Advancing Diagnostic Skills Training in the Undergraduate Curriculum

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Abstract

Problems in complex technical systems tend to be undefined and the result of multiple causes. Diagnostic work to identify these problems is performed by engineers and technicians who need high level cognitive skills along with extensive system knowledge. However, there are few proven strategies to teach high-level diagnostic skills beyond using decision-trees or learning from experience of many years on-the-job. The objective of this research project is to test undergraduate engineering and technology students' development of diagnostic skills by analyzing complex technical systems using a computer-based instructional program requiring visual mapping activities. An intelligent engine provides feedback to students by comparing student drawn visual maps with those drawn by an expert. Preliminary findings reveal good potential for this computer-based program to efficiently develop a student's diagnostic skills. Partial support for this work was provided by the U.S. National Science Foundation's Transforming Undergraduate Education in Science, Technology, Engineering and Mathematics (TUES) program under Award No. 1140677.

1. Overview

This project focuses on the development and field testing of instructional design concepts and educational software to teach diagnostic skills necessary to identify and solve problems in complex technical systems. Using concept mapping software along with expert-system programs, the overall software package will enable undergraduates at the junior and senior-level in technology and engineering programs to benefit from personalized, iterative interactions that will permit them to design visual maps of a diagnostic strategy and evaluate their diagnostic strategy of a problem by receiving one of several feedback messages, including those of an expert. In some cases, students will be permitted to refine and resubmit their diagnostic approaches.

The computer-based modules are developed in the Lectora authoring system and incorporate the VUE concept mapping software. The self-paced, interactive modules will include an introduction stage, a visual mapping tutorial stage and a technical system and problem stage. Three technical systems will provide the context for a technical problem, the systems are: 1.) the electrical power grid, 2.) a complex manufacturing system, and 3. to-be-determined. The educational software can be tailored to include other technical systems and technical problems.

2. Theoretical Basis

Advancing diagnostic skills training for technology and engineering students is based on several theoretical anchor points: the first is cognitive development theory associated with the higher-order thinking skills of analysis and problem-solving; second is the application of hierarchical learning strategies in the acquisition of concrete, abstract and process concepts; and third, the proven practice of using iterative feedback, rubrics and expert examples in improving learning. These

foundational theories and principles will be integrated into educational software developed and delivered by stand alone or networked computers thereby adding to the toolkit of STEM instructors.

Through diagnostic learning, the ability of the individual to analyze causes based on information regarding the effects, one responds to cues, which correspond with effects. A significant characteristic of diagnostic inference is the ability to take into account alternative causes of the observed effect (Waldmann, 2000). Because the observation of effect cues lead to diagnostic conclusion (inferences) about the causes that occurred earlier in time and were not actively encoded, diagnostic learning is also a test of the workers' competence to form and update mental representations in the absence of direct stimulation (Waldman, 2000).

Many technical diagnostic problems are well defined with a clear goal, as there is a definite cause and outcome and a proven algorithm to ensure that the problem is solvable. There is, however, the requirement of advanced cognitive skills such as analytical, creative, and practical thinking when diagnosing technical problems. Okes (2010) states that, "Problem is often not a single problem, but many different problems," (P.38). In such cases the diagnosis will be difficult since there are likely to be multiple causes. According to Waldman (2000), causes for diagnosis are the interface of the reality of any technical workers in which effects are manipulated. The ability to diagnose multiple causes of a common effect versus a common cause for multi effects require the technician to learn about these fundamental causal relationships correctly. And this ability is improved through practical experience and the ability to evaluate of the causes and solutions of problems. Waldman (2000) believes that a combination of technical expertise and logical and creative thought processes are essential for diagnosing a problem. Okes (2010) makes a distinction between creative problems and analytical problems; in that, with creative problems, multiple solutions are necessary; however, analytical problems require the right solution that will not be known until a proper diagnosis is performed. For analytical problems, it is the utilization of a diagnostic process, or root-cause analysis, that will result in finding solutions.

3. Field Testing

Five universities that are part of the PhD in Technology Management Consortium will be involved in field testing. Consortium universities are: Bowling Green State University, East Carolina University, Indiana State University, North Carolina A&T State University, and University of Central Missouri. In addition to this field testing, faculty at Bowling Green State University and Indiana State University will conduct robust testing of all modules. Other universities may also participate in field testing.

4. Results

Anticipated impacts of this project are to improve the ability of junior and senior students in engineering and technology to diagnose problems in complex technical systems. Overall, the project will help learners develop a more agile habit of mind when performing diagnostic tasks. Broader impact of the project will be to provide industry, government and the military with a graduate who posses flexible diagnostic skills resulting in a smarter workforce to improve our nation's overall competiveness.

It is too early in the project to have substantial findings, however, it is expected that partial results will be available by August 2013. To learn more, please visit the project website at: www.diagnosticskills.org.

References

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