Identifying the Nature of Knowledge Using the Pressures Applied to a Computer Mouse

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Abstract. The nature of knowledge retention is not that a student either knows or doesn't. Using signal detection theory, the correct and incorrect responses a student provides can each be subdivided into two more levels of knowledge using the student's confidence of answer correctness. The proposed study will attempt to link confidence of answer correctness to the categorized pressures applied to a computer mouse allowing for the partitioning of responses. Twenty participants that were part of a pedagogical methods study will be retested using a computer-based multiple choice test and pressure sensitive computer mouse. Participants will also rate their confidence of answer correctness. It is hypothesized that the analyzed pressures applied to the computer mouse will indicate the confidence of answer correctness. Using the categorized pressures from the computer mouse allows for the real-time assessment of a student's knowledge to guide pedagogical follow-up.

Keywords: knowledge, pressure sensitive computer mouse, confidence of correctness.

1 Introduction

Assessing how much students truly understand is an age-old challenge for educators. An ideal assessment is one that can easily probe a student on materials, but can understand the depth of knowledge about the materials. A good instructor can easily question a student to investigate whether they have a complete understanding or if they still lack basic knowledge; however, these types of assessments are not always feasible. Many educators rely on multiple choice exams, which have many benefits such as ease of grading, standardization, and scalability. However, how accurate can multiple choice exams be for assessing the knowledge of materials? When a student answers a multiple choice question correctly, it is assumed that the student has sufficient knowledge about the topic of interest. Should the student answer incorrectly, it is assumed that some form of review is required. However, the answer given, particularly on a multiple choice exam, does not give transparency to whether the student actually understood the question or the topic.

The nature of knowledge retention is not that a student either knows or doesn't, but is much more complex. Using signal detection theory [1], both correct and incorrect answers can be subdivided into two categories.

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1. Correct
    a. Based on appropriate knowledge (i.e., Desired)
    b. Correct – Based on guessing (i.e., Lack of knowledge)
2. Incorrect
    a. Lack of knowledge
    b. Based on inappropriate knowledge

Were there a way to identify these four cases, the follow-up to the response could be more appropriate. Case 1a is recognized as the desired educational outcome and the student would be rewarded for being correct. Case 1b and 2a would both require review of the topic to increase the student's knowledge and Case 2b would require correction of the inappropriate knowledge. Without being able to identify the cases, Case 1b would not require the needed topic review and Case 2b would not specifically address identifying and correcting the inappropriate knowledge.

Detecting these four cases is important to apply the correct educational remediation. As described above, not identifying these cases leads to inappropriate education follow-up half the time. Identifying guessing behavior is possible by measuring the response time based on previously difficulty rated questions from a large number of subjects [2], but this is impractical for regular and small size classes and would require always using the same difficulty rated test questions.

Self-assessment of confidence of judgment of the correct answer is a possible method to identifying the four cases. People generally tend to be over-confident about answer correctness, but there is a correlation between confidence and answer correctness [3]. The feedback on answer correctness the student sees when viewing the results of the post lesson test will tend to better calibrate and reduce the overconfidence of judgment of answer correctness [4]. The problem with the self-assessment of confidence of answer correctness is that it is a disruptive burden for the student during testing.

This paper proposes a more automated system for identifying the four cases. Preliminary pilot studies using the click signature obtained from pressure sensors on a computer mouse acquired during the task performance has indicated that a greater distortion in the signature occurs when the task increases in difficulty. It has also been shown that the pressures applied to a computer mouse can be use to assess cognitive load [5, 6, 7, 8]. It is hypothesized that the mouse click signature can be used to identify the four cases that occur when responding to a question.

Among the questions this study will attempt to address are:

1. Is confidence of judgment a good indicator of correctness of answer?
2. Is the mouse click signature a good indicator of correctness of answer?
3. Does confidence of judgment correlate with mouse click signatures?

Table 1 shows in bold the two desired response paths for a student who has knowledge of a topic and has answered a question in a post lesson test upon completing a topic. Then a few months later answers the same or similar question in a retention test. The first desired path of the state of knowledge is that the student retained the correct knowledge to respond to a question. The state of knowledge should be correlated to the student's confidence rating and in turn also correlated to the categorized pressures applied to a computer mouse. The second desired path of the state of

Table 1. Response to the same or similar question in post lesson and retention tests

Post lesson test response	Retention test response	State of Knowledge	Student's confidence rating	Categorized Mouse Pressure
Correct	**Correct**	**Retained correct knowledge of question (1a)**	**Certain**	**Lower distortion**
		Initially guessed correct in post-test (1b)	Uncertain	Higher distortion
	Incorrect	Did not retain correct knowledge (2a)	Uncertain	Higher distortion
		Incorrectly retained knowledge (2b)	Certain	Lower distortion
Incorrect	**Correct**	**Corrected the state of knowledge (1a)**	**Certain**	**Lower distortion**
		Correct guess in retention test (1b)	Uncertain	Higher distortion
	Incorrect	Did not retain correct knowledge (2a)	Uncertain	Higher distortion
		Retained Incorrect knowledge (2b)	Certain	Lower distortion

knowledge is when a student was incorrect in the post lesson test, but corrected and retained the correct state of knowledge. The student would be similarly confident of answer correctness and have a correlated mouse pressure response.

The words marked in bold are the two desired response paths for a student answering a question in the retention test indicating the state of knowledge, confidence rating and categorized mouse pressure.

2 Method

Approximately twenty participants will be retested using a computer-based multiple choice survey and pressure sensitive computer mouse. Participants will also rate their confidence of answering correctly.

2.1 Subjects

Approximately twenty participants that were in a CPATH grant to assess different methods of teaching computer science will be recruited for retesting of the knowledge they obtained in the computer class. The class would have ended two to four months ago and this test will access the participant's retention of the content of the class. Data of answers to the same or similar questions will be available for analysis.

2.2 Equipment

Participants will be taking the retention test using a computer and respond to questions by only using the computer mouse. The computer mouse being used is a

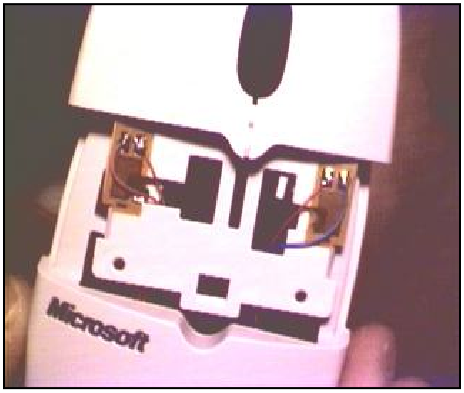

Fig. 1. Internal view of a computer mouse with pressure sensors on the buttons

pressure sensitive computer mouse (PSCM) where data on the pressures applied to the PSCM will be collected for analysis and categorization (see Figure 1).

2.3 Task

The task will be a set of computer based multiple choice questions. The first set will consist of "confidence of answer correctness" calibration questions. Then a set of topic retention questions from the previously taken computer programming class will be given followed by a final set of calibration questions.

Calibration Questions: The set of calibration questions will consist of ten multiple choice response questions selected to create varying levels of "confidence of answer correctness." An example of a question that should elicit a high "confidence of answer correctness" would be: "What is the sum of 4 + 9 + 10?" An example of a question that should elicit a low level of confidence of answer correctness would be: "What is the remainder of 37871 divided by 97?" Participants will be asked on the subsequent question to rate "confidence of answer correctness" for each question.

Confidence of Answer Correctness Question: A standard 5-level Likert scale will be used to assess the participant's "confidence of answer correctness." An example is shown below.

> The answer I gave to the previous question is correct. Please select one response.
>
> Strongly disagree
> Disagree
> Neither agree or disagree
> Agree
> Strongly Agree

Retention Questions: The retention test will be comprised of five to ten multiple choice response questions that are similar or the same as those the student had been previously tested on in the post lesson test. Participants will be asked on the subsequent question to rate "confidence of answer correctness" for each question. An example of a retention question is shown below.

> What will be the value of i after the statements at the right have been executed?

A.	11	int i = 10;
B.	33	int j = 33;
C.	34	while ((3 * ++i) < j)
D.	10	i = i + j++;
E.	None of the above	

2.4 Procedure

The participant will be briefed on the three sets of questions (i.e., calibration, confidence & retention) and how to answer the questions. There will be a time limit for each set of questions. The participant will not be allowed to use any aids when determining the answers to the questions.

3 Results

Analysis 1: An analysis on the data collected from the pressure sensitive computer mouse (PSCM) during the calibration question will compare high to low "confidence of answer correctness" to the pressures applied to the computer mouse. Previous pilot studies indicate that minimal difficulty is indicated by a sudden sharp pressure on the mouse button when selecting a response while high difficulty is indicated by a distortion of the pressure on the mouse button. It is hypothesized that responses to the "confidence of answer correctness" will be correlated to the level of distortion of the pressures applied to the computer mouse.

Analysis 2: An analysis on the data collected from the pressure sensitive computer mouse (PSCM) during the retention question will compare high to low "confidence of answer correctness" to the pressures applied to the computer mouse. It is hypothesized that to obtain the optimal correlation between "confidence of answer correctness" and the categorization based on the level of distortion of the pressures applied to the computer mouse for the set of retention questions, the normal distortion for an individual in mouse pressures as determined from Analysis 1 will be needed to normalize the data for each individual. Previous studies have found individual differences in pressure variation unique to the individual [9, 10].

4 Discussion

Assuming Analysis 1 and Analysis 2 can produce a reliable categorization of the pressures applied to the computer mouse indicative of the "confidence of answer correctness" it becomes possible to distinguish with the pressure sensitive computer mouse in real-time the four cases of response to a question. The benefit of real-time assessment of a student's knowledge to a question into four cases is that appropriate pedagogical follow-up can be executed immediately following the response. Using this method can improve both the assessment of a student's knowledge and appropriately respond to the state of a student's knowledge improving the learning outcome.

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