VLCL
Designing a virtual laboratory model for learning the C++ language

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Abstract:

Virtual laboratories are considered one of the innovations of modern technology, which is considered an extension of the development of electronic simulation systems that seek to provide the best solutions to the problems faced by the traditional laboratory. Virtual laboratories transcend time and geographical restrictions and solve capacity problems. Continuing this trend, the researcher decided to create a virtual laboratory system for learning the programming language (C++) to link the electronic aspect with the actual application component, especially for procedures that are difficult to implement. The design focused on the technological requirements associated with the terminology used in the curriculum.

This system was applied to a sample of students from the Computer Department at the College of Education, Bani Waleed University. Teachers' opinions about using this system were also measured through questions collected from questionnaires for previous scientific research on virtual laboratories, and the results were positive.

Keywords: VLCL, E-learning, Distance education, Virtual lab, C++ programming.

VLCL
تصميم نموذج معمل افتراضي لتعلم لغة السي ++

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الملخص

تعتبر المختبرات الافتراضية أحد ابتكارات التكنولوجيا الحديثة والذي يعتبر امتداداً لتطور أنظمة المحاكاة الإلكترونية التي تسعى إلى تقديم أفضل الحلول للمشاكل التي يواجهها المختبر التقليدي، فالمختبرات الافتراضية تتجاوز القيود الزمنية والجغرافية وحل مشكلات القدرات. استمرارًا لهذا الاتجاه، قرر الباحث إنشاء نظام معمل افتراضي لتعلم لغة البرمجة (C++) لربط الجانب الإلكتروني مع عنصر التطبيق الفعلي، وخاصة للإجراءات التي يصعب تنفيذها. ركز التصميم على المتطلبات التكنولوجية المرتبطة بالمصطلحات المستخدمة في المنهج.

وتم تطبيق هذا النظام على عينة من طلاب قسم الحاسب الآلي بكلية التربية جامعة بني وليد. كما تم قياس آراء المعلمين حول استخدام هذا النظام من خلال أسئلة تم جمعها من استبيانات لأبحاث علمية سابقة حول المختبرات الافتراضية، وكانت النتائج إيجابية.

الكلمات المفتاحية: VLCL، التعلم الإلكتروني، التعليم عن بعد، المختبر الافتراضي، برمجة ++C.

Introduction:
Virtual reality, which duplicates real life using artificial or fictitious environments, is an important advancement in education. The student engages in, interacts with, and deals with an imagined environment through his senses, a computer, and a few assistive technologies. In addition, the technical advancements that have taken place, particularly those that pertain to direct communication, and the potential development of the contemporary teaching methodology known as virtual education were aided by the introduction of multimedia technology, remote audio and video transmission, and virtual dialogue groups. Research has shown that this environment impacts the learner to the extent of its honesty and realism. Education is no longer restricted to giving the students information and presenting it to them in a ready form; therefore, the teacher's role is to memorize that information and store it in the student's memory until the time of the exam. Education now focuses more on using scientific thinking skills in a scientific way with new educational technologies, especially virtual laboratories, which operate the mind to process situations that the student encounters in the fictional educational environment created for him in the virtual laboratory and produce outcomes that are comparable to those of the real laboratory (Alexiou, et.al,2005).

In this study, we discuss our experience creating a virtual laboratory (VLCL) for teaching C++ programming because it enables remote learning and has many benefits over conventional teaching techniques. A computer-based laboratory that enables the interactive usage of computer simulations of actual things, instruments, or processes is known as a "virtual laboratory".

A VLCL is an electronic system that functions through software, which reduces abstraction in understanding. It is an electronic system based on communication that employs computer simulations of the fundamental ideas and procedures of the C++ programming language. It also helps students understand concepts better, boosts their cognitive activity, encourages the growth of their algorithmic thinking and problem-solving skills, helps them reach the goal of "procedural and conceptual understanding of algorithms," and lessens abstraction in concept understanding.

Problem Statement:
VLCL is an electronic system that functions through software, which simplifies abstraction in conceptual understanding. Numerous educators and academics in the area of computer science education contend that certain students find it challenging to comprehend the abstract ideas involved in programming. There are various causes for these challenges:

1. In some colleges, class sizes exceed 60 students, making it difficult for the teacher to focus on each student individually.
2. Some colleges have labs, but they are not used for the intended purpose because the time allotted for lectures is insufficient to accommodate the students and because there are more students than available equipment.
3. The hardware is not constantly updated or maintained, making it incompatible with newer programming environments. Given the foregoing, the research challenge can be described as follows:
   What is the proposed scenario for creating a virtual lab to teach C++ programming?

Related works:
Most studies and projects related to teaching programming to students, whether beginners or experienced, rely on different types of visualizations, animations, and simulation of algorithms using various programming languages, including:

- "Teaching and learning using virtual labs: Investigating the effects on students' self-regulation", the primary objective of this systematic review is to assess the influence of VLabs on the practice of self-regulated teaching and learning. Initially, a total of 51 articles were sourced from the Web of Science database following the PRISMA guidelines and the specific criteria outlined in this study, ultimately narrowing down to 16 eligible articles. findings indicate a global trend in higher education institutions shifting towards online education. Furthermore, the results suggest that virtual labs hold promise in fostering self-regulation and facilitating meaningful learning, particularly in times characterized by social distancing, such as the COVID-19 pandemic (Reginald,2023).

- "Designing a Virtual Laboratory for Teaching Programming", this paper outlines the design of a virtual laboratory dedicated to teaching fundamental programming concepts. The design process takes into account technological prerequisites as well as those related to content and educational structure, informed by preliminary research. The paper also introduces conceptual, functional, and architectural models for the virtual laboratory. (Shivacheva, 2017).

- "Design Virtual Learning Labs for Courses in Computational Science with Use of Cloud Computing Technologies This paper conducts an examination of the methodology for designing and executing a virtual learning laboratory (VLL) by leveraging cloud computing technologies within an Application as a Service

(AaaS) framework. The paper concludes by providing insights into the practical implementation of the approach through a detailed case study. (Dukhanov, 2014).

The researcher drew valuable insights from prior studies, which facilitated a comprehensive understanding of the design concept. This knowledge proved instrumental in proficiently analyzing data, executing the system, and assessing its impact on user satisfaction. Additionally, the researcher was able to learn from the shortcomings and limitations that previous researchers encountered, thus enhancing the overall quality of the study.

The design method:

To describe the schematic representation and functional specifications of the components of the software system, explain how users interact with the system, and express a general idea of the software system's potential uses, VLCL's design is based on UML, a contemporary method of software modeling and documentation. To explain the design esthetic (Tuparov, 2012):

- Class diagram of the variables in the system figuring1.
- Use cases for system functionality.
- Effect on the surroundings (actors who are active subjects).
- Establish a connection between use possibilities and current issues (using use case diagrams). Figure 2.
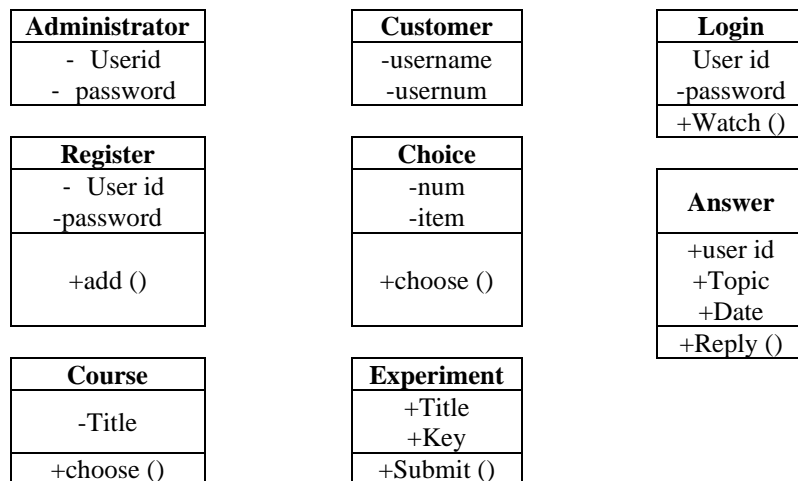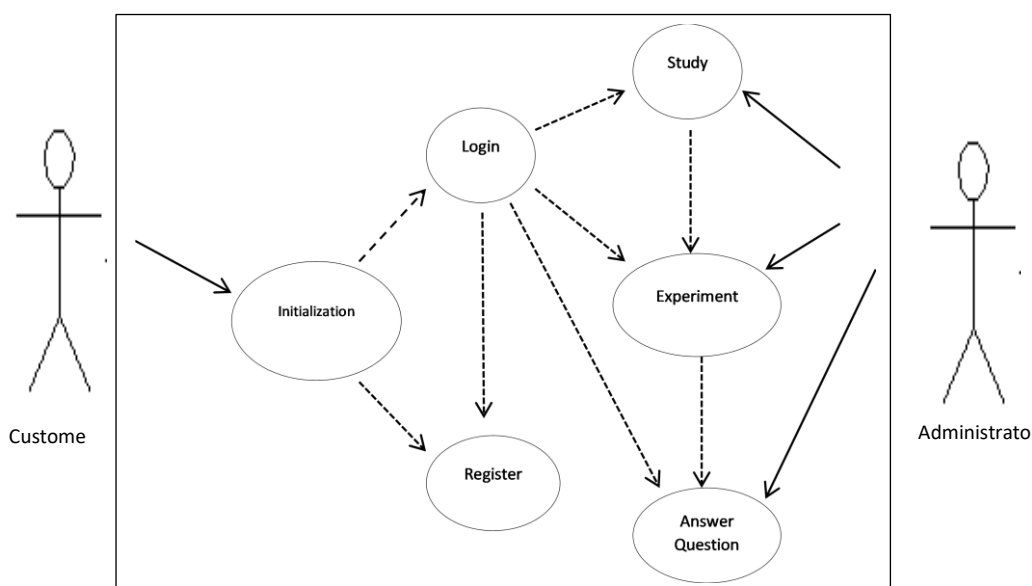

Figure 1 Class diagram

Figure 2 Use case diagram.

The virtual laboratory user groups are identified following the analysis and design of the functional needs, along with a thorough explanation of the steps that must be taken by each user to perform the functions in line with his or her rights. Design features:

- It must not depend on the operating system being utilized; it must be platform-agnostic.
- Optimal resource usage on both the client and server sides, meaning that it should not require more user resources than are already available.
- No specific program installation is necessary beforehand.
- The "presence" of both the teacher and the student in a virtual environment is not always necessary.
- Having a user-friendly interface
- It will be created using open-source software.

VLCL Architecture:

The VLCL system's architecture seeks to make it easier for students to understand and retain information by offering a sequence of course components that is both integrated and entertaining, with the potential to lengthen learning time. With the teacher's assistance, it can be used repeatedly, as many times as necessary, without being dispensed. Additionally, it offers a chance for review (Supahar, et.al, 2020).

The semantic structure of the VLCL software system is straightforward and user-friendly, and it comprises a set of terminology that is provided for the fundamentals of programing curriculum using C++. Figure 4 displays this terminology. The architecture of the VLCL and a detailed description of each unit are shown in the accompanying figure:
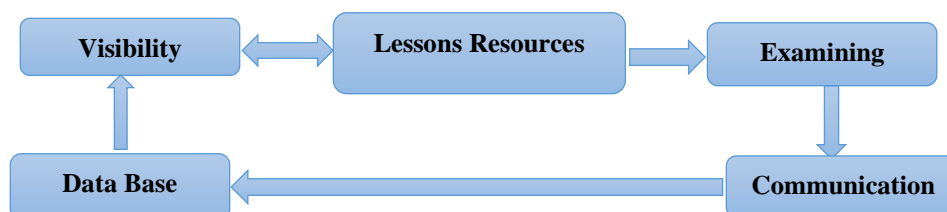
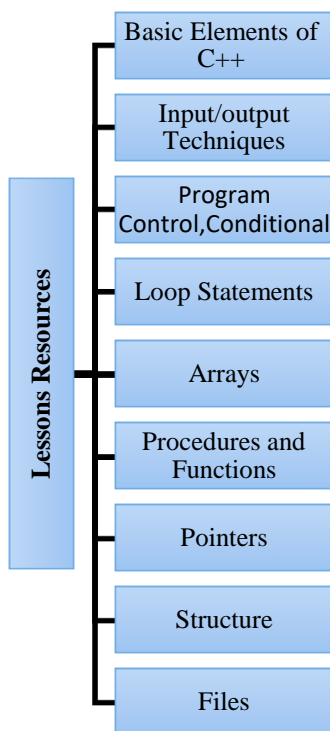**Figure 3** Architecture of VLCL.

Figure 4 Lesson resources in VLCL

1. **Basic Elements of C++**: It identifies: the symbols used in the language, declarative names (variables, constants), data types, tools used in the language (arithmetic, relational, logical, exact), and the priority of operations for arithmetic tools.

   - Input/output techniques include assignment operators, input functions, and output functions.
   - Program Control, Conditional: Learn how to execute sentences if a certain condition is met, the conditional operator if and else, and the switch statement.
   - Loop Statements: for loop, while loop, do-while loop, break statement, continue statement, and nested for loops.
   - Arrays: one-dimensional, multidimensional, and strings.
   - Procedures and Functions: This includes identification and declaration, scope of variables, arguments passed by value and reference, and recursive functions.
   - Pointers: static and dynamic variables, stack memory, defining a pointer type variable, operations on pointers, pointers and functions, pointers and functions.
   - Records: declaring a record; defining a record type variable; arrays and records, registers, and functions.
   - Files: declaring the creation of a file Text files.

2. **Examining**: The tests include several types of questions and exercises related to the skills and knowledge collected after the learning process through interactive teaching units, in order to judge the extent of the student`s knowledge and familiarity with the subject.
3. **Visibility**: A specific part of the website window of the relevant Interactive Learning Unit (ILU), provides the possibility of displaying information and images to reduce abstraction of concepts and increase visibility, in order to facilitate knowledge and perception.
4. **Database for VLCL users**: Administrator, instructor, and learner users of the system are separated. To participate in discussions and evaluate information, the user profile includes registration information and rights. Additionally, it includes data on students' achievement levels and test retake frequency. The power of the administrator is established by granting different users access to the system. Additionally, he has the power to use, save, and create reports using the database. The learner's authority is restricted to gaining access to educational resources, investigating programming codes by entering data and running simulations, and finally being able to take the appropriate test and receive an evaluation score. In contrast, the teacher is in charge of creating interactive learning units, tests and exercises, and simulations.
5. **Types of Communication**: The system can be accessed via either synchronous communication, which provides online chat, or asynchronous communication, which supports email and discussion forums.

VLCL implementation:

The student logs in via email to view the lessons, which are divided into two parts: explanation by reading the text and following the programs, and video explanation to include sound and images. The main system interface contains the tabs shown in Figure 5 for providing educational services. To determine the amount of knowledge and acquaintance with the subject, the student evaluates himself using a series of optional questions and runs the program's code to acquire the results in the assessment portion. We point out that all alternatives are accessible through the online interface, where every package can be executed independently and without regard to the order in which it is presented (for instance, conducting a self-examination or displaying a video demonstrating any vocabulary).
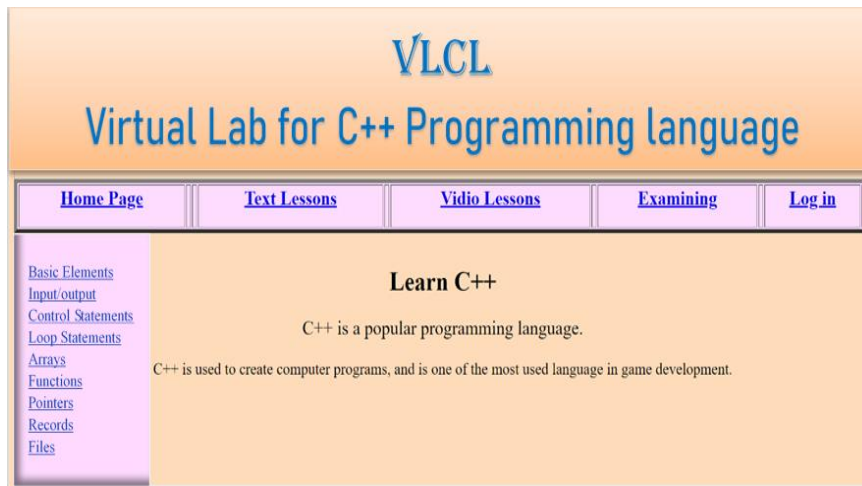
Figure 5 Main VLCL interface.

VLCL Evaluation:

Through questions and programs, the evaluation method measured the degree of academic accomplishment of the student. A questionnaire was used to assess the teachers` views and satisfaction with using VLCL.

1. Figure (6) demonstrates the processes for a single exercise or question when the learner is given three chances to complete it. If the response is accurate, a message is sent to reinforce it, and the evaluation results are kept so that the teacher may track weak and strong areas. Give him the right response if the answer is incorrect, and he can continue on to the next practice without taking his grade into account.
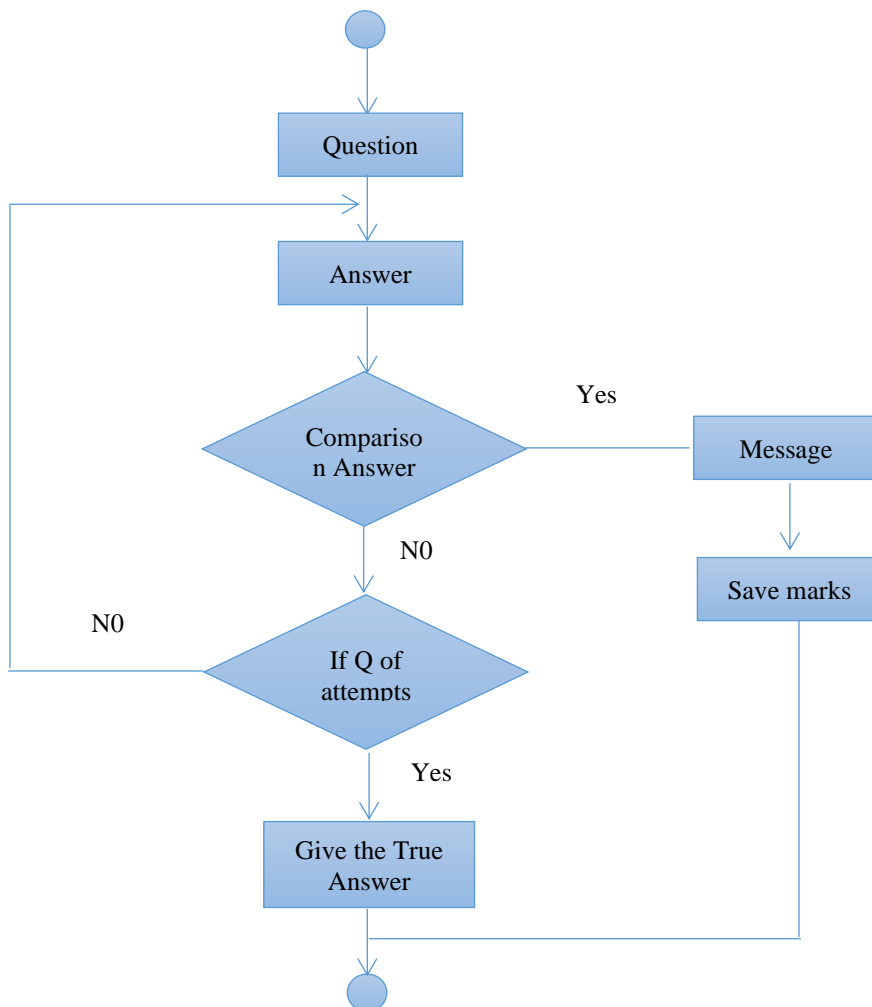

Figure 6 Sequence of steps for one exercise

2. Surveying the instructor's opinions about using the virtual lab to teach C++ in order to gauge their attitudes, as indicated in Table 1.

Table 1. A questionnaire measuring teachers' using VLCL

	Paragraph	I totally agree	I agree	I do not agree
1	The virtual laboratory increases student academic achievement	25	15	-
2	The virtual laboratory achieves the objectives of the prescribed curriculum	23	10	7
3	The virtual lab increases the interaction between students	33	7	-
4	The virtual laboratory is considered an alternative to the real laboratory	19	6	15
5	The virtual laboratory is characterized by suspense and excitement	20	18	2
6	The virtual laboratory provides greater opportunities for training	35	5	-
7	The virtual lab helps in the assessment process	25	10	5
8	The virtual laboratory is a burden on the teacher	9	23	8
9	The virtual laboratory is considered an alternative to the curriculum	-	15	25
10	The virtual laboratory requires additional time in the schedule	30	10	-
11	Traditional teaching methods yield better results than e-learning	-	-	40
12	The virtual laboratory is compatible with the individual differences in the students	12	22	6
13	E-learning gives the learner additional skills	20	20	-
14	E-learning is more effective than traditional education	28	12	-
15	E-learning helps perseverance and enhances participation, motivation, and desire for education.	37	3	-

Conclusions:

Based on the findings of the survey in Table 1 which was given to 40 instructors, it was determined that all of the educators favoured assessing their opinions toward using VLCL to teach C++ programming. Additionally, the instructional program generated an immediate response when it was tested and given to a group of children, and it was well-liked. This is evident from the correct responses recorded, which resulted from the material being presented using text, voice, and visuals. The same conclusion was reached by several results. It is evident from the foregoing that the VLCL system aids:

- Using interactive graphic design to simplify actual life so that it concentrates on what is needed without being distracted by concepts.
- Creating a secure environment for the user that, aids in removing any material, spatial, or temporal challenges faced by learners.
- Providing interactive coverage of every practical C++ course concept. Because of the constrained resources and time allocated for the practical component, this is challenging to accomplish in a real laboratory.
- There is learning available for all necessary and conceivable acts and situations.
- The student has complete control over the virtual system environment, including the ability to change, speed up, or repeat the presentation as well as the facts and events that occur.
- Through interactive graphic design, real reality is simplified because it concentrates on what is necessary without being distracted by concepts.
- Ensuring that the user is in a secure environment, which aids in removing any material, spatial, or temporal barriers that may stand in the way of learning.
- Interactively covering every practical C++ course concept. Due to the restricted resources and time allocated for the practical component, this is challenging to do in a real laboratory.
- Learning is possible for all necessary and conceivable deeds.

- Giving the student complete control over the information and events in the virtual system environment, and the option to change, speed up, or repeat the presentation.

Future work:
- Immediate implementation of the VLCL system. By selecting an appropriate implementation platform that is connected to the appropriate tools, a successful product is ensured.
- Making plans to create a technique for creating virtual programs that adhere to the structural criteria for the caliber of educational virtual reality software.

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