

Measuring tacit knowledge: the hidden dimension of laboratory classes and engineering practice

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Laboratory classes are valuable learning experiences, which can be used to effectively teach the link between theory and real-world behaviour of engineering systems and materials. Work in the engineering laboratory environment also provides students with opportunities to validate conceptual knowledge, work collaboratively, interact with equipment, learn by trial and error, perform analysis on experimental data, and how to operate tools and equipment safely (Feisel & Rosa, 2005). Although the main aim of laboratory work is to provide opportunities to learn and gain experience, we understand relatively little about what actually happens in a typical laboratory class.

Studies of engineering practice (e.g. Christiansen & Rump, 2007; Eraut, 2007; Huet, Culley, McMahon, & Fortin, 2007; Lam, 2000; J. P. Trevelyan, 2007; James P. Trevelyan, 2008; e.g. Wong & Radcliffe, 2000) have shown that implicit and tacit knowledge is just as important as explicit technical knowledge. Tacit knowledge develops in research laboratory work and many authors have commented on its importance, particularly in troubleshooting (e.g. Barley & Bechky, 1994; Gorman, 2002; Mody, 2005; Zucker & Darby, 2001). Experienced troubleshooters and technical investigators rely on significant tacit knowledge (e.g. Christiansen & Rump, 2007; Flesher, 1993; e.g. Johnson, 1989; MacPherson, 1998).

Through their laboratory classes, we could expect that students might acquire explicit and tacit knowledge. Nonetheless, when evaluating laboratory work for engineering students, the assessment involves only explicit specified learning outcomes. Tacit knowledge, implicit knowledge or practical intelligence has not been assessed or measured although it might be as valuable an outcome as explicitly stated learning objectives (Sternberg, Wagner, Williams, & Horvath, 1995). However, it is not easy to assess the level of tacit knowledge that students bring to the laboratory classes and any that they might 'unintentionally' gain through the experience. Tacit knowledge or practical intelligence can be defined as 'unintentional learning', and could also be useful learning outcomes from a laboratory experience alongside the explicitly defined outcomes. Could this be measured?

Typically laboratory classes have been evaluated by assessing explicit knowledge and student perceptions of their laboratory experience. We have not been able to find any research undertaken to measure tacit knowledge or 'practical intelligence' acquired during laboratory work. Of course, workshop skills have been traditionally assessed by observing students performing their work and the quality of the artefacts created in the process. Tacit knowledge is a critical part of these skills. Workshop skill courses formed a significant part of engineering education but were displaced by mathematical and science-based courses in the 1950s and 1960s.

Conventional approaches to assessment in engineering education focus mostly on explicit cognitive learning outcomes. Experienced engineers have told us that engineering graduates do not seem to be aware of the kinds of tacit or implicit knowledge needed in their work. This may result from the way in which explicit knowledge is valued in engineering education through only assessing explicit knowledge. This implicit devaluation of tacit knowledge might significantly impair engineering students' ability to acquire and value tacit knowledge. Developing ways to include effective assessment of tacit knowledge could be one way to overcome this difficulty.

Research Questions

The aim of this research is to find ways to measure changes in practical intelligence in order to assess unintentional learning, tacit knowledge, in engineering laboratory classes. In other words, we wish to develop ways to measure the experiential and "hands-on" component of learning laboratory classes.

We would also like to test the relationship between tacit knowledge acquired in laboratory classes with the ability to diagnose simple faults in laboratory equipment arrangements.

Theoretical Framework

Since the early 1980s there was extensive research (e.g. Sternberg et al., 1995) to find better ways to predict job performance to help with employment selection processes. This was part of a debate among psychologists on the relative value of general intelligence as a predictor of job performance. This research provided several situational testing methods which can be used to measure 'practical intelligence' or 'relevant job experience'. We intend to apply these methods to measure practical intelligence acquired through participation in laboratory classes.

Methodology

In the first phase of this research randomly selected students were observed individually during their laboratory experiments. The students were then interviewed informally after they had completed their assigned tasks. Through these early observations and interviews, we predicted the kinds of practical experience and tacit knowledge that students would acquire while they were doing the experiments.

We are in the process of designing an on-line survey instrument to measure practical intelligence related to introductory electrical engineering laboratory exercises which will be used to test a large sample of students (Razali & Trevelyan, 2007). The aim of this survey instrument is to assess practical intelligence by measuring some aspects of students' practical knowledge related to the laboratory experiments. The instrument describes a number of tasks, problems or fault conditions in which experience, tacit knowledge and implicit knowledge will be needed. The survey lists between 10 and 20 possible response items, each of which describes one possible method to solve the problem or execute the task. The response items were created as a result of careful observation of both students and experts and include highly appropriate responses and

also common inappropriate responses made by students. Respondents rate the appropriateness of each response item on a Lickert scale. The respondent score is calculated by calculating the deviation from the average responses of a number of domain experts such as technicians and experienced laboratory demonstrators.

A simple example is wire stripping. The respondents are asked to rate the appropriateness of different methods and tools for stripping insulation from wires. The response items include different types of pliers, using one's teeth, scissors and several professional wire stripping tools. Most of the response items consist of small illustrations to avoid issues with language comprehension. We have found that it is not easy to comprehend the basic level of knowledge (or lack of it) faced by students, including knowledge of technical terms.

The survey instrument will be used to test students before and after they perform the relevant laboratory exercises. A control group will be asked to complete the survey twice with a similar elapsed time between exposure, but without completing the laboratory task. We will test a null hypothesis that there is no statistically significant difference in the results between the respondents who perform the laboratory exercises and the control group. If this hypothesis is proved to be false, we can conclude that we can detect the acquisition of tacit knowledge. The results may also show if there is any difference in the level of practical intelligence among students before and after attending the laboratory experiments.

In the third phase of this research we will select a sub-sample of survey respondents and invite them to participate in a simple fault diagnosis task on some of the equipment they will have used in their laboratory classes. These students will be observed performing a troubleshooting task and their performance will be evaluated. We expect that this study will provide qualitative data that can be used to help understand the contribution of learning implicit and tacit knowledge to the ability to perform fault diagnosis tasks. We also hypothesize that practical intelligence acquired in laboratory experiments will be correlated with performance in troubleshooting tasks on similar circuits.

Findings

We have attempted to show the possibility of measuring practical intelligence or tacit knowledge that has not been assessed or measured in the past when evaluating different laboratory experiences for engineering students.

If we can devise effective ways to measure tacit knowledge acquisition by engineering students we may be able to alter their learning behaviour by including tacit knowledge tests in assessment processes. It is well known that assessment practice drives student learning behaviour (Gibbs, 1995). Testing tacit knowledge may motivate students to acquire the ability to learn practical intelligence which could ultimately make them more effective as practicing engineers. It is possible that they will learn to value the tacit knowledge and possibly relate better to tradespeople and technicians on whom engineers need to rely to achieve practical results from their work.

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