STUDENTS' LABORATORY WORK PERFORMANCE ASSESSMENT

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ABSTRACT:

Laboratory activities are very important in engineering education. Performance assessment of students' laboratory work is time consuming and an ongoing challenge for teachers. Laboratory work performance assessment is traditionally done by the teacher grading students' written report of the laboratory activity, despite the fact that the report is often 'doctored'. Assessment of laboratory work based solely on students' reports has been criticized as failing to address espoused aims. The assessment situation of laboratory work is compounded by the widespread adoption of virtual laboratories (vlabs) where assessment is no less critical. This paper presents a laboratory work performance assessment model for the Virtual Electronic Laboratory (VEL) environment. The model harnesses the strengths of Bayesian Networks (BNs) and is based on ideas from Intelligent Tutoring Systems (ITS), learning theories and definitions of learning.

1 Introduction

Laboratory activities are very important in engineering education and can be enhanced by Computer Aided Learning (CAL) tools. Vlabs, a CAL tool, have been adopted to enrich laboratory activities and are proven to impact positively on students' learning. However, the major driving force for all learning activities is assessment without which there is no measure of student performance [1]. Laboratory work assessment is done by the teacher grading students' written report, despite the fact that the report is often 'doctored' [2]. Assessment of laboratory work based solely on students' reports has been criticized as failing to address espoused aims. Also, grading reports is challenging and time consuming, especially for large classes which pose problems of fair, consistent and timely assessment. The assessment situation of laboratory work is compounded by vlabs where the need for performance assessment is no less critical.

Presented here is a LAboratory Performance (LAP) assessment model. The LAP model would provide a framework for fair, consistent and timely assessment of students' laboratory work in a VEL environment. The model is based on the constructs of cognitive abilities and skills and harnesses the strengths of BNs. Every ability is a potential for performance with respect to a domain but each potential has to be thought of in probabilistic terms [3].

2 The Virtual Electronic Laboratory

The VEL consists of a Graphical User Interface (GUI)) and a set of Server applications. The GUI (Figure 1) is an interface to practically construct and simulate electronic circuits. Components and devices are provided on the GUI.

Figure 1: The virtual electronic laboratory GUI

A set of server applications run at the back-end together with Spice Opus Lite, for simulating constructed circuit. Spice Opus is invoked after the schematic of the constructed circuit is captured and netlist is generated. All actions and events (mouse clicks and key strokes) on the GUI are time stamped and logged for performance analysis.

3 The Assessment Model

4.1 Foundation of the Model

Learning is viewed from three schools of thought: behaviourism, cognitivisim and constructivism. Behaviourism asserts that learning takes place as a result of the response (R) that follows a specific stimulus (S) and by repeating the S-R cycle there is conditioning into repeating that particular response whenever the same stimulus is applied. Constructivism and cognitivism assert that internal mental processes and states/traits, such as abilities/skills among others, combine to produce an instance of behaviour, but constructivism views learning within a social context.

Cognitive learning is one of the four broad aims of laboratory work [1]. Individuals come to a given cognitive task with differing backgrounds of stored mental states and traits resulting from learning which support and determine the limit of individual performances [4]. Abilities are discernable from their effects in terms of performance and are inferable from observable behaviour because internal traits are reflected in behaviour [4]. The assessment model takes this behaviour observation and trait inference perspective. The base structure of the performance assessment model is rooted in our model of learning.

4.2 Our learning model

Learning theories and models have impacted on the educational process (instruction, learning and assessment). Learning theories are ideas about how learning may happen and are meant to be applied in the instructional process in order to facilitate learning and assessment. The aim here is not the discussion of theories and models of learning but the integration of ideas from the literature on learning to generate a model of learning to serve as the basis for the assessment model. Our model of learning is based in part on the theories presented by Race [5] and Marzano et al [6] and rich definitions of learning from various sources [7][8][9]. The learning model expresses our view of learning and constitutes a framework for the performance assessment model presented in this paper.

In developing the model, the question “What is a model of learning?” needs to be answered. To this effect it is suggested that a model of learning is a way of conceptualizing the learning process in such a way that learning can be addressed by instruction and assessment. This leads directly to the learning model below which is concerned with the basic components of learning that are assessable. Thus, the model is confined to the broad framework of learning as consisting of four variables: knowledge, abilities/skills, understanding and motivation:

- Knowledge (Learning as knowing): acquiring and storing facts, concepts, rules, principles.
- Abilities/Skills (Learning as doing): acquiring and applying abilities and skills; mastering procedures and techniques.
- Understanding (Meaning Making, Making Sense of): learning as knowledge; association of facts, principles and concepts in relation to specific tasks or problem situations.
- Motivation (Wanting to learn): This is the energizer for the first three.

This framework (schematically depicted in Figure 2) constitutes the basis from which to derive a set of variables for the assessment of students’ laboratory work performance. This is consistent with a view of assessment as a generic term for a set of processes that measure the outcomes of learning, in terms of knowledge acquired, understanding developed, abilities and skills gained [1]. Harvey’s [10] assertion that assessment is the process of estimating the extent to which learners have developed their knowledge, understanding and abilities buttresses this view. The use of this framework for laboratory performance assessment is consistent with Campbell’s [11] and Campbell et al’s [12] definitions of performance as a direct function of declarative knowledge (knowledge about facts, principles, goals and things), procedural knowledge and skills (processes underlying performance behaviours) and motivation, which they identified as affecting task performance. “Motivation represents the combined effect of three behavioural parameters: choice to expend effort, choice of level of effort to expend, and choice to persist in the expenditure of that level

of effort" [11]. This definition of motivation is consistent with de Vicente and Pain's [13] taxonomy of measurable motivational trait variables. These variables are indicated as direct determinants of performance.

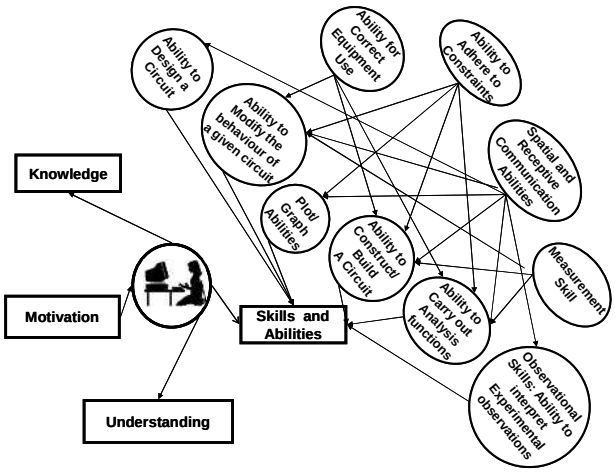

Figure 2: Schematic representation of the framework for the assessment model.

4.3 The Assessment Model

The assessment model is BN based. To build the model, we take a modified approach of [14]. Figure 3 is a high-level representation of the model based on the above approach. Student behaviour refers to student's observable actions (mouse clicks and key strokes). These actions are closely "observed" and logged for analysis. The click streams are transformable by filtering, aggregation and abstraction in order to allow actions and sequences of interest to emerge [15] and yield information and data that can be used as primary input into the assessment model.

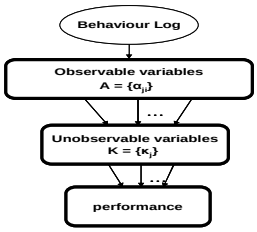

Figure 3: High-level view of the assessment model

The analysis of the click streams must be done in the context of the model in order to yield the evidence (evidence extraction) necessary to infer performance.

4.4 Evidence Extraction from Behaviour

Evidence variables derive their values from the analysis of the log of a student's behaviour. For every ability or skill (unobservable variable) κ_j, that students' are expected to demonstrate or apply to carry out a laboratory activity, a set of evidence or observable variables α_{ji}, i = 1 to m, are required to infer that the student has demonstrated or applied the ability or skill. We have established rules for evaluating α_{ji} from the student behaviour data, e.g., if a student is required to apply the ability to calculate and use a feasible value for a circuit component (i.e. κ_j = Calculate and use a feasible value of a component), to carry out a laboratory activity. This may require the application of a formula and the use of a calculator in order to arrive at a feasible value for the component. It may be inferred, from the student behaviour, that he applied the desired ability, from the Bayesian network segment of Figure 4.

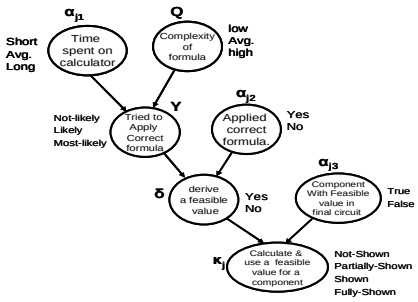

Figure 4: Bayesian network segment

Knowing the amount of time (α_{j1} = Time spent on calculator) the student spent using the calculator and the complexity of the formula (Q = complexity of the formula) we may infer that the student tried to apply the correct formula (Y = tried to apply the correct formula). Knowing that he/she tried to apply the correct formula and/or that he applied the correct formula (α_{j2} =Applied correct formula) could help arrive at a measure of belief that the student derived a feasible value (δ = Derive a feasible value) for the component. Knowing that he/she derived a feasible value and/or that the Component with a feasible value is in the final circuit (α_{j3} = Component with Feasible value in final circuit) will help reason about κ_j, his ability to calculate and use a feasible value of a component for a laboratory activity. To reason about κ_j, we need to instantiate the evidence variables α_{j1}, α_{j2} and α_{j3} from the analysis of the student behaviour. Q will also need to be instantiated but it does not derive its value from the analysis of the student behaviour. The sets K = $\{\kappa_j\}$ and A = $\{\alpha_{ji}\}$ have to be identified and the rules for deriving the values of α_{ji} from the student behaviour have to be specified with help of experts in the domain. The behaviour log has to

be analyzed at different level of granularity for the κ_j's. The problem of identifying the set K and the associated αji for each element κ_j, is done with the help of experts and achieved using cognitive ability-evidence maps, two-dimensional matrices of abilities and evidence variables.

5.2 Calibration of the Model

Since the model is a measurement tool, there is need to calibrate it. In the context of this work, calibration is the process of obtaining initial estimates and assignment of values to the BN variables. This includes the assignment of prior probability values to evidence variables and the creation of conditional probability tables for other variables. Any or a combination of the following methods may be used to calibrate a BN:

- principle of maximum entropy
- direct expert calibration
- empirical estimation and/or use of subjective estimates
- Estimation/Maximization technique (EM)
- pencil and paper testing of each skill by items

Cost and time constraints make the use of direct expert calibration more attractive.

6 Conclusion

Assessing students' laboratory work performance is challenging. The LAP model designed around four learning related clusters: knowledge, abilities/skill, understanding and motivation has been presented as a possible means of easing the teachers' workload and promoting fair, consistent and timely assessment of students' laboratory work. The model is intended to evaluate students' performance based on a list of discrete behaviours. The criteria against which performance is inferred are hierarchical and various methods are used to describe the level of performance and inference is made on the basis of evidence from identified criteria.

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