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Redesigning Laboratory Courses in Information Technology Program: An Inquiry Based Learning Approach

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***Abstract*—Laboratory courses in Information Technology programs are pivotal for hands-on learning and skill development. They prepare students for real-world applications, nurture critical thinking and teamwork, and offer practical problem-solving experiences. These courses bridge the gap between theory and practice, helping students become industry-ready and ethical technology professionals. However, challenges in the conduct of laboratory courses include limited access to resources like computers and software, maintaining up-to-date content in a rapidly evolving field, addressing diverse student backgrounds and abilities, preventing plagiarism and cheating, and managing large class sizes efficiently. These challenges can impact the quality of hands-on learning, require effective teaching strategies, and demand careful planning and adaptation to ensure a productive learning environment. Inquiry-based learning (IBL) is an educational approach that centers on active student engagement and exploration. It involves students posing questions, problems, or scenarios and then actively seeking answers or solutions through research, investigation, and critical thinking. Inquiry based learning, when implemented in lab courses promises to promote connection to the real-world problems, problem solving skills and application of engineering knowledge to solve complex problems. In this paper, a hybrid inquiry based approach is adapted for the conduct of three laboratory courses in B.Tech Information Technology Program. The implementation was experimented over different batches of around 390 students. The proposed approach resulted in significant improvement of the attainment of course outcomes. It also had profound impact on the transferable skills of the learners such as critical thinking, problem solving skills, attention to detail and management skills. The impact of the proposed approach is measured and the quantitative results demonstrate the effectiveness of the proposed instructional design.**

***Keywords*— Cloud Computing Lab;Computer Networks Lab; DBMS Lab;Design of Experiments; Inquiry based learning**

***JEET Category*—Practice**

I. INTRODUCTION

LABORATORY is a crucial element within the realm of engineering education. Laboratory courses facilitate the development of abilities, such as effective communication and acquisition of knowledge, teamwork, during lecture sessions facilitates a deeper comprehension of theoretical concepts among students.

There is no ambiguity in realizing the significance of laboratories in engineering education. All courses must be supported with lab modules as far as possible. However, conventional engineering laboratory strategies are not sufficient to meet course outcomes. It is very challenging to design laboratory courses which will motivate students to spend more time on experimentation and improve their learning. Inquiry-based learning (IBL) is an educational approach that emphasizes the active engagement of students in the learning process through the exploration of questions and problems It is a pedagogical approach employed in engineering education with the aim of promoting active learning and fosters an environment that motivates students to engage in inquiry, explore complex issues, and provide effective resolutions, so augmenting their abilities in critical thinking and problem-solving. In the field of engineering, there are several manifestations of inquiry-based learning, including laboratory experiments, collaborative group projects, and comprehensive case studies. The approach is characterized by its versatility since it enables students to effectively utilize their theoretical knowledge in order to address practical engineering difficulties. This approach also recognizes the existence of diverse student backgrounds in terms of their prior experience with laboratory work and their individual expectations. Consequently, it emphasizes the importance of designing courses that can effectively accommodate and address these variations. Inquiry-based learning not only equips engineering students with practical problem-solving skills but also encourages a deeper

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understanding of the subject matter by involving them in active exploration and critical thinking

II. Related Works

There are a multitude of learning methodologies, which can be classified into many groups. Narrowing the focus to those approaches that closely align with inquiry-based learning, the following provides a summary of typical learning methods. Problem-based learning (PBL) is a constructivist educational method in which the primary objective is for students to engage in problem-solving activities. In this educational approach, the focus is on a particular problem and its corresponding context. Students engage in the process of determining the knowledge and skills necessary to address the problem effectively. PBL is typically centered on collaborative activities, wherein a community of learners offers support throughout the learning journey. This approach fosters critical analysis and the cultivation of effective problem-solving abilities, which are recognized as suitable learning objectives Savery and Duffy (1995). Bell (2010) is recognized for highlighting the importance of project-based learning, and subsequent research has expanded on its benefits and applications in modern education. In Project Based Learning, students typically work in small teams, tackling complex, authentic challenges and producing tangible artifacts. It helps students develop higher order thinking skills and fosters a meaningful and experiential approach to learning. PBL is characterized by its emphasis on active engagement, critical thinking, and the application of knowledge to practical situations.

Mohammad Habibi et.al (2016) explores the Pros and Cons of Laboratory Methods used in Engineering Education and conducted study with 5th year undergraduate student at the University of Wisconsin Platteville majoring in Electrical Engineering. The author insights different instructional methods implemented in engineering curricula - the cookbook, design-based, and proposal-based and proposes a method with right balance of all the three method such that students learn in depth concepts and practical skills that help them succeed academically. The cookbook technique involves presenting students with a series of sequential instructions, guiding them through the process of prototyping, conducting experiments, making observations, and drawing conclusions based on their observations. In the design-based approach, students are solely presented with specifications and requirements. Individuals are required to generate their own set of instructions in order to successfully execute the design. The proposal-based approach is students are mandated to formulate a project proposal, construct their own set of instructions, and afterwards undertake the development process and conducting experiments to evaluate the efficacy of their design. The major concerns of Proposal and design based are identified as the volume of work and unavailability of systematic grading for projects. From the survey, the authors concluded that students can be introduced to material by completing a cookbook project and can work into three to four design-based projects. At the end of the semester a proposal-based project can be used to encapsulate material learned throughout the course and provide students with a memorable experience.

Traditional laboratories cannot be converted into an inquiry-based activity labs by just removing the instructions. Designing the inquiry-based laboratory include meaningful possibilities for student inquiry, openness in experiments and discussions. Students acquire inquiry practices, when they were given opportunities to practice generating research questions, designing experiments, collecting and analyzing data, and drawing conclusions. Buck et al. (2008) emphasizes the need to move beyond traditional approaches and characterizes the possible level of inquiry in undergraduate laboratory courses.

Ali Abdi (2014) conducts study and compares the performance of two group of students, one group instructed through traditional approach and the other with inquiry based. To determine the effectiveness of inquiry-based learning method over traditional instruction, an achievement test which consisted of 30 items was administered as pre-test and post-test to students both in the experimental and control groups. The results showed that students who were instructed through inquiry-based learning were achieved higher score than the ones which were instructed through the traditional method. Hence the literature evidences the inquiry based learning approach can help to progress effectively.

Masha Smallhorn et al. (2015) show how inquiry-based learning improves engagement and learning results for large first-year biology cohort, redeveloping laboratories. Laboratory experiments were redesigned as guided inquiry, and educators helped student teams design and conduct them. Inquiry-based laboratories improve students' science attitudes, understanding, confidence, and attrition rates. The remodeling of first-year biology labs has had a significant impact on both. student happiness and outcomes. This highlights the shift to inquiry-based learning and the extra contact time in labs have boosted learning first-year biology student outcomes at Flinders University. These findings also stress the necessity of including undergraduate student-centered learning curriculum. Learning entails giving pupils chance to think and ask questions supported by evidence.

Emily Wiseman (2020) implements inquiry-based laboratory approaches as a substitute for conventional laboratory classes. To overcome the common practice to include a solitary inquiry-based exercise towards the conclusion of a conventional course, so limiting students' chances to engage in similar experiences prior to transitioning to subsequent courses. Here the authors have examined three iterations of inquiry-based experiments as part of a redesign process of developmental biology designed for advanced undergraduate students. In the investigation, students delivered slideshow presentations showcasing their respective initiatives and were subsequently provided with feedback from their peers and instructor. Subsequently, a grading rubric was devised and verified to evaluate students' utilization of scientific methodologies. Significant levels of student engagement were identified through anecdotal

evidence and replies obtained from student questionnaires. The level of interest and active participation exhibited by students in the course. In general, the findings of this study suggest that implementation of inquiry-based laboratories in several iterations is a highly promising approach for the instruction of scientific abilities, hence facilitating their enhancement.

In bio-medical research program (M.C. Morsink et.al (2021) facilitated Inquiry-based Laboratory Research Education using an innovative tool -Virtual Labstore. It provides students with access to a 3D online laboratory stockroom where they can explore available materials and purchase items for experiments. This approach aligns with inquiry-based learning, where students are encouraged to ask questions and actively engage in the learning process. It is observed that Virtual Labstore (External resource) supports Inquiry-based approach by providing a platform for students to explore, experiment, and learn in a digital environment. To implement Inquiry based learning, sufficient resources are required.

From the literature study, it could be inferred that there are some common challenges in conduct of the laboratory courses in Indian context and are given below:

- The approximate proportion of credits for laboratory courses excluding projects is only 15% in the engineering curriculum.
- Plagiarism and copying of codes is observed to a greater extent as the specifications of the experiments are same for all the learners.
- Minimal emphasis on adopting industry standards and professional practices is done due to limited contact hours.
- Assessment in psychomotor and affective domain is not given much importance.
- Product development as an outcome of a laboratory course has not been much concentrated.
- The disjointed list of experiments as specified in the curriculum has a limited focus in creating holistic learning experience.

In order to address the challenges, the proposed experimental study has adopted inquiry based instructional design for the conduct of three laboratory courses namely Computer Networks lab, Database Management lab and Cloud Computing lab. The effectiveness of the instructional design has been analyzed by measuring the impact on learning outcomes. Learner Satisfaction Index is assessed from the responses of course exit surveys

III. Research Questions

The motivation for the experimental study is supported by the following Research Questions:

RQ1: What are the considerations in the conduct of laboratory courses to promote inquiry based learning?

RQ2: What is the impact on instructional design based on inquiry based learning in enhancing learning outcomes of laboratory courses?

TABLE I
Levels of Openness in Inquiry

Levels	Problems	Methods & Tools used to solve	Solutions
Level 0	Given	Given	Given
Level 1	Given	Given	Open
Level 2	Given	Open	Open
Level 3	Open	Open	Open

RQ3: What is the impact of laboratory courses in enhancing the transferable skills of a graduating engineer?

IV. Considerations for Inquiry based Learning

Following are the considerations for designing the laboratory courses to promote inquiry among the learners.

- The cognitive level of attainment, the learners expected to attain
- Degree of inquiry to be implemented
- Resources and guidelines for the learners to carry out the inquiry
- Expected outcomes
- Formative feedback

TABLE II
Rubrics for Inquiry in Lab Courses

Deliverables	Guided Inquiry	Open Inquiry	Authentic Inquiry
Identification of Problem	Provided	Provided	Not Provided
Relevant Background	Provided	Provided	Not Provided
Design of Solution	Provided	Not Provided	Not Provided
Results & Inferences	Not Provided	Not Provided	Not Provided

- Rubrics for evaluation

The cognitive level of attainment plays an important role in determining the need and degree of inquiry implemented in a course's content delivery. Lower order thinking skills such as understanding a concept well and internalizing the same do not require inquiry-based tools. Skills at this level may very well be facilitated using well established techniques such as Feynman technique (The Feynman technique) and Leitner system. Lab

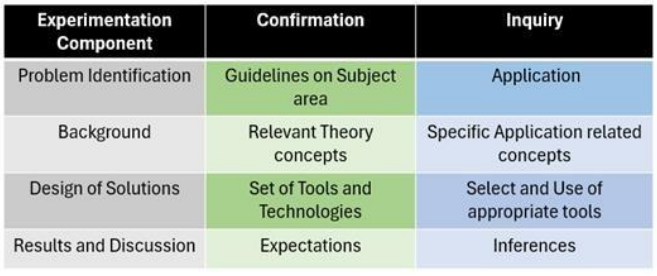

Fig. 1. Hybrid inquiry approach for lab courses

courses are often expected to impart and improve higher order thinking skills among the learners. Inquiry based instruction design would inherently support the attainment of higher order

thinking skills such as 'analyze' and 'evaluate'. However degree of inquiry needs to be assessed based on the cognitive level of attainment the learners expected to attain. Table 1 given defines the degree of inquiry employed in a course (Laura B Buck et al, 2008).

For experimentation in lab, Identification of problem, necessary theory background, design of solution, Results and deducing inferences from results are considered important.

Confirmation: Implementing CRUD operations on Databases.
Inquiry: Identifying suitable application areas in which implementation of CRUD operations is crucial.

Confirmation: Implementing node-to-node communication in a network
Inquiry: Identifying suitable network scenario for node-to-node communication

Fig. 2. Sample Confirmation and Inquiry for Problem Identification

Based on the solid references/guidelines given to carry out the above items, three levels of inquiry are defined (Laura B Buck et al 2008) as shown in the Table II.

In Indian Engineering education setup, authentic inquiry is found to be an appropriate approach for capstone projects. While guided inquiry provides little room for exploration, open inquiry provides very little information on the design of the solution to the learners. Also, Open inquiry requires solid guidelines for defining the problems. This restricts the exploration of the domain under study. Hence in this paper, hybrid inquiry approach as shown in the figure 1 is leveraged.

Confirmation: Theory relevant to creating a table, adding/updating/deleting a record.
Inquiry: Theory relevant to the identified application areas such as automating event management / automating patient registration for a healthcare application

Confirmation: Theory relevant to establishing node to node communication – fundamentals of socket programming
Inquiry: Theory relevant to the identified network scenarios such as simple chat application / content delivery network.

Fig. 3. Sample Confirmation and Inquiry for Background Theory

In this hybrid inquiry approach, guidelines regarding domain areas in which problem needs to be identified will be given to the learners. Implementing CRUD operations on databases, establishing node-to-node communication in computer networks and using cloud platforms as a service for application development are examples of subject areas. However, specific problems relevant to application of these domain areas will be left open for exploration. For example, identifying a suitable problem such as automating student registration for events in which implementation of CRUD operations on databases would be crucial is left to the exploration of learners. This is summarized in figure 2

The next component of experimentation is acquiring the necessary background knowledge for solving the problem identified. Necessary background knowledge relevant to the subject area will be given to the learners, whereas the background knowledge relevant to the application areas shall be left for exploration by the learners. A sample Confirmation and inquiry action items are shown in figure 3.

Confirmation: Databases such as MySQL, MongoDB, Oracle – Schema – Table properties - Connecting DB to an application – CRUD operations on DB
Inquiry: Selection of suitable database for the application chosen – Implementation of schema for the application – Development of Tables, identifying necessary Primary Key, foreign key, Design of Views and Joins

Confirmation: Socket Programming in C and Java, Transport layer Protocols such as TCP, UDP, RTP, Application layer protocols such as FTP, Telnet etc.,
Inquiry: Selection of suitable protocols for the application chosen – Implementation of client- server communication.

Fig. 4. Sample Confirmation and Inquiry for Design of Solutions

Design of solutions is the next important component of experimentation. In this component, guidelines are given in detail for the set of tools and technologies relevant to each of the subject areas chosen for problems. The learners are expected to make use of right tools and technologies to solve the problem chosen. An example is shown in figure 4. The last important step is the communication of results and deducing useful inferences. Expectations are given in detail to the learners and they are allowed to explore the results to produce meaningful insights. An example for results communication is given in figure 5.

Fig. 5. Sa

Thus the hybrid inquiry approach facilitates accomplishment of strong foundation knowledge required to carry out effective inquiry on the subject under study. Also, the hybrid approach provides opportunities for the learners to explore through the applications of the concepts learnt and experiment them deep and wide, enabling them to achieve higher order thinking skills.

Implementation of this hybrid approach on three different lab courses are described in the following section.

V. INSTRUCTIONAL DESIGN USING IBL

A. Cloud Computing Lab

Cloud computing lab course is offered to the students of VI semester. The course inherently requires the students to explore through the various use cases of Cloud computing. Incidentally, the Cloud computing course is taught along with courses such as Internet of Things, Machine learning and Mobile Application Development, Hence in the Cloud computing laboratory, students are given opportunities to explore through the various cloud services and platforms available to realize IoT and ML

applications. The objectives of the cloud computing lab course are set as follows:

- Students should be able to recognize tools, techniques and platforms available on cloud for developing, deploying and provisioning applications.
- Students should get familiar with the commercial cloud service providers such as AWS, Azure, IBM and Salesforce and their service offerings.

The course plan for the Cloud computing laboratory is designed based on the hybrid inquiry based approach. The design is presented in the table III below.

TABLE III
HYBRID INQUIRY APPROACH BASED LAB COURSE PLAN FOR CLOUD COMPUTING LAB

Experimentation Components	Confirmation	Inquiry
Problem Identification	○ Characteristics of cloud computing, ○ Need for Cloud computing	○ Real-world Problem areas which require cloud related tools and technologies to arrive at a solution
Background	○ Key Technology enablers of cloud computing ○ Cloud Services, and Other Cloud-based Platforms	○ Necessary cloud services and tools required for solving the problem chosen
Design of Solutions	○ Implementation of sample cloud services to add authentication, database, and storage to a sample application ○ Use-case on cloud platform for application development ○ Using cloud services for monitoring.	○ Selection of necessary cloud services for the chosen application ○ Identification of suitable cloud services from commercial cloud service providers ○ Implementation of the same
Results and Discussion	○ Three-tier application with authentication and storage realized with cloud offerings	○ Realizing the application that actually solves a real-world problem

B. Database Management Systems Lab

Database Management Systems Lab course is offered to IV semester students of IT department. This course aims to provide a strong foundation in database design concepts and to give adequate exposure to the SQL with the help of the Oracle RDBMS environment. It also deals with connecting the database to a programming language and thereby creating web application for real world scenarios. In Database Management Systems Lab, students were given opportunity to explore open source large datasets (Eg.Kaggle) and identify new insights that could deliver value for their stakeholders. The objectives of the course are as follows:

- Students should be able to design database with integrity constraints and appropriate normal forms
- Students should be able to implement SQL data model for a given application
- Students should be able to develop projects by incorporating database concepts with PHP connectivity.

TABLE IV
HYBRID INQUIRY APPROACH BASED LAB COURSE PLAN FOR DATABASE MANAGEMENT SYSTEMS LAB

Experimentation Components	Confirmation	Inquiry
Problem Identification	○ Various functionalities of DBMS. ○ Need for creating and maintaining databases for real world applications and emerging technologies in Databases	○ Real world scenarios that require database creation and maintenance
Background	○ Relational database principles ○ Relationships (how tables are related to each other, the role of foreign keys) ○ Basic SQL queries of the form	○ Necessary relations, tuples, attributes, primary keys, foreign keys and relations are identified for the chosen application
Design of solutions	○ Implementation database design with appropriate use of normalization techniques. ○ Case study on sample database design documents using tools ○ Sample document for database creation SQL queries	○ Selection of suitable tools for drawing schema diagram, ER diagrams for the chosen problem. ○ Creation of tables and retrieval of information using SQL queries.
Results and Dicussion	○ Web application incorporating database concepts with PHP ○ connectivity	○ Realizing the application that actually solves the problem

Team Name	Student details	Application details	Dataset used
GREEN TRENDS	Student 1 Student 2 Student 3	Agriculture Management System	Crop recommendation dataset https://www.kaggle.com/datasets/?siddharthss/crop-recommendation-dataset?resource=download&select=Crop_recommendation.csv
THE CRUDS	Student 1 Student 2 Student 3	Assemblage management system	Railway schedule in India https://drive.google.com/drive/folders/1F07vd1_AYSEl5aZCZAXIwUCwcnsYchEC?usp=sharing

Fig. 6. Sample applications and real world application data.

The course plan of is designed on Hybrid Inquiry based approach and presented in Table IV.

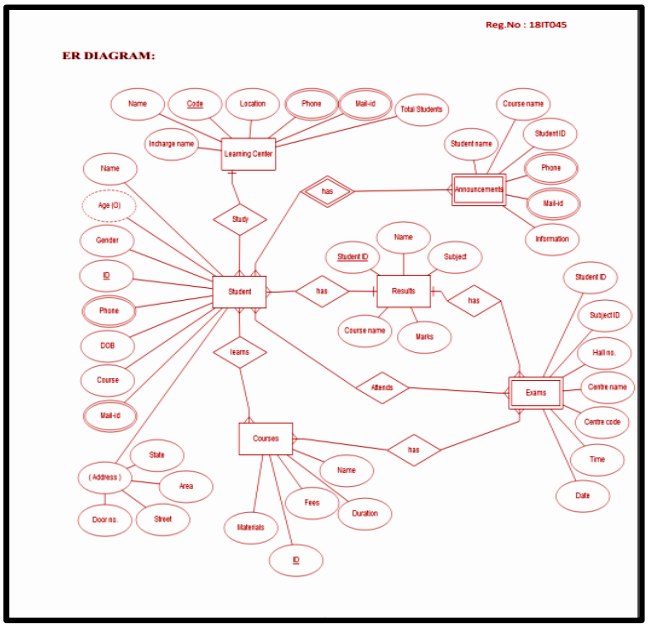

Fig. 7. Sample ER Diagram

Initially, students were asked to form team of size 3 and were assigned an unique application to practice database design, query writing, and management tasks. Assigning unique applications as shown in figure 6 eliminates plagiarism to a greater extent.

To provide deeper understanding of the application, the project teams are made to draw schema diagram and Entity relationship diagram using design tools such as Smart Draw,Creately.com and Lucidchart.

2a) ADD COLUMN IN THE TABLE:

Query:

ALTER TABLE student_details ADD XII_percentile int;

Screenshot:

Object Type TABLE Object STUDENT_DETAILS

Table	Column	Data Type	Length	Precision	Scale	Primary Key	Nullable	Default	Comment
STUDENT_DETAILS	APPID	Number	-	-	0	-	-	-	-
	NAME	Varchar2	50	-	-	-	-	-	-
	FATHER_NAME	Varchar2	50	-	-	-	-	-	-
	MOTHER_NAME	Varchar2	50	-	-	-	-	-	-
	ADDRESS	Varchar2	50	-	-	-	-	-	-
	BLOODGROUP	Varchar2	50	-	-	-	-	-	-
	MOBILENUMBER	Number	-	-	0	-	-	-	-
	XII_PERCENTILE	Number	-	-	0	-	✓	-	-

1 - 8

2a) ADD MULTIPLE COLUMN IN A TABLE:

Query:

ALTER TABLE student_details ADD (X_percentile int,JEE_mark int);

Screenshot:

APPID	NAME	FATHER_NAME	MOTHER_NAME	ADDRESS	BLOODGROUP	MOBILENUMBER	XII_PERCENTILE	X_PERCENTILE	JEE_MARK
1	Priya	Rajagopal	Sumathy	Chennai	B+ve	9486629749	-	-	-
2	Kaushik	Murugan	Sasikala	Bangalore	B+ve	9487849749	-	-	-
3	Dhaya	Baskaran	Parvati	Chennai	O+ve	6354087849	-	-	-
4	Jeya	Moorthy	Sudha	Neyveli	B-ve	6369350259	-	-	-
5	Aditya	Govind	Kalpana	Madurai	A+ve	9876543259	-	-	-
5	Aditya	Govind	Kalpana	Madurai	A+ve	9876543259	-	-	-

Fig. 8. Database Design by Team Members

To manage time and work load constraints and to assess individual contribution, every member in a team works with a single table only. It is ensured that all DDL, DML and DCL operations are performed individually by the student in the assigned table design as presented in Figure 8. This activity has provided extensive hands on experience to all the team members.

As a result, Inquiry based approach have helped the students to create an ERD and build database using SQL. Students found the activity to be interesting as it is directly connected with a real time application of their choice. The technical competence of database design has been evaluated through a series of inter related tasks conjunction with the project. This differs greatly from the "drill-and-practice" method that is occasionally employed when teaching languages like SQL.

C. Computer Networks Lab

Owing to the exploding growth of the internet and communication technologies, there is a high demand for networking professionals in the IT industry. The courses on Computer Networks (Theory) and Computer Networks laboratory have been designed to provide practical exposure in designing, configuring, testing and administering wired computer networks. The conduct of Computer Networks lab does not deal with any application development as an end product but focusses mainly on exposure and practice to a wide variety of networking tools for configuration and maintenance. Conducting network labs presents challenges such as resource availability, complex networking concepts, security concerns, and the need for scalability. (Gao, 2018 and Gurgel, 2013) Instructors must also keep pace with evolving technology and decide between real hardware and software simulation. Privacy, interoperability, and safety considerations add complexity, while assessment methods and remote lab options require careful planning. Overcoming these challenges is essential for providing students with valuable hands-on experience in networking and preparing them for real-world scenarios and many educationists have attempted using exclusive testbeds, simulation tools and customized assessments. (Janitor, 2010 and Jayalakshmi, 2012). In the proposed instructional design, the list of experiments are grouped under three categories namely

- Socket Programming in Java
- Simulation Exercises using CISCO Packet Tracer, OPNET
- Configuration, Analysis and Testing using WireShark

The experiments on socket programming include connection oriented and connection less sockets, design of concurrent servers, Remote Method Invocation and creating multicast sockets for group communication. Utilizing the standard library functions in java.net package is crucial for the successful completion of the experiments. Learners are provided with unique applications like solving a set of linear equations, matrix manipulations, string manipulations, complex number

manipulations etc., All these applications are to be coded using the client server paradigm. Few standard services such as file transfer protocol, telnet, remote login were also practiced This enables the students to not only explore networking packages but also other packages for performing mathematical and

Parameter	Max Marks
Complexity of the Application chosen	10
Uniqueness of the Code	10
Use of Comment lines and standard coding practices	5
Viva	10
Sub Total	35
Completion of experiment on time	5
Documentation	10
Sub Total	15
Total	50
Signature of the faculty with Date	

Fig. 9. Rubrics for Socket Programming exercise

scientific operations. The rubrics for assessment is presented in Figure 9. It could be noted that standard coding practices, timely submissions and documentation are given exclusive weightages in the grading.

Simulation of various topologies and its performance analysis, Local Area Network using switched Ethernet and fast Ethernet were done using OPNET. Cisco Packet Tracer was

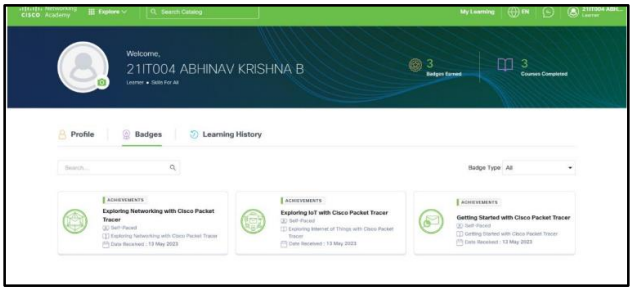

Fig. 10. Sample Badges in Cisco Packet Tracer

used for the configuration of Domain Name Servers, FTP servers, Dynamic Host Configuration Protocol services, Telnet Services and SMTP server. Learners also configured various type of firewalls such as application level gateways and packet filtering routers and also Virtual Private Networks using CISCO packet Tracer.

Enrollment in the CISCO platform "Skills for all" has been done by the CISCO Networking Academy of the Institute. Learners were able to earn three badges in the platform as represented in figure 10.

To promote hands on experience on various simulations of computer networks, leaners were assisted in completion of Open University certification on "Discovering Computer Networks: Hands on in the Open Networking Lab". A sample certificate is presented in figure 11.

A wide variety of networking tools are used in real time environments for managing and administering networks. It is

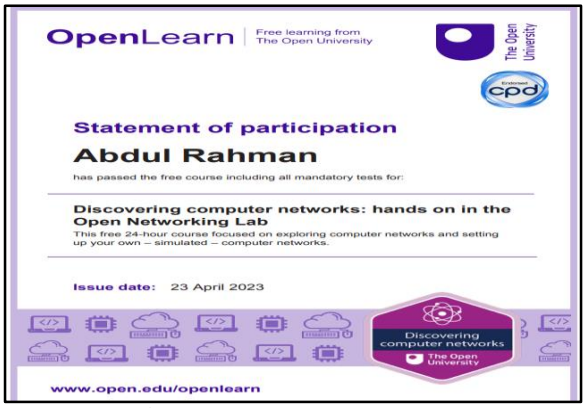

Fig. 11. Sample Certification in Open University

practically impossible for the instructor to cover a rich set of tools because of limited contact hours. Learners were made to explore any one of the networking tool as part of inquiry based leanring and study the capabilities of the tool in teams. A presentation report which includes the details of installation, operational procedures, limitations and a worksheet which contains possible questions to test the understanding about the tool has been submitted by the learners. Learners found framing questions as an interesting activity which made them to explore the functionalities of the tool in depth. These best practices have resulted in significant enhancement of learning outcomes.

VI. Impact Analysis of IBL

The impact of the proposed hybrid inquiry approach is measured through the following tools

- Focused Student satisfaction survey on the inquiry based approach
- Course Outcomes measurement of two batches - one batch for which confirmation based instruction style was followed and the other batch for which inquiry based instruction style was followed.
- Course Exit Survey which analyzes students' feedback on various aspects of the course conduct.

In the proposed approach, the design considerations are based on four major components of experimentation i.e. Problem Identification, Background, Design of Solutions and Results communication. To ascertain the impact of this design, a survey was conducted among the students. The questionnaire was short and essentially invoked their responses on how much they enjoy the lab courses based on inquiry approach and the set of skills they acquired through this approach. The results of the survey are presented in figures below.

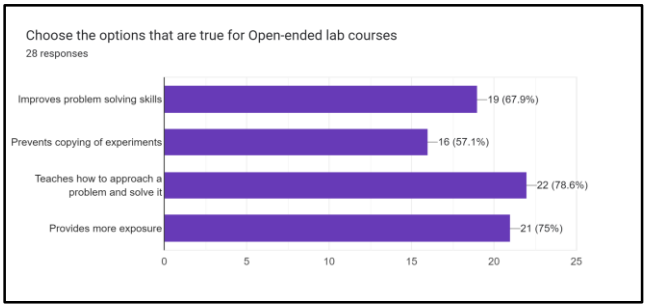

Fig. 13. Benefits of Inquiry based approach in students perspective

Fig 12 shows that majority of the students enjoyed working on the open ended experiments in the lab. When asked to ascertain the benefits of inquiry based learning in labs, majority have felt that they learnt how to approach a problem and solve it and the inquiry based approach facilitated exposure to variety of tools and techniques. The results are presented in figure 13 below

The last question in the survey has elicited interesting responses from students. When asked, they felt adequately supported with the guidelines, the responses are distributed evenly on the scale from low to high. If the responses had fallen on the positive side, it would have reflected that the lab courses were majorly based on confirmation approach. But many learners have felt that they are on their own to deduce solutions. This reiterates the hybrid approach employed in the study is more on the inquiry based style. The results are presented in figure 14 below.

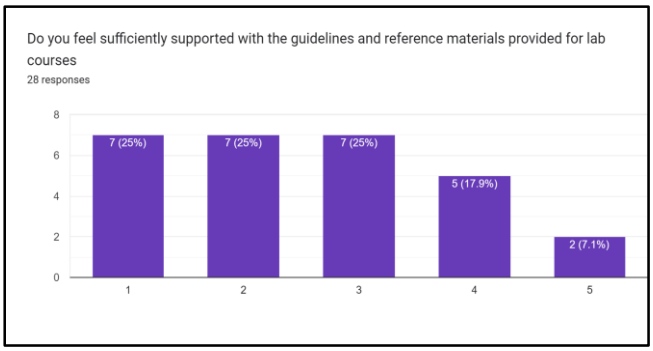

Fig. 14. Adequacy of support

Thus the responses from the students clearly indicate that the mix of confirmation and inquiry based approach leveraged in the course plan met the objectives of arousing curiosity among the learners, made them to explore multiple options of tools and technologies to arrive at the solution.

Impact of the proposed approach on the attainment of Course Outcomes is observed at the next level. To measure the impact, course outcomes attainment of two batches of students are compared. One batch belongs to the academic year 2019-20 and the other belongs to 2020-21 academic year. Confirmation based instruction style was followed for 2019-20 batch and hybrid inquiry based instruction style was followed for the 2020-21 batch. Their CO attainments are presented in the figure 12 and figure 13 below. From figure 15, it can be observed that except CO1, students have not achieved the expected outcomes. And the proficiency achieved was very less compared to the target set.

The figure 16 below shows the CO attainment of the batch 2020-21, for which the inquiry based instruction style was adopted. It is clear from the attainment shown in fig below that the inquiry based instruction style has very positively impacted the CO attainment. Almost, all the COs have met the target.

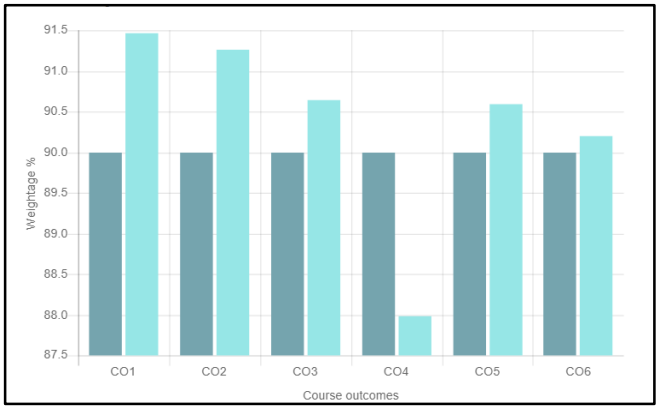

Fig. 16. CO Attainment of Computer Networks lab course – Experimental Group (2020-21 Batch)

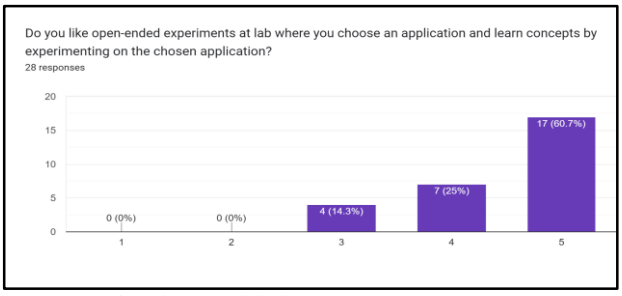

Fig. 12. Focused Students' satisfaction survey

The course exit survey of the students of the three courses are analyzed to measure the impact of the approach on the other aspects of the course run such as Relevance of the course, Appropriateness of the experiments, appropriateness of the guidelines, Assessment and COs attainment in learner's perspective. The results are presented in figure 17, 18 and 19.

The course exit survey clearly indicates that the students feel that they have attained the expected outcomes. Also, they feel positive about the appropriateness of the experiments and the assessment items. Further, impact of the lab courses were observed in other aspects such as placement and participation in technical contests/hackathons. The figures 20 and 21 below indicate the number of participation over the past six years.

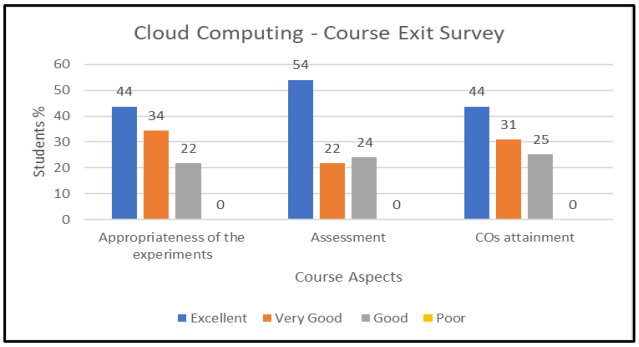

Fig. 17. Course Exit Survey results of Cloud Computing Lab

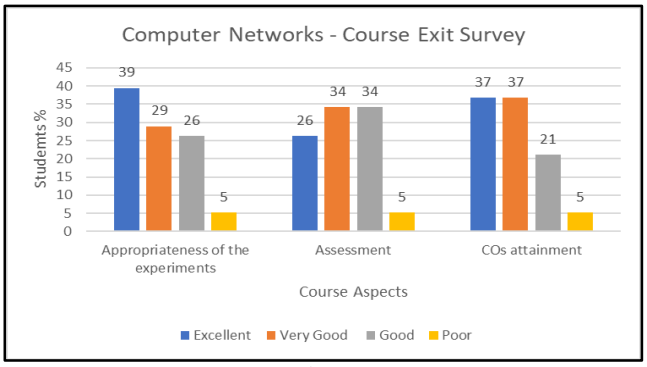

Fig. 18. Course Exit Survey results of Computer Networks Lab

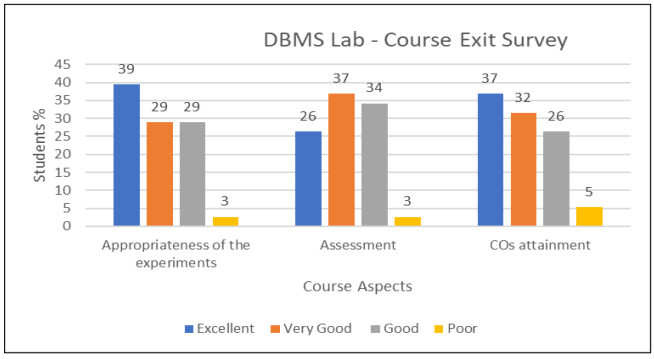

Fig. 19. Course Exit Survey results of DBMS Lab

Academic Year	Total No of students (N)	Total Eligible/Willing	Total Placed	Internship Count	Single Placement Count	Dual Placement Count	Placement Percentage	Total Job Offers (Including Sharing Offers)
2015-16	129	113	97	52	97	30	85.84	203
2016-17	139	112	100	45	100	37	89.28	186
2017-18	134	107	91	45	91	35	85.04	155
2018-19	129	101	87	47	87	7	86.13	147
2019-20	125	105	102	56	99	32	97.14	139
2020-21	133	94	81	39	82	13	87.23	148

Fig. 20. Placement of IT Students from 2015-21

Name of the Hackathon	Theme	No. of teams participated/outperformed
CREATRIX HACKATHON	Upgrade Projects to Products	**15 Teams**
HONEYWELL HACKATHON	Real Time Projects	20 teams
TCE HACKATHON	Digital TCE and Digital Madurai	33 teams
GUVI AND MITHRAI - HACKATHON.	Artificial Intelligence Open Hackathon	Secured Ist place
HCL HACKATHON	Creating better lives through technology	II place
TCE_HBTU HACKATHON	"Waste Management for Urban Areas".	15 teams

Fig. 21. Participation in Technical Contests/hackathons in 2020-21

Group (2019-20 Batch)

VII. Implementation Challenges and Mitigation Strategies

Further, the important challenges encountered while implementing the hybrid inquiry based instruction design and the mitigations followed are listed below.

Challenge 1 - Making students to feel adequately supported, especially the slow learners. Since inquiry based approach expects the learners to explore and compare many options for deducing the solutions, some students found it difficult.
Mitigation - To mitigate the above problem, the exercises were assigned to students in teams. So that, through peer learning slow learners may get the needed support.

Challenge 2 - During experimentation, major challenges were encountered during the Problem identification phase and design of solution phase. It has to be ensured that students choose appropriate problems that need deep and wide analysis and implementation to be able to learn the concepts effectively. Also, the design of solution need to be comprehensive.
Mitigation - The appropriateness of the problem chosen and sufficiency of the solution designed are ensured through systematic formative feedback mechanisms. This ensures that the instructor reviews the progress made by each team and give them directions for improvement. Students got confidence to participate in International Hackathon-Resfest and Smart India Hackathon to showcase their Programming skills, problem solving skills and presentation skills which they inculcate through inquiry-based lab and won cash prize and a funded project from ISRO, internship offer for 6 months LPU.

VIII. Conclusion

There are several differences in conducting a laboratory course using traditional and hybrid inquiry-based pedagogical approaches. The first challenge is that teaching professionals must be adaptable and capable of responding to students' needs at various levels. The second problem is keeping track of students who advance at various rates. The third challenge encountered was around assessment design. Based on our observations of the students, we provided an workflow for the hybrid inquiry-based methodology that was employed, along with a list of crucial elements that, in our opinion, contributed to the methodology's success. These characteristics included the magnitude and complexity of the data provided, the open-ended nature of the challenge, the ability for students to learn concepts as dictated by project needs, and the involvement of teaching personnel while students are learning.

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