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Computer Assessment of Practical Skills (CAPS) using Scaffolding Methodology as Enabler of Learning

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Abstract

The crucial role of hands on experiments in the school science curriculum is universally accepted. However, a formal assessment of practical skills is lacking, with most schools employing the traditional theory based or multiple choice questions (MCQs) to evaluate students.

In this paper we discuss a framework for 'learning-enabled assessment' of practical skills, which gives due consideration to both the structure of the practical assignments and the feedback that promotes learning.

This approach opens up many new possibilities that require constructivist learning and higher order thinking skills. Judgment of skills based on performance reports may decrease the student's confidence. Whereas scaffolds used during the assessment process can improve a student's proficiency.

The design for various online scaffolds used during assessment, that help students' focus and redirect their efforts to the appropriate task needed for mastery of a skill is discussed here. Early studies have shown that students prefer this assessment to the traditional one; as intervention includes the appropriate hands-on simulation or an interactive animation for the concept.

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Introduction

The National Focus Group on "Teaching of Science" suggested prevention of marginalization of experiments in the school science curriculum. In this regard, investment is required for improving school labs to promote an experimental culture. However, there seem to be two main difficulties.

1. Experiments require a certain minimum infrastructure; a lab with basic equipments and materials. Azad et al. [1] have shown that learners have access to the physical lab for only a short period of time, the learning cycle is limited as the time is often not sufficient to try different scenarios.
2. Assessment of practical skills in science in an objective manner is a difficult task. The difficulty increases manifold if the assessment is to be carried out when a class size is large. Thus lack of infrastructure and more important, lack of reliable assessment has resulted in the unfortunate neglect of experimental work in many of the schools.

The Central Board of Secondary Education (CBSE), India has mandated continuous assessments in both theory and practical skills. As per the current assessment scheme, theory and practical examinations have a weightage of 60% and 40% respectively.

The practical examination comprise of two components.

1. One is the multiple choice format, which raises a question. How to test accurately, when majority of the questions are in the multiple choice format where intelligent or random guessing is common; as there are no negative marks for incorrect answers?
2. The other component is the actual performance of the experiment by the student in the lab.

Currently, CBSE has made sure that expensive equipments are not part of the practical curriculum so that most schools can afford it. Online labs can remove this limitation and allow students to practice in all areas of experimentation, irrespective of the expenses or cost involved. Integrating online labs with assessment of practical skills can offer support for the Continuous and Comprehensive Evaluations (CCE) program mandated by CBSE.

Scaffolds Used During Assessment

One of the most important components in course evaluation is the assessment of lab work. Today, lab work is often judged by the results (summative assessment) observed in the written lab reports (reporting related skills) submitted by students after experimentation, rather than evaluating the skills acquired by students and providing immediate feedback (formative assessment) while conducting the experiment in the lab (procedure related skills). Practical skills assessment needs to evaluate both reporting and procedure skills. Weightage for procedure and reporting skills in each experiment need to be determined based on the lab objectives set for that particular experiment.

An often neglected but important component in making learning effective is the assessment for learning, as traditional assessments for labs are often limited to theory and multiple choice questions.

Our objective is to design and develop a system for Computer Assessment of Practical skills (CAPS) capable of assessing an experiment's procedural, manipulative and reporting skills. Having these experiments available online, addresses the issues of simultaneous access for large number of students and their evaluation.

Literature Review

Bryce and Robertson [2] (1985) in their review of the literature regarding assessment in the lab, wrote that in many countries teachers spent considerable amount of time in supervising lab work, but the bulk of science assessment is traditionally non-practical in nature.

Based on a study in the context of learning in Biology conducted by [3] Yung (2001) in Hong Kong, he presented data that demonstrate the complexity of assessment in school science labs. He claims that even as we enter the 21st century, teachers continue to assess their students using paper and pencil tests, thus neglecting many of the most important components of students' performance in the science lab in general, and the inquiry laboratories in particular.

Continuous assessment of practical work is necessary to adequately cover the variety of tasks and skills that comprise a total program of science-based practical work. The advantage of the continuous assessment of students' work in the lab is discussed in detail in a comparative study by [4] Ganiel and Hofstein (1982). Computer Assisted Assessment (CAA) can stimulate, motivate, be diagnostic and reinforce learning by providing directed feedback [5] (Freeman & Lewis, 1998).

[6] Gibbs et al. (1997) have addressed the purposes of lab work as;

- Developing practical skills.
- Familiarization with lab equipment, techniques and materials.
- Developing data-recording and analysis skills.
- Developing experimental design and problem-solving skills.
- Developing communication and interpersonal skills.
- Developing technical judgment and professional practice.
- Integrating theory and practice.
- Motivating students.

Even in schools with labs, considering the varied ability level of students, the allocated time for experiments is often not enough for all students to complete their tasks satisfactorily and gain sufficient experience through the process [7] (Boyle et al. 1997).

Scaffolding is the precise method that enables a learner to achieve a specific goal that would not be possible without some kind of support [8] (Sharpe, 2006). [9] Puntambekar and Hubscher (2005) described the central features of scaffolding as; common goals, ongoing diagnosis, dynamic and adaptive support, dialogues and interactions, and fading for transfer of responsibility. Scaffolding can also be characterized as, helping the learner with the more difficult or extraneous portion of the task allowing the learner to complete the primary learning objectives, the real task, of the activity [10] (Shepard, 2005). He links scaffolding with formative assessment through the shared characteristics: eliciting prior knowledge, providing feedback, teaching for transfer, and teaching students to self-assess.

Human tutor scaffolding may be more valuable than computerized or written scaffolding because of a human tutor's ability to pick up on subtle cues from the student [11] (Holton & Clarke, 2006). However, several authors acknowledge that one-to-one scaffolding cannot readily occur in a classroom with many students and one instructor.

Amrita Learning

As part of the Amrita Learning initiative, we have created an Adaptive Learning Management System (ALMS). ALMS emulates a one-on-one tutoring system based on intelligent learning principles. Various modalities support the different visual, auditory and kinesthetic (VAK) learning styles, and learning preferences support tutorials, animations, videos, graphics, simulations and summary or detailed information [12].

The initial application of the ALMS was in the development of adaptive assessments with automatic presentation of multimedia tutorials for intervention based on proficiency levels [13].

Amrita Learning Online Labs (ALOL)

Amrita Learning Online Labs is based on the idea that lab experiments can be taught using the internet, more efficiently, less expensively, and offered to students who do not have access to physical labs. It was developed to supplement the traditional physical labs. It may even replace the traditional labs as in the case of rural schools in India, where lab facilities are missing, enabling them to compete with other students in better schools, thus bridging the digital divide [14].

ALOL further helps the students prepare themselves before attending a lab by becoming acquainted with the equipments, going through pre-lab exercises and taking pre-lab quizzes, both on the content of the work and on the safety considerations of the lab, all through online exercises.

[14] Raghu Raman & Nedungadi have detailed the steps to provide students access to online science labs; to perform, record and learn experiments; anywhere, anytime. There are ranges of learning models in which these resources can be used and the benefits of using these as learning aids have been widely accepted. Online labs may be offered as a pre-lab learning

tool; to provide additional activities, to support teaching or learning of a concept and to evaluate the student. It can also be used as a supplementary learning in schools which have the physical equipments to perform the experiments, but have no physical labs.

Computer Assessment of Practical Skills (CAPS)

Assessments can be enhanced using multimedia to assess higher order thinking skills, problem solving, and can enrich the experience. In our system we discuss about allowing a student to explore, construct and experiment before coming to a solution.

The Computer Assessment of Practical Skills (CAPS) tests the following skill areas:

1. Procedural and Manipulative skills.
2. Concepts and Understanding skills.
3. Reporting and Interpretive skills.

Implicit feedback occurs with Amrita Learning Online Labs, in that the learner sees the results of his action. However to provide formative assessment to assist learning, further feedback is required.

With CAPS, students will be able to;

- Perform the actual experiments on the computer and record answers (steps followed in performing the experiment will also be recorded and observed).
- Manipulate, observe and interpret or predict during assessment even with multiple choice questions.
- Get immediate feedback on their actions.

Assessment of Procedural and Manipulative Skills

Under this category a student must be able to select the appropriate apparatus (Figure 1) or sequence the steps (Figure 2) needed to perform the experiment and remove unrelated ones. The student should know the limitations of the apparatus and be able to assemble and handle the instrument. The student should be able to rectify errors in an apparatus and dismantle the experimental setup.

The student may be asked to choose either the correct apparatus or the materials needed for an experiment, or assemble the materials for a given set.

For example, a commonly used experiment for Newton's Second Law of motion is the cart experiment, where the cart accelerates when an external force is applied to it. The aim of this experiment is explore the relationship between the magnitudes of the external force and the resulting acceleration.

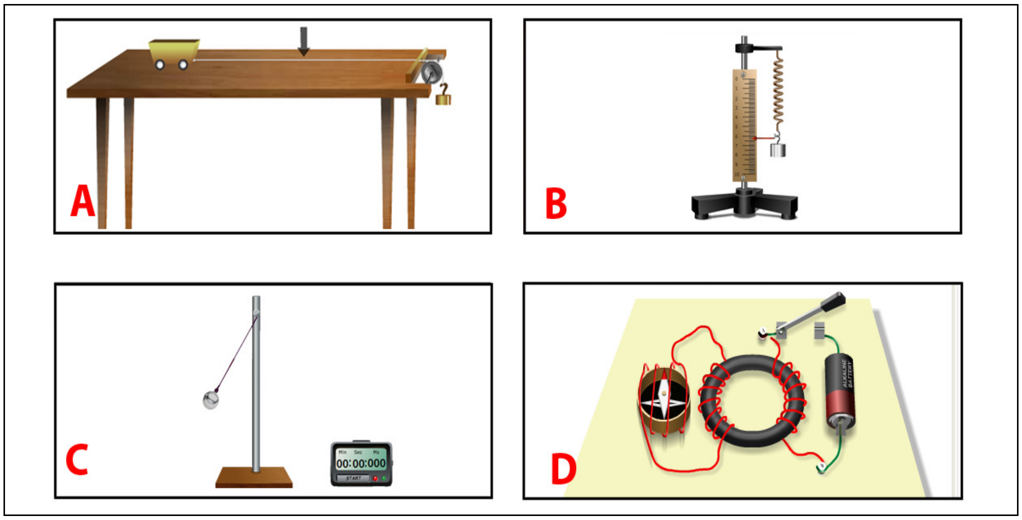

Figure 1: Assessment asking the student to select the right apparatus

The variables for this experiment include changing the friction, the weight of the cart, and the weight to be hung, and the distance moved by the cart. In another instance of this simulation, time is a variable, while the distance is fixed.

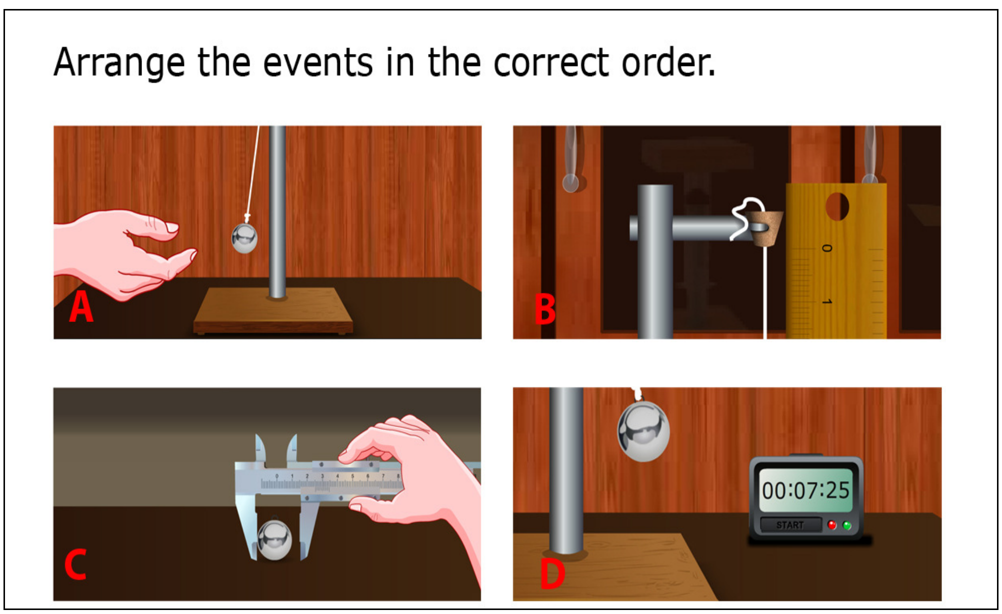

Figure 2: Assessment asking the student to sequence the steps for the experiment

Assessment of Concepts and Understanding of the Experiments

This includes reading the instruments correctly, noticing the color changes or any visible changes, locating the desired parts in a specimen, and understanding the scientific concepts and applications of the experiments.
The following sample question shows the scaffolds used for an experiment.

In an experiment to test the pH of a given sample using pH paper, four students recorded the following observations:

Sample Taken	**pH paper colour turned**
a. Water	Blue
b. Dilute HCl	Red
c. Dilute NaoH	Blue
d. Dilute Ethanoic Acid	Orange

Which one of the above observations is incorrect?

Figure 3: Multiple choice question testing understanding of concepts

Choice a) is the incorrect observation and hence the correct answer choice. In case a student incorrectly selects choice b) instead of a), the first interactive animation (Figure 4) would be shown to teach the learner that b) is actually a valid choice and then the second instance of the animation (Figure 5) is shown to teach that a) is an incorrect choice. The student can perform both the simulations to understand the concepts.

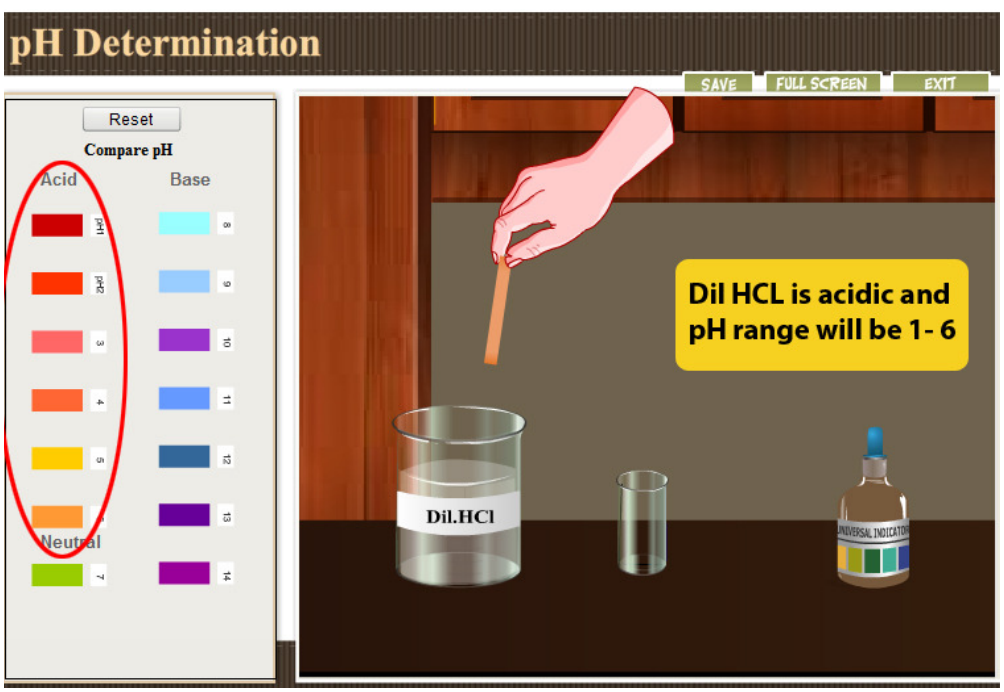

Figure 4: First Scaffold to learn from the error

The simulation shows dilute HCL is acidic based on the color change. Its pH value can be obtained by comparing the color of the pH paper to the colored boxes with the PH value shown against each box.

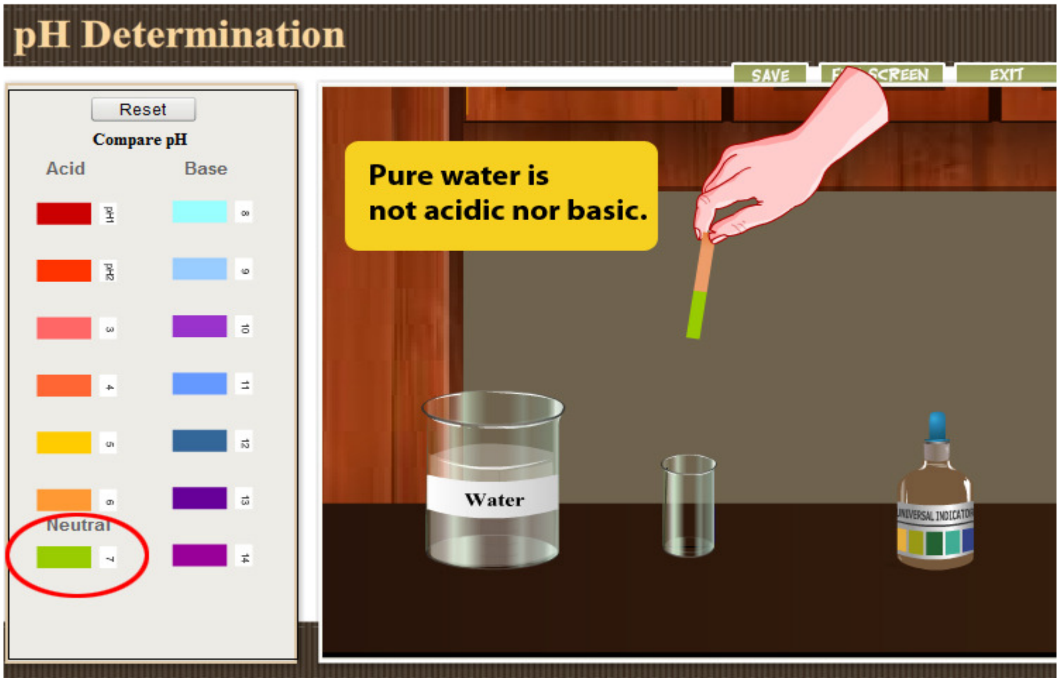

Figure 5: Second Scaffold to help learn from the same error and show the right answer

The simulation shows water is neutral based on the color change of the pH paper and thus is non acidic.

Assessment of Reporting and Interpreting Skills

These include recording the observations, data and information, correctly and systematically; classifying and categorizing; making correct calculations with observed data, and using the right formulae; reporting results using correct units, symbols; and interpreting the results correctly.

- Record the observations, data information (Figure 6).
- Choose the appropriate graph and label them.
- Plot the data points on a graph (Figure 7).

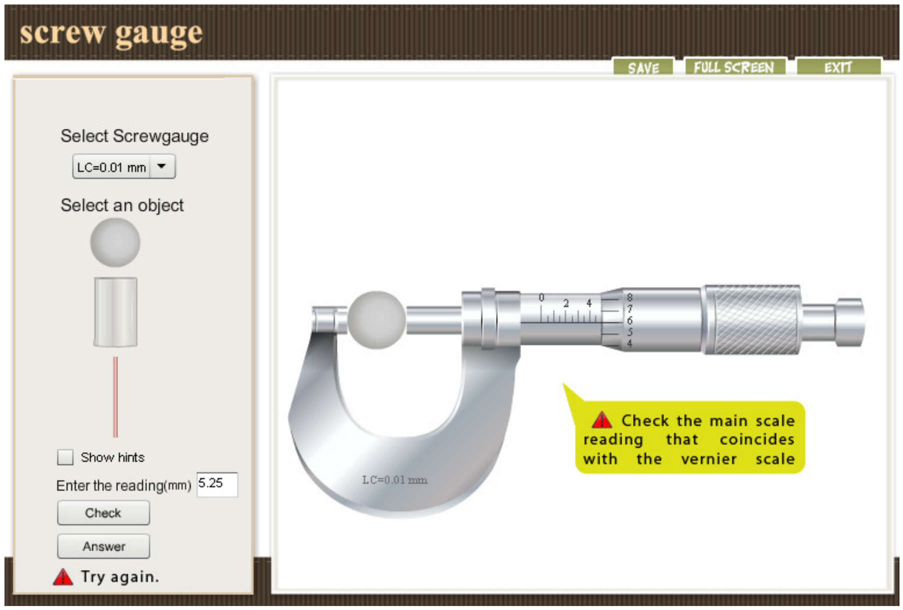

Figure 6: Assessment with feedback to compare student reading of data to stored experimental data

Take the case of assessing a student's ability to record observations. A simulation is shown with a fixed starting set of variables and viewed up to the end. This part is a passive viewing by the student and can be replayed by the student. Then the student may be asked to choose the correct table format and enter the variables and the recording observed. Sample questions can include recording information about the experiment, observing results and creating a graph for the readings.

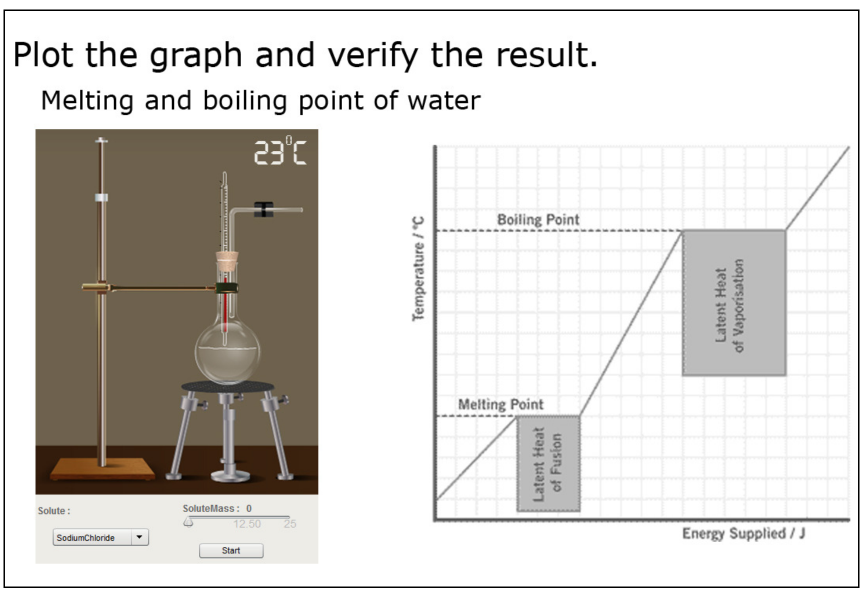

Figure 7: Assessment to plot a graph based on the simulation

Assessment scheme for a sample experiment based on the skill areas

Skill Area	Weightage
Procedural and Manipulative Skills	35%
Concepts and Understanding	40%
Reporting and Interpretative Skills	25%
Total	100%

The weighting for the different skill area can be varied based on the nature of the experiment and as such the assessment scheme must be transparent to the students.

Recording and Reporting of experiment data

We track every input of the student, including the current state of the experiment, mouse clicks, variable changes, pages visited and time spent. This provides a complete history of all student activity. Based on the analysis of this data, the learning style and the student level; scaffolding intervention in the form of thinking clues, tutorials, reviews or help is provided, much as the teacher would do in such a situation.

Such data can provide insights for both teachers and students into strategies, common mistakes and missing concepts after exercises. It is also possible to distinguish between a problems solving attempt from one involving guess work.

Initial results

This project was implemented for a period of 13 weeks with 36 students and 3 teachers. Total of 3 sets of experiments where considered. On an average each student spent 2 sessions of 25 minutes each per week working on the system.

Figure 8 below summarizes the results of a questionnaire given to the students. 5 point Likkert scale was used to administer the survey.

1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree

Questions	Average score
Simulations were helpful to understand the concept	4.9
I like the way system provides hints during experiment	4.7
I like the way I can manipulate the equipments using simulations	3.8
The system is easy to use	4.7
I like the fact that I can see the results of my work immediately	4.9
I like getting immediate feedback on my work	4.8
I do not see too much advantage of CAPS over the traditional approach of physical labs	2.6
The actual process of using CAPS is enjoyable	4.8
The project should be extended to all Science subjects	4.7
It has helped me understand concepts in the subject	3.5

Figure 8: Results of Questionnaire proposed to the students

Conclusions and Next Steps

Given the high costs of building a physical lab and the amount of time it occupies in the school curriculum, effective assessment of practical skills is important. Though there are many online labs such learning enabled assessments for online experiments with scaffolds are still not commonly available.

The main considerations of a new technique for assessing online labs that are discussed in this paper are;

- Design and architecture of online labs with scaffolds built into assessment for online labs for procedure, manipulative and report related skills.
- Additional cost and time involved to build such scaffolds for the online assessment taking into account the time spent in creating animations, taking videos, drawing graphics, making simulations, preparing tutorials, procedure or detailed information and developing the appropriate software.
- Early studies have indicated that the majority of the students are interested in learning enabled online assessments.

Future work includes studies analyzing the patterns of student usage and their perceptions of online labs and using this to determine the interventions that maximize learning for the student.

Acknowledgement

This project derives direction and ideas from the Chancellor of Amrita Vishwa Vidyapeetham, Sri Mata Amritanandamayi Devi. This work is funded by Amrita Vishwa

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RAGHU RAMAN is the Principal Investigator for the National Mission project on ERP and for the Online Labs for Schools from Department of IT. He heads the Center for REsearch in Advanced Technologies for Education (CREATE) at Amrita, guiding research projects in the areas of Adaptive Learning Systems, ERP Systems, Virtual Labs with scaffolds, Intelligent Video surveillance, Multimedia technologies in education that has societal impact. Raghu has over 22 years of executive management experience from NEC Research Labs, IBM, and Informix etc. He is the PI for the National Mission on ICT ERP Project and for the Ministry of IT Online Virtual Labs project.

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