demonstrate an understanding of IPR and ethics.	Demonstrate an ability to understand the concepts of IPR related to research.
10	Use of software tools for plagiarism an d referencing.	Modern tool usage	Demonstrate an ability to identify modern engineering tools	Identify modern engineering tools.

1. Did the exercise give a feel of experiential learning?.
2. Did the activities complemented the learning of the theory course content?.
3. Whether the technical support extended for performing the activity was satisfactory?.
4. Whether the implementation of the activities and assessment was planned and systematic?
5. Any other suggestions for further improving the exercise to enhance the effectiveness of teaching-learning process.

4. Results

The various individual learning activities undertaken resulted in extended learning of the concepts and addressing several graduate attributes, which would have been difficult to achieve by the conventional didactic approach. The quantitative attainment of the activities assessed ranged between 7 to 9.5 on a scale of 10 as shown in Fig.1.

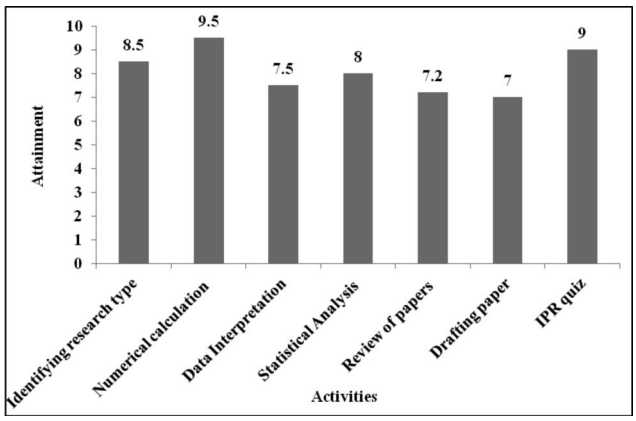

Figure.1. Quantitative attainment of activities (on a scale of 10).

The attainment of numerical calculation of bibliometric parameters was maximum as the concept was well understood. The students were able to perform calculations and correlate to its significance in the scientific domain. They were able to extrapolate the calculated data with the real time data available on the journal web home-page, thus making the understanding of the bibliometric parameters more meaningful. The image-based quiz conducted for identifying different IPR interested the students and resulted with an attainment of 9. The attainment of students' learning with respect to identifying the research type was 8.5, wherein the students were able to read and articulate the type of research conduct in the research paper. Statistical analysis of data using Minitab software provided experiential learning with an attainment of 8. Here, the students were able to create the Design of experiments (DOE) matrix, substitute the empirical data and correlate the statistical significance of the obtained response using the software tools. This experience enabled them to connect the statistical data to real-time biotechnological processes. Interpretation of results based on data showed an attainment of 7. 5, which reflected their ability to understand the complex problems and their interpretation by applying the domain knowledge. The activity involving the review of papers for IMRAD parameters and drafting of a review article showed an attainment of 7.2 and 7.0 respectively, indicating the ability of challenge in reading, assimilating and drafting the review article at an undergraduate level. Overall, an average attainment of all the activities was 8.1 on a scale of 10. However, three activities (2,3 & 10) were assessed qualitatively. Formulation a research problem statement needs the understanding of the problem through literature and identifying the gaps. This activity demands quality time, as the student needs to read between the lines of the paper assigned. Use of software tools for plagiarism and referencing gave a hands-on experience of using the freely available open source tools to reference the papers and check the quantum of data for plagiarism. This reinforced the concept of ethical practices in the scientific community.

The consolidated outcome of the feedback collected revealed that, the exercise gave them a feel of experiential learning, were satisfied with the technical support for performing the activities and the assessment methods followed. Few opined that providing template worksheets for the activities would streamline the activities across the groups and would make it more structured for implementation and assessment.

5. Conclusion

The integrated student-centric pedagogical practices provided an opportunity for creative teaching-learning process. The continuous mode of engaging the students through active-learning resulted in enhanced knowledge of the subject. It is concluded that, an integrated approach with multipronged activities can lead to effective learning. However, further scope for improvement in the study exists in the form designing template worksheets for the activities and their fine-tuning in terms of better assessment and widening the horizons of the concepts dealt with.

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