Database Virtual Laboratory for Guided Learning

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Abstract: Innovations in information technology resources hae given wings to the development and advancements of new age learning environments. This chapter reviews some of the existing virtual laboratories and proposes a virtual laboratory for Database sytems. The proposed Database virtual laboratory is a complete Learning Management System(LMS), which has been designed after careful consideration of all the necessary parameters for any LMS like the pedagogy of teaching and learning, student engagement, pitfalls, and cognitive levels. The use of our own Database Management System (GU_DB) in the Virtual laboratory has proved significantly advantageous in terms of student and teacher communication. The students rating in a questionnaire after the end of the evaluation phase showed encouraging results.

Index Terms: Computer Science Education, Database Systems, Learning Centric Pedagogy, Virtual Laboratory.

I. INTRODUCTION

Laboratory work is an integral part of computer science courses. The rise of technological advancements has led to innovations and improvement in the online educational system, including online learning courses. The innovative approaches help the courses to be designed as per the changing requirements of the next generation learning. In order to achieve effective learning for science subjects, laboratory work should be integrated with e-Learning environments. For courses like Computer Science laboratory work is an integral part of learning, thus providing a virtual laboratory environment for computer science courses can prove beneficial for effective learning.

Virtual laboratories offer flexibility allowing students to visit laboratories at their convenient time and enabling them to revise concepts as and when needed. Additionally, Virtual laboratories are beneficial in situations where the students are deprived of the laboratory infrastructure or have insufficient access to the laboratory resources.

The joint ACM-IEEE Curriculum Task Force (1989) recommends that computer science courses should be supported by extensive laboratory work. Kuox et al. (1996) discuss the ACM working group on computing Laboratories guidelines for the use of laboratories in computer science education. It discusses the relevance between the lecture and the laboratory, the pedagogy, the support of other resources like internet, teacher, institute, technology, etc. In computer science courses, laboratories are an integral part of the learning experience. The instructors must consider all the objectives of the subject while designing tasks for laboratory-related work. The Learning objectives provide a clear idea about the outcome expected from the course getting designed. As, In today's world, students are turning towards e-Learning environment, it is essential that e-Learning environments integrate virtual laboratories to provide complete learning.

This paper describes the development of a Virtual laboratory in Database systems, which is a complete Learning Management System, with clear Learning objectives designed for the student. The system has been developed, keeping in mind all the cognitive levels. A **learning-centric pedagogy** is followed in the Learning management system to ensure that a balance is maintained between student-centric and teacher-centric pedagogy. The pedagogical perspective helps in providing the much-required guidance to the students, which is often lacking in many online environments. The virtual laboratory aims to provide advanced technological and pedagogical experience to the user. *The heart of the Virtual laboratory developed is the database management system used in the background. In the earlier part of the research, authors have developed their own Database management system(GU_DB)*, which is used in the Database virtual laboratory in the back-end as the database. The database virtual laboratory is carefully designed to provide specific hints to the user so that when the user makes any mistake while writing the SQL queries, the hints help the users to recall the concepts learned and hence the student can learn from his own mistakes (pitfalls). The effectiveness of the system was evaluated by recording the learning experience of postgraduate students of computer science department after using Database Virtual laboratory. The students rating in a questionnaire after the end of the evaluation phase showed encouraging results

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RELATED WORK

A whole heap of research already exists on e-Learning systems and different online learning materials or learning courses. However, all those e-Learning contents involve delivering the content only; very few of them include live student interaction or student engagement. In the past, researchers have suggested that the learning activities should be adaptive based on the environment and student needs. It promotes courseware reuse and adaptive educational systems. [1] have proposed a knowledge tree where learning goal or objective is adaptive with the learning need of the student.

As mentioned earlier, computer science courses are not entirely instruction-based, and most of the subjects demand extensive practical work along with the conceptual clarity of the said subject. The traditional laboratories are the solutions for the implementation of the concepts learned. However, with the growing Information technology needs and innovative learning environments, the demand is to have laboratory access at their own pace, time, and place. Plenty of research is being conducted to provide the students with the traditional laboratory environment on a virtual platform while also making the entire experience more interactive, however it is rare in the area of computer science.

[2] in their paper, suggests that the e-learning tools should be comparable with the traditional classrooms. They believe that learning effectiveness, student satisfaction, faculty satisfaction, access, and cost-effectiveness are the five metrics that drive investigations into online education.

Online methods can augment the ABET engineering competencies. In Table 1, Here is the list of some of the skills blended with online methods.

Table 1: Potential value added to ABET engineering competencies [2]

Competency	Potential Value Added by Online Education
A recognition of the need for, and an ability to engage in life-long learning.	Learning to learn in off-campus modalities while still on campus will significantly assist the transition to lifelong learning.
A knowledge of contemporary issues.	Integration with the internet-enabled world permits combining education with current knowledge.

Many researchers have argued that the students have started losing interest in traditional eLearning curriculum. The area of Learning requires significant innovations, wherein the student's interest can be maintained and adhere to the learning capacity of the students concerning different learning levels of the students. However, STEM (Science, Technology, Engineering, and Maths) courses still demand more efforts in learning skills. The engineering or computer science course is not complete without the laboratory work. Hence, there is a demand for the virtual/remote laboratory which can satisfy student's need for practical implementation in the digital content. However, to make laboratory learning effective and maintain student's interest, the pedagogical perspective has a vital role to play. The pedagogical

effectiveness helps design the course with all the learning objectives in mind, which results in a learning-centric virtual laboratory getting developed.

[3] in their research discuss that Computer Science is a discipline that uses the growing and demanding e-Learning environment to deliver the computation, technology, and knowledge to the learners. Computer science needs practical sessions as the central part of its educational process.

The engineering bodies for accreditation (ABET) strongly recommend for lab sessions/ practical sessions in their evaluation criteria

As the focus is on computer science domain, the practical sessions in computer science courses are of limited duration. The fixed lab time slots in most of the colleges make the lab work limited or restricted to a particular time slot. The need for today's technological era is to let the student's practice/implement lab work in their pace and time. A separate infrastructure in the form of remote/virtual laboratories is required to provide such a facility,

In other engineering disciplines, researchers have proposed the following virtual laboratories.

[4] introduced an online simulator for Microelectronic devices. They designed and implemented an MIT device simulation WebLab (WeblabSim). It was an online simulator wherein the students could explore the behavior of microelectronic devices. WeblabSim makes device simulator readily available anywhere, anytime.

In August 2005, [5] proposed a virtual lab model for introductory computer science courses. The model consists of seven modules, and each one corresponds to a specific topic of the course. Every module provides several different services to a particular topic of the course. Every module offers various services to assimilate theory and practical exercises. The proposed model was partially implemented and gave a better understanding of theoretical concepts

(Kuleshov, 2008) Rightly points out that the interactive simulations allow students to explore a topic by comparing and contrasting different scenarios. Users may get more in-depth exposure to the subject matter either by modifying parts of existing simulator or by building a new simulation from scratch.

In 2015, [6] proposed the usage of Service Oriented Architecture (SOAs) to overcome the limitation of Learning Management Systems towards the practical implementations in computer science education. The developer uses SOA to develop the required resources as services and then integrates them in the LMS. Their experimental works are carried out in Sultan Qaboos University, Oman.

In February 2016, [7] proposed a web services approach to support interactive LabVIEW based Remote experiments under MIT's iLab Shared Architecture(ISA). Experiment lab server Architecture (ELSA) was developed as an extension to ISA, fulfills the requirements of an ISA process agent and uses web services to connect the client with the lab Server. Elsa automatically manages the initial definition and runtime traffic of experiment-specific input-output parameters.

Once the experiments are created, remote experiment configuration, start-up, and operation are easily achieved

In August 2016, [8] proposed a remote lab system for measuring linear dimensions in the process of e-learning. It was implemented at the University of Novi Sad, Department of Technical Sciences. It is an excellent example of a mechatronic structure where different engineering areas (automation, pneumatics, mechanical) are integrated into one.

In November 2016, [9] reviewed different technologies which could be used for the development of different types of virtual/remote laboratories in the education system. They conclude that the Remote Laboratories (LRS) lack interactivity and there are many technologies available which could be integrated to develop an interactive LR. They also explored various disadvantages of techniques which require compulsory installation of add-ons as a prerequisite. Such considerations should be eliminated to create an interactive and open platform LR/VR.

II. PROPOSED WORK

A. Background

There are many e-Learning repositories and courses available on e-Learning contents. However, the e-Learning contents mainly focus on delivering content to a mass audience and allow sharing of pools. These type of learning environments do not provide student interaction, and their primary focus is good quality e-content/tutorials. However, for computer science courses, as per ABET guidelines, laboratory work is equally important, along with good quality course content. With the increasing technological advancements, even the laboratory work is required on the e-Learning platform, which results in the laboratories being available remotely. Hence, there is a need for Virtual Laboratories. However, good quality Virtual Laboratories are rare. The computer science virtual laboratories are even lesser. Virtual Laboratories have two broad categories: Virtual laboratories in research and Virtual Laboratories in Education. Virtual Laboratories in education are referred to as the simulation environment that adds an environment and human touch to the virtual interfaces (Virtual Laboratory, 2019). The primary purpose of a Virtual Laboratory is to provide remote access to laboratories in the area of Science and engineering. The traditional laboratories have a fixed time slot per batch and cannot be made available 24/7.

Moreover, they are limited to a particular department. Hence to overcome such geographical limitations and provided laboratory access any time, virtual laboratories can be used. The virtual environment gives an advantage of sharing costly equipment's which otherwise might be limited to a few users due to constraints on time and geographical distances. Such virtual environments provide the benefit of addressing a large number of students at once, and the subject expert develops the content at one location, which can be accessed by students in different geographical areas. The virtual laboratory research is still in its infancy stage, and there is an acute shortage of good quality virtual laboratories. Virtual laboratories in research would allow researchers at different physical locations, each with unique expertise,

computing resources to collaborate efficiently in a virtual environment. Such projects can pool resources towards a shared goal. (Virtual Laboratory, 2019)

Authors could review that various remote or virtual laboratories are mostly based in engineering disciplines. Most of the models proposed were simulator-based and provided access to the program on a remote computer or a server. Authors believe that a virtual laboratory proves more efficient if it caters to all the needs of a complete Learning Management System. It should provide step by step guidance in the process of learning.

The virtual laboratories should be such that students should seek to spend more time and should feel that they can learn more by using the virtual laboratory. The system aims at providing a virtual environment to the students at their own pace and convenience. The system would also prove beneficial for the category of students belonging to some remote locations, who are getting deprived of access to high-end technology or good learning material.

The authors have developed a complete **Learning Management system** (LMS) for the course of Database systems in computer science. The Learning Management System is designed after careful consideration of all the necessary parameters like proper pedagogical approach, student engagement, and cognitive levels. The system will include the complete tutorial of the subject, will guide the users on how to write a query, will show the step by step procedure of simulator interactions and will allow users to make mistakes, i.e., the system will have pitfalls also wherein the user will be able to learn from his/her mistakes. The system will also provide the facility for self-assessment to the student. The user gets an entire subject class at one place, which also integrates the laboratory work required for the said subject. It implies that the user will not have to go anywhere else to try the Queries learned in the Tutorial; he can implement the same within the system.

Any system when referred to as a Learning Management System (LMS), **"learning"** plays a significant role. The learning of a student depends directly on how a teacher has been able to design/devise the **pedagogy** of the subject to be taught. [10] Redefines Pedagogy as the "interactions between teachers, students, and the learning environment and the learning task." This type of pedagogy implies that how the teacher communicates with the students plays a vital role in deciding the student understanding. The **instructional strategy** which teacher selects as per the requirement of the course also becomes an essential criterion in the knowledge of the subject. Over a while, different pedagogical approaches are proposed like Teacher-centric, Learner Centric, and Learning Centric.

The **Learning centric** pedagogy gives the benefit of both learner-centric pedagogy and teacher-centric pedagogy. O'Sullivan, M., (2004) in his research says that Learning Centric pedagogy can prove useful only when teachers consider the number of students in the class,

the physical environment and the availability of teaching and learning materials. Vayna F. (2009) suggests that teachers should be flexible and carefully adapt their pedagogical approaches based upon the teaching environment.

Table 2: Traditional Laboratories Vs Virtual Laboratories

Traditional Laboratory	Virtual Laboratory
Fixed Time and Place	Any time and Place based on user's requirement
Expensive	Less Expensive compared to Traditional Laboratories
Learning and Assessment are done as per traditional methods of teaching	Complete Learning Management System (LMS) at one place
All students addressed in one group at one time	Personalized Learning
Less student engagement	Higher student engagement
Teacher/Learner-centric Pedagogy	Learning Centric Pedagogy

The Virtual Laboratories highly emphasize on **Student Engagement**. The digital platform brings with them the limitation of getting diverted easily from the focus area. Hence, If the need for the course is that a student should spend more time in a virtual laboratory, and practice and learn more, then the system developed should be more engaging and exciting. The system needs to focus on learning centric pedagogy to achieve the same. All the experiments designed must provide some learning to the student, and student should enjoy that learning. Hence, the appropriate definitions of Learning Objectives lead to a proper Learning management system getting developed. The Learning objectives, in turn, should be aligned with the cognitive levels which help in catering the needs of all types of students and engaging all types of students. The appropriate cognitive level selection helps in defining the task correctly, and hence, the assessment gets adequately represented.

The cognitive levels cater to the varied student's requirements with different skills and learning abilities. Hence the cognitive levels like (Recall, Understand, Analyse) and High order cognitive levels like Apply or create could be integrated with the Learning centric pedagogy which increases the student engagement for all the category of students.

The proposed Virtual laboratory (Database Vlab) is developed after considering all the pedagogical aspects stated in the previous sections, and the efforts are made in the direction of increasing the student engagement in each of the parts: be it Tutorial, Experiments or the Assessment questions. The Learning objectives are clearly defined concerning the cognitive levels, and the Task and assessment questions are designed accordingly.

The distinguishing feature of the proposed virtual laboratory is the integration of tutorial with the laboratory, step by step guidance, inbuilt evaluation, and hints to the students. Moreover, the Virtual laboratory (Database Vlab) is an entirely web-based system which is accessible from any device, hence provides the advantage of learning and implementing the topic learned from "anytime anywhere." The fundamental requirement of any web-based system is that it should have an effective GUI which easily attracts users. The Virtual Laboratory aims to provide users with a rich

experience of learning Database Management System concepts(SQL Queries) by implementing different SQL queries under one umbrella of learning, implementing, and evaluating self. The significant advantage of the proposed system is the Learning Management System (LMS) developed, uses the Database Management System Prototype ([1]GU_DB-developed by the authors) in the back end. Hence the error messages are customized as per the requirement. The system can provide accurate feedback in the form of hints about the mistakes/errors in the query written by the student. The student is not supposed to struggle to understand the error message provided by the database engine. The Gu_DB database engine offers hints to the student, which leads them to the correct query.

B. *Database Virtual Laboratory*

The goal of the virtual database laboratory is to increase the student's knowledge by self-motivating them to implement the concepts learned in the virtual environment. As the Virtual laboratory is integrated into a complete Learning Management System, it gives the advantage of integrating two environments, Traditional and Virtual. The Database Virtual laboratory adds a human touch in the virtual environment in the form of Hints provided in the system. The Hints give the feeling of interaction to the students in a virtual environment.

Database Virtual Laboratory is divided into various parts like Theory of the subject(Tutorial), examples, procedure for implementation, Query Editor and Self –Assessment(Evaluation).

The system aims to be a complete Learning Management System (LMS), which can meet all the requirements of any Learning Management System. It also follows the ABET standards and considers all the cognitive levels like Recall, Understand, Create, Evaluate, and Apply aligned with the **Learning objectives** when designing a Virtual Laboratory for Database Systems in computer science. As the teacher develops the Learning Objective for the course, he/she knows the specific learning requirements of the individual. Moreover, keeping in mind the pedagogical perspective teacher plans several assignments/tasks to promote learning and support individual learning process as per the cognitive levels.

The Database Virtual laboratory has the following major components

    a. Tutorial of the subject with examples
    b. PreTest(MCQ Questions)
    c. Procedure (Guidelines on using the system)
    d. Query Editor: Experiments (DDL, DML, DQL, and TCL)
    e. PostTest: Self-Assessment (Theory and Practical)
    f. Feedback

The proposed system caters to the requirements of all types of users, and the learning objectives are designed

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[1] The earlier research of authors focused on development of Daabase Management system , which is named as GU_DB

accordingly. The system features high order thinking skills questions also for "above average" students. The Evaluation is categorized into two categories: Theory Assessment and Practical Assessment. Theory assessment would focus on Conceptual questions (MCQ) which is based on the fundamental cognitive levels like Recall, Understand, Analyse, and practical assessment would focus on writing SQL queries based on the higher cognitive levels like Apply and Create.

The diagram in figure 1 displays the first screen of Database Virtual laboratory
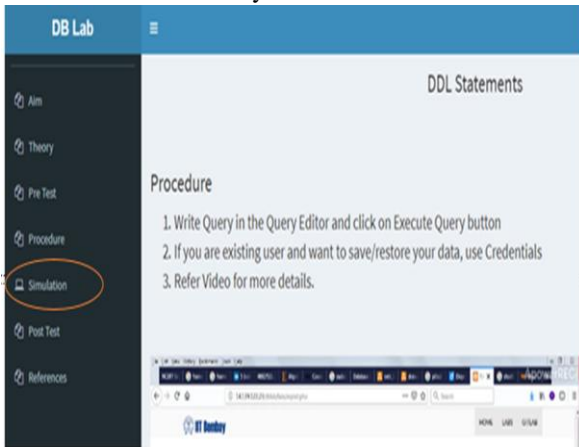
Fig 1: Screenshot displaying the link of the simulator

The architecture of Database Virtual Laboratory

The diagram in Figure 2 displays the Architecture of the Database Virtual Laboratory System
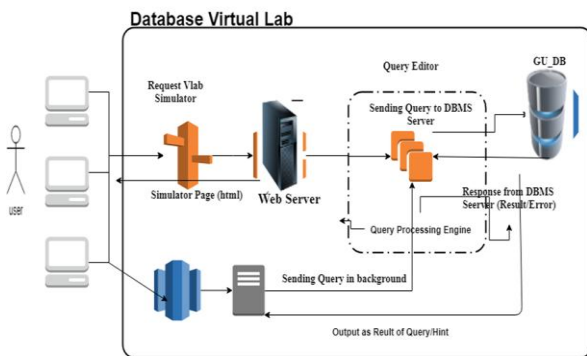

Fig.2. The architecture of Database Virtual Laboratory

The Database virtual laboratory consists of various components like Vlab (Virtual Laboratory) Simulator, Web Server, Query Editor, Query Processing Engine, and GU_DB.

DataBase Management System prototype (Gu_DB)

There are various database management systems available for the students to implement the database knowledge they have gained. The Database systems are divided into two broad Categories viz.: **Proprietary Databases** and **Open Source Databases.**
Table 3: Open Source Vs Commercial Databases (Shah, 2017)

Open Source	Commercial
Available under free licensing	Huge Licensing cost
Need to rely on Community support	Dedicated support by the vendor is provided
Fewer features compared to Commercial	Feature Rich Database
Less support for advanced features	Support for information replication, Back up and retrieval of data
Reliability-based on community support	Reliability & Stability
Simple to implement	Expert knowledge required
Eliminates single point failure	The entity to hold responsible for any kinds of bugs
Communities can add new features	Wait for next release from the vendor

If a Proprietary Database is to be used, fees for purchasing the same is to be paid either individually by the student or by institute if they have the database course in the syllabus. For the said reason, most of the colleges/universities/institutes have moved towards Open Source Databases. However, none of these databases, whether open source or commercial, are equipped to guide the students on how things are to be done.

Authors have developed the Database management system prototype (**GU_DB**) to integrate the features needed for guided learning and consider the pedagogical aspect of the learning system. The commercial or Proprietary databases have a commercial viewpoint but do not have much of academic considerations. The **GU_DB** is equipped with almost all the features of an Open Source database system, and additionally, it is used as an Assisted Learning Management System (Academic approach) in **Query Editor** wherein the student learns from the mistakes and is motivated to try new queries with different case studies provided.

The DBMS developed by the authors has many such distinguishing **features,** which makes it different and unique. It is integrated with almost all the essential functionalities required for any Database management system. One of the distinctive features of the system is the **pluggable** nature of the database, which makes communication with the front end system easier. Authors discuss here an overview of database management system prototype, as complete detailing of the database (GU_DB) is out of the scope of this paper.

C. Query Editor

The Query Editor is an integral part of the entire system. The Query Editor allows the communication between the web-based system (Front end- Database Virtual Laboratory) and the back end DBMS (GU_DB). The authors of the paper were motivated to develop GU_DB, which can be used with the front end to provide guided learning to the students. The user enters the Query in the Editor based on the understanding he gained from the Tutorial provided. **The Query Processing Engine parses the query to the Database Engine as displayed in figure 3** if the Query is syntactically correct Tabular output is generated from the result, else a self-explanatory hint is presented to the user. The detailed explanation for the same appears in the later part of the paper

Database Virtual Laboratory for Guided Learning

The Virtual Laboratory(Vlab simulator) communicates to the back-end database(GU_DB) as displayed in the above diagram. It consists of the remote server, which hosts the author's developed database system discussed earlier.

The diagram in figure 3 displays the Query Parsing Architecture in the system
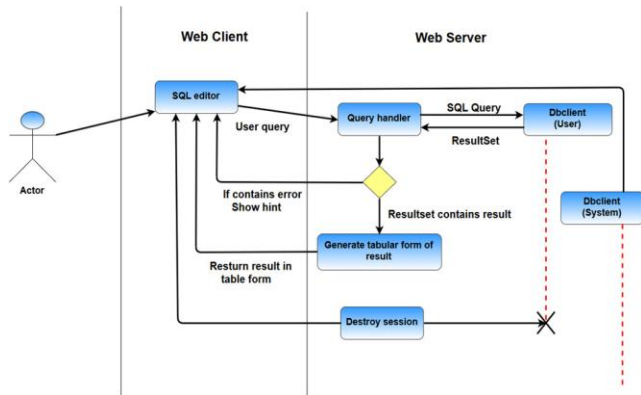

Fig. 3: Query Parsing Architecture in the system

In the diagram in Figure 3, it can be noticed that the Query Editor communicates with the database in the back end. The database used is the author's database system prototype developed for the virtual laboratory named as GU_DB.

The web-based system (Virtual laboratory simulator) communicates with the database to execute the queries entered by the user.

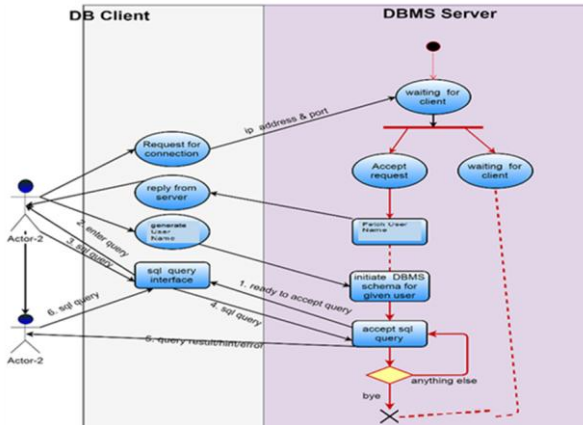The diagram in figure 4 displays the overview of the client-server communication

Fig 4: Client-Server Communication

As can be observed from the diagram in Figure 4, once the request for connection is received, the system connects to the server and manages the data.

The integral virtual laboratory section of the Learning Management system is the Query Editor. When the user clicks on the **simulator**, the client connects to the back end, and the simulator in the form of **Query Editor** is initialized.

The user gets one of the two outputs from the server:

1. Data/Table generated from successful execution of the query.

2. Self-explanatory Hints if the query has some syntactical errors. This will guide the learner towards writing a correct query.

Hints are carefully designed, to help the learner learn from his own mistakes. The system gives due considerations to the pitfalls, to incorporate the guided learning approach.

A. Hints

The Hints have been prepared with utmost care to give the user self-explanatory message which will guide the user towards the correct query. Hence, the user will be able to learn from his own mistakes and will solve the problem by learning from mistakes. This type of process will guide the student to think out of the box and increase his potential of trying.

B. Technicalities in development of Hints

To analyze the syntax and determine syntactical correctness, authors have used the finite automata, which consists of a Finite set of states, and it will recognize the pattern based on the user input. FA is the purest form of machine to recognize patterns. The diagram in figure 5 represents how the query travels from the lexical analyzer to the syntax checking process. The Hints, as displayed in "Process 4" of Figure 5, are fetched from the FAtable as per the rules defined.
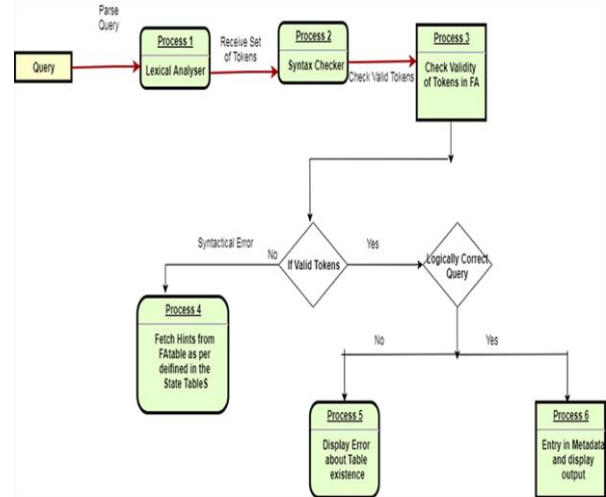

Fig 5: Hint Process for any Query

To implement syntax checking of all of the queries in the experiments, authors have used Deterministic Finite Automata (DFAs), and the same is represented in the **state transition diagrams.** Deterministic Finite Automata, as shown in Figure 6 display syntax rules for Queries.
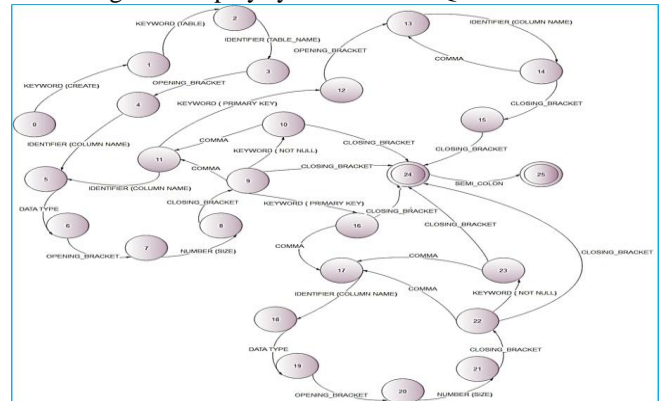

Fig 6: State Diagram of Create Table statement

Query Editor Interface

The **Query Editor** is a web-based editor which connects you to the database management system- GU_DB. The DBMS developed by the authors has been developed without using any third party database dependencies. Authors have incorporated various features of SQL like Data Definition Language commands (DDL). Data Manipulation Language Commands (DML), Data Query Language Commands (DQL) in the form of experiments in the Virtual Laboratory for Database. The DBMS developed by authors that is the GU_DB gives the flexibility in providing exact hints to the user based on the mistake the user has made. Unlike other systems which have to rely on the message received from the database: be it MySQL or PostgreSQL, GU_DB is capable of generating own customized message for each mistake user makes. This feature plays a vital role with reference to the pedagogical perspective in student learning.

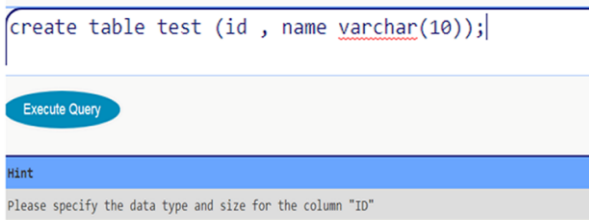E.g., the user wants to create a table and issues the following query

Fig 7: Screenshot displaying hints to the user

As it is observed in figure 7 screenshot, the user gets a definite hint of his mistake of adding datatype and size. Hence the user gets the chance to learn from his mistake, writes the correct query, and gets the message "Table Created".

As mentioned in the previous section of the Paper, **Query Editor** is an integral part of the entire Learning Management System.

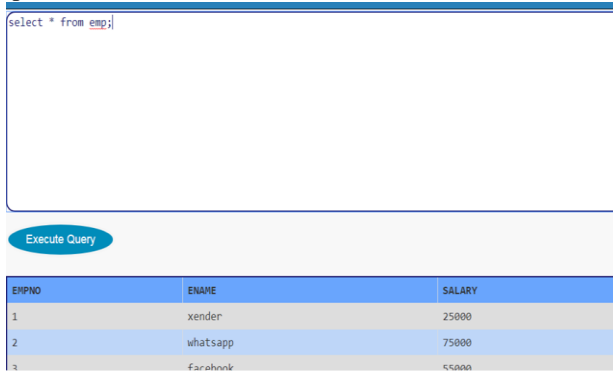The following figures represent Screenshots of some of the experiments.

Fig 8. Correct Query – Output Displayed

III. RESULTS

In order to understand the effectiveness of the Virtual laboratory and the effects of newer pedagogy, the students were not provided with any training on the usage of the system, which helps to resonate more effectively.

The students of semester-II (MCA) of the computer science department of Gujarat University performed experiments like Data Definition Language statements (DDL), Data Manipulation Language Statements (DML) and Data Query Language Statements (DQL)) in the Virtual Laboratory for Database as part of their study. Following this, students were provided with the questionnaire and were asked to individually respond to the questions posed for each of the categories. Students were asked to rate the system for each of the categories described below. Responses from the students were analyzed, and it was observed that it helped the students gain conceptual clarity and develop logical skills after using the Virtual laboratory for Database. The evaluation results are displayed in the Graph-1 below.
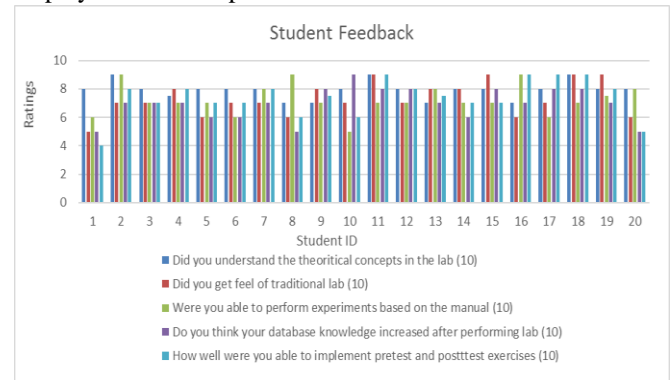
Graph-1. Student Feedback ratings

The responses received from the students are encouraging. Table 4 shows the average of all the ratings received.

Table 4: Average ratings of the responses received

Average of the Ratings				
Did you understand the theoretical concepts in the lab -10	Did you get a feel of the traditional lab -10	Were you able to perform experiments based on the manual (10)	Do you think your database knowledge increased after performing lab -10	How well were you able to implement pretest and posttest exercises (10)
7.925	7.3	7.225	6.95	7.35

IV. CONCLUSION

Virtual laboratories are limited in the area of computer science, and particularly in **Database systems**, they are even rare. Hence, the authors were motivated to develop a complete Learning Management System in the form of Virtual Laboratory for Database systems which can provide a guided learning experience to users and helps them to gain a thorough understanding of the concepts and implement the concepts learned at their own pace. Once the users have applied the concepts learned, they can self-evaluate their knowledge in the test cases provided for practical implementation. As the developed Virtual Database Laboratory consists of the prototype DBMS (GU_DB), it offers complete control over the entire Learning Management System, giving the user a whole assisted learning experience at one place.

Therefore the Learning Management System becomes a full Guided Learning experience which has a traditional laboratory feeling and can give all the advantages of the Digital Learning environment. The pedagogical consideration in the development of the virtual laboratory offers the power of addressing all categories of students. Moreover, the tasks designed are based on the Cognitive levels and hence provides proper assessment methodologies.

The evaluation results are encouraging. The learning component of the students was enhanced after using Virtual Laboratory for Database, and they got the feeling of learning by trying and learning from their own mistakes.

V. FUTURE WORK

The authors plan to include automated evaluation of SQL queries in practical assessment for queries written by the user. The user will be graded based on the correctness of the query. The distinguishing feature of this assessment would be that the users would be provided with partial marks if the query is partially correct.

The authors plan to include many other experiments like Joins, Subqueries, and many more to the Database Virtual Laboratory in the near future.

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